TJNAF HALL B CLASDC GAS OPERATORS MANUAL

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I Introduction

The CLAS Gas System, DC GAS, supplies high purity gas mixtures to the detectors. The gas is mixed, stored, and a metered delivery is supplied. The system also maintains a constant differential pressure between the atmosphere and detectors by pumping the gas out of the detectors.

Gas is supplied via the boil off from 160 liter dewars or from the bulk supply tanks located on the concrete pad next to the gas shed. Pressure is reduced to 160psig at the supply panel in the gas shed. It is then split into 2 identical circuits, #1 supplies the Region 1 and 3 buffer tanks and #2 supplies the Region 2 buffer tanks. This would allow for the option to use a different gas mixture for the Region 2 detectors.

Gas is mixed in each of the circuits by metering flow using Mass Flow Controllers, MFCs. The thermal conductivity of the mixed gas is constantly monitored using the Panametrics Thermal Conductivity Units (TCUs). This thermal conductivity reading is compared to that of the standard gas mixtures used to produce a calibration curve unique to each unit. Once the proper ratio of gases has been obtained by adjusting the mixture to produce the proper thermal conductivity, the MFCs are setup to operate in a master/slave mode in which Argon gas flow is the master and the CO2 gas slave follows to maintain the set ratio.

The mixed gas flows to the supply buffer tanks. The Region1 and 3 supply buffer tanks have a combined volume of 23,000 liters, while the Region 2 tanks have a combined volume of 7700 liters. Gas is stored in these tanks at ~150psig. The tanks can supply gas for for a period of time in case of a problem with the bulk supply or the mixing equipment.

The supply buffer tanks supply gas to the DC metering panels. Gas flows out of the tanks, through filters, and a 30 psig pressure reducer. A small portion of the gas is diverted to sensors, which measure the oxygen and moisture content to assure mixture purity. Gas is then metered to the hall by MFCs, Mass Flow Controllers.

Gas flows down several hundred feet of piping to the gas control panel in the Hall. Here solenoid valves direct flow to the detectors or bypass the gas flow to the exhaust piping depending on the situation. Pressure transducers monitor the pressures at the chamber exhaust manifolds. If this pressure exceeds the setpoint the solenoids are de--energized and the gas supply and exhaust are isolated from the chambers.

During normal operation the gas flows to the supply manifolds where it is split up to supply each of the 6 sectors in each Region. The gas exits the individual sectors and enters the exhaust manifold. Pressure in the exhaust manifold is monitored by a capacitance manometer, which sends a control signal to a controller which operates a control valve on the inlet of the gas return vacuum pumps. This controls gas flow out of the detectors in order to maintain a constant differential pressure between the atmosphere and chambers. In case of equipment failure, power loss, or extraordinary transient the detectors are protected by oil filled bubblers which will vent the gas to atmosphere or break vacuum which exceeds ¼ inch water column.

Gas exhausted from the return is exhausted to the atmosphere while a portion of the return gas is diverted to oxygen and moisture sensors to monitor contaminants. Contaminant levels indicate the leak levels in the system.

II Controls Overview

The DC gas system consists of 2 identical mixing systems and 3 separate supply and return systems. Each of these subsystems has its own controls, monitoring, and protection system.

Controls can be broken down as follows:

GAS MIXING
R1 & R3 Mixing - MKS Multi Gas Controller #1
Ch#1 - Ar
Ch#2 - CO2
Mix #1 ratio – Omega DP25E TCU1
R2 Mixing - MKS Multi Gas Controller #2
Ch#1 - Ar
Ch#2 - CO2
Mix #2 ratio – Omega DP25E TCU2

DETECTOR GAS SUPPLY
R1 gas flow to detector - MKS Multi Gas Controller #1 - CH#3
R2 gas flow to detector - MKS Multi Gas Controller #2 - CH#3
R3 gas flow to detector - MKS Multi Gas Controller #1 - CH#4

DETECTOR PRESSURE CONTROL
R1 control pressure - MKS type 146 Controller - PC1
R2 control pressure - MKS type 146 Controller - PC2
R3 control pressure - MKS type 146 Controller - PC3
R2 gas return flow - MKS Multi Gas Controller #2 – CH#4 + CH#5
R3 gas return flow - MKS Multi Gas Controller #1 - CH#5 + CH#6
R1 gas return flow - MKS Multi Gas Controller #1 - CH#7

PROTECTION CIRCUIT
R1 #1 OMEGA DP25-EAR
R2 #2 OMEGA DP25-EAR
R3 #3 OMEGA DP25-EAR

The analog outputs of these instruments are wired to ADCs for inputs to the EPICS based monitoring system and alarm handler. The EPICS system monitors the gas system and has no control function. It is intended as a warning and troubleshooting tool only.

The MKS Multi Gas Controller is a multi channel controller matched to the MKS MFC units. All functions and instrument setup is performed within a menu system. By using the numerical and arrow keypad all functions can be accessed. A detailed technical manual is used as a reference and guide to operations. **Improper use could cause gas system malfunction and detector damage. Only properly trained and authorized personnel are permitted to operate these controllers.**

The MKS type 146 vacuum gauge measurement and control system is used to maintain a constant differential pressure between the atmosphere and the detector. A capacitance manometer type differential pressure transducer senses the differential pressure and sends a voltage signal to the MKS type 146 controller. The MKS type 146 controller then adjusts the position of a proportioning solenoid valve located on the inlet side of the vacuum pump to increase or decrease return gas flow. Thus by controlling the amount of gas exhausted from the detector the proper differential pressure is maintained. A detailed technical manual is used as a reference and guide to operations. **Improper use could cause gas system malfunction and detector damage. Only properly trained and authorized personnel are permitted to operate these controllers.**

The OMEGA DP25-E process controller is used to monitor the differential pressure at the detector exhaust manifolds. A Dwyer Magnahelic indicating differential pressure transmitter senses the differential pressure at the exhaust manifold. A 4-20ma signal is transmitted to the DP25-E unit. A digital display reads out directly in inches of water column. The unit has relays that are set to isolate the gas system from the detector in case of a system failure or power loss. The protection system is designed to fail safe under all faults including power loss. An operator's manual is used as reference and guide to operations. **Improper use could cause gas system malfunction and detector damage. Only properly trained and authorized personnel are permitted to operate these controllers.**

III Operator Certification

The DC gas system uses high pressure gas and cryogenic liquids. The Control system uses complex specialty electronics and instruments. There are personnel and equipment hazards associated with improper operation of this equipment. Because of this, only properly trained and authorized persons are permitted to operate this equipment. Only certified operators are authorized to operate the system.

There are 3 levels of certification:

Level 1 -- Persons certified as a level 1 operator are trained to perform the following actions.

1) Change out gas supply containers.
2) Take manual action to isolate the detectors from the gas system in case of an emergency.
3) Isolate the gas system supply in case of a system failure.
4) Take readings of gas system control displays and compare to normal operating parameters.
5) Investigate problems indicated by the EPICS alarm handler

Level 2 -- Persons certified as a level 2 operator are trained to perform the following actions.

1) Recover the system from an automatic or manual protection bypass.
2) Operate the MKS multi gas controllers
3) Operate the MKS vacuum measurement and control system
4) Operate the Omega DP25E units.

Level 3 -- Expert certification

A system expert must be able to troubleshoot, repair, replace, set up, and reconfigure the system and it's components as required to permit safe operation of the system.

Certification requirements are as follows:

The person must demonstrate the required proficiency and knowledge to safely perform all the actions associated with that level.

Level 1 requirements are based on the operator having a basic knowledge and understanding of the system. The operator will be able to perform routine operations and emergency action designed to protect the detectors from damage. The operator can only perform the tasks specifically listed.

Level 2 requirements include all Level 1 requirements. A Level 2 operator must be proficient in operating all controls and instrumentation as well as having a detailed understanding of system operation.

Level 3 requirements include all Level 2 requirements. A Level 3 operator must be able replace failed components, setup controls, and manually mix gas. This requires in depth knowledge and understanding of all components in the gas system. Only a system expert can certify a level 1 or level 2 operator.

IV Level 1 Operations

Gas Supply

The Gas supply manifold is on the outside wall of the Hall B Gas Shed, Bldg. 96B. Argon and Nitrogen gases are supplied from bulk tanks which are filled by the vendor. The vendor monitors the bulk tank levels via a land line and schedules tankers to fill them. In an emergency or for maintenance purposes, portable dewars can be used to supply these gases under direct supervision of a system expert. CO_2 gas is supplied from high pressure dewars, the operator must monitor the dewars and change them out before they go dry. Experience with these containers allows one to determine if it is almost empty by it's tilt weight. Also note that the CO_2 dewar supply pressure range is 150-200psig. This means that the supply should never exceed 200psig and that it should never fall below 175psig. Therefore, the on line dewar must deliver CO_2 at pressure above that of the backup dewar, but below 200psig. Similarly, the backup dewar must deliver CO_2 at pressure above 150psig, but below that of the on line dewar. The reasoning behind this is that in case the on line dewar goes empty, the backup dewar will be capable of supplying the system for normal ops. In theory, the backup dewar will never be needed because the operator will change out the on line dewar prior to it “going dry" .

CO2 Dewar Operation

The CO_2 dewars must be ordered through the JLAB stockroom system. At least 4 dewars should be on hand at all times. Dewars should be ordered on a 1-1 basis, as soon as one is removed from the manifold a replacement should be ordered. Extra dewars should be ordered ahead of time prior to holidays such that they are on hand when required. There is a 2-3 weekday or workday delay between ordering and delivery. For example, if an order is placed on a Friday, delivery may not happen until the following Wednesday

The CO_2 dewars must be monitored as necessary from the time they are delivered by the vendor. The pressure buildup circuits must be adjusted as required to produce an internal pressure >200psig and <350psig. Frequent monitoring of pressure and levels in the dewars is required in order to insure a dependable gas supply.

There are heaters installed between the dewar and the pressure regulators. These heaters prevent the pressure regulators from freezing up. CO_2 flow to the mixing system will be disrupted if the regulator freezes. These heaters should be operated from the period of Fall to Spring.

Procedure for CO_2 Dewar Change Out

1) Close the gas supply valve on the dewar you are going to remove from service.
2) Close the inline valve on the flex line for that same dewar.
3) Remove the flex line and valve assembly from that dewar using a wrench.
4) Move the empty dewar to the designated part of the concrete pad.
5) Move a full dewar to the place the one you removed was.
6) Install the flex line to the new dewar with a wrench, verify the gasket is in place.
7) Open the gas supply valve on the dewar.
8) Open the gas supply valve on the flex line.
9) Adjust the pressure regulators as required to maintain a 150-200 psig supply pressure.

Detector pressure protection solenoid Valves

Solenoid valves are installed in the system to isolate the drift chambers from the gas system in case of a component failure or power outage. A Dwyer Magnahelic indicating differential pressure transmitter monitors pressure at the exhaust manifold of each region. The 4-20ma signal sent by the transmitter is received by an Omega DP25-E process controller with dual alarm relays and analog output in the Hall B Gas Shed.

The DP25-E unit has a digital display that reads out directly in inches of water column. The relays are controlled by set points programmed into the controller by the expert. All relays are normally open (NO); under fault conditions the relays open, and are active between the high pressure limit and the low pressure or negative pressure limit. These relays control the safety solenoid valves in the hall via the solenoid valve control unit, DC GAS Master Control box, in the gas shed. The DC GAS Master Control box permits either automatic or manual control of the solenoid valves. Manual control is sometimes needed to recover the system from an over or under protection isolation.

If the protection system fails and the control system is unable to maintain detector pressure within limits, the solenoids must be de-energized manually in order to isolate the detectors from the gas system to prevent a catastrophic gas window failure.

Procedure for Emergency Manual Remote Bypass

1) Determine if there is actually a problem by observing the display of the DP25-E.
2) If the digital display shows a negative value or a value >0.225"wc, the respective detectors should already be bypassed.
3) Check to see that the green solenoid status light is off for that respective detector on the DC GAS Master Control.
4) If the green solenoid status light is on, the solenoids are energized and the protection system has failed.
5) If the protection system has failed turn off the power to the DC GAS Master Control. This will place the system in a safe condition by de-energizing the solenoids and bypass the detectors.
6) The DC gas on duty system expert must be alerted to this action.
7) The DC on duty shift person must be alerted to this action.
8) Only a level 2 or 3 operator can recover the system from bypass operation.

Isolating the Gas system from the high pressure gas supply

Preliminary Discussion

The bulk gas supply tanks, the supply buffer tanks, and/or supply dewars, hold a large supply of gas at high pressure. It is possible that a failure could occur resulting in the uncontrolled escape of gas. It would be dangerous to enter the gas shed if such a failure had occurred. All high pressure supplies of gas would have to be secured from outside the gas shed.

Procedure for Isolating the HP Gas Supply

1) Close all 8 supply valves on the gas supply manifold on the outside wall of the gas shed.
2) Close the inlet and outlet valves on each of the 4 gas supply buffer tanks located between the gas shed and Hall C. This is a total of 8 valves. MV403, MV404, MV407, MV408, MV307, MV308, MV303, and MV304.
3) The uncontrolled escape of gas will decrease as the lines vent to atmosphere through the fault.
4) Contact the DC gas system expert.
5) Call the DC on duty shift person and alert him to the fact that the gas system is inoperable.

Normal Operating Parameters

The gas system can be seen as a number of components connected together in series. If any one component fails or malfunctions the system will not perform its function. Parameters such as pressure and flow are used to describe the inputs and outputs of these components. A fault anywhere in system can be located by checking these parameters.

Gas Supply
Argon bulk storage tank supply pressure 150-200 psig
CO_2 dewar supply pressure 150-200 psig
Nitrogen supply pressure 25-55 psig

Gas Mixing
Argon supply - 150-165 psig
CO_2 supply - 150-165 psig
#1 conductivity meter - 10% set to match reference calibration gas
#2 conductivity meter - 10% set to match reference calibration gas
Storage Buffer Tanks - All 4 tanks - 100 +/- 25 psig

Gas Metering
Region 1 and 3 metering supply 36 psig
Region 2 metering supply 36 psig
R1 flow varies as required to minimize detector dark currents.
R2 flow varies as required to minimize detector dark currents.
R3 flow varies as required to minimize detector dark currents.

Pressure Control and Pressure Protection Setpoints
Controls are set to maintain detector pressure >0.030”wc and <0.080”wc during normal operation as indicated on the OMEGA DP25-EAR controllers located in the gas shed.

MKS Type 146 Controller Setup Parameters

Parameters	***R1-PC1***	***R2-PC2***	***R3-PC3***
SETPOINT	0.060*	0.060*	0.060*
LEAD	0.5	0.05	0.05
GAIN	5	20	20
INTEGRAL	1	3	3
BASE	25	25	25
START	45	50	45
PRESET	50	50	45
ALPHA	20	20	20
UNITS	torr	torr	torr
SENSOR CAL	ln	ln	ln
SENSOR RANGE	10 torr	1 torr	1 torr
SENSOR RESOLUTION	10^{-3}	10^{-3}	10^{-3}
DISPLAY LAG	5	15	15

Refer to the MKS Type 146 manual for complete instructions on setting the above parameters. Some of the parameter values are determined by the hardware used and others by the application.

* This setpoint is adjusted such that detector pressure is >0.030"wc and <0.080"wc during normal operation as indicated on the OMEGA DP25-EAR controllers located in the gas shed

Responding to problems indicated by EPICS

The EPICS alarm handler monitors inputs to ADC channels. These inputs are the outputs from various instruments. It is these instruments which directly monitor and control the DC gas system and not EPICS. The controls and instruments provide inputs to EPICS for use as a remote monitoring and warning system. EPICS cannot be used for control of any component in the gas system.

There are multiple components between the alarm handler's computer screen and the analog input signal coming out of the instrument being monitored. The first step in responding to an alarm is to verify the actual operating condition of the system.

There are only a few conditions that require immediate action. The following procedures are designed to prevent equipment damage and data loss.

Procedures

1) Check actual system operating parameters to verify the problem. If the problem is real continue. If the problem only shows up on the alarm handler, it is an EPICS or IOC problem. No further action is needed.

2) If detector pressure is out of the normal operating band and the system did not automatically go to bypass, manually switch to bypass. (Call the DC gas system expert)

3) If the mixing ratio is incorrect, isolate the gas supply to the mixing panel.

-- For #1 panel (R1 and R3) Close MV119, MV116, MV011, MV010.

-- For #2 panel (R2) Close MV215, MV212, MV017, MV016.

These actions will prevent any further change to the mix.

4) Check the gas supply pressures. If any are out of the norm change out the supply dewar. Call the DC gas system expert if the problem cannot be solved by changing out an empty dewar.

5) If an automatic bypass condition has occurred call the DC gas system expert.

6) Refer to the appropriate section of the DC GAS System Operators manual for further guidance.

V Level II Operations

Operating the MKS Multi-Gas Controllers

The MKS Multi Gas Controller is menu driven. The technical manual supplied with the unit should be used as a reference and guide to operations.

I will cover the basics of setup and operating the unit.

There are screens which are used to monitor and control MFC operation.

----The **USER Display** shows all MFC flows and supply buffer tank pressure. This display is used to display system status during normal operations.

----The **Extended Display** allows setpoint adjustment of each channel and shows the current status of each MFC. This is the display that permits you to adjust flow and to turn on or off individual MFCs. The operational mode and gas type is also displayed. A highlight box can be moved around the screen using the arrow keys. When an item is highlighted the value can be changed by using the numerical keypad. Once the new value is entered the highlight box must be moved to another position for the new value to take effect. The extended display is used to adjust gas mix ratio and detector flow rates. Individual MFCs can be turned on and off when the extended display is shown on the MGC. To turn OFF an individual channel first press OFF on the keypad and then press the channel #. To turn ON an individual channel first press ON and then press the channel #.

----The **Instrument Setup Display** is another set of menus. Each menu selection permits the system to be setup for different MFCs, operational modes, and gas types. All settings must be entered correctly for the MGC to properly control the MFCs.

--**Range Selection**: This is where you enter the range of the MFC. All MKS MFCs have the same output voltage, 010 vdc, regardless of their range. The 0 vdc corresponds to 0 flow and the 10 vdc corresponds to the maximum range of the MFC. A 100 liter/min MFC has exactly the same input and output as a 1 liter/min MFC. The MGC setup determines system operability. An error in this part of the setup can have catastrophic consequences.

--**Gas Selection:** MFCs are gas specific. The gas in use must be entered properly for the MFC to operate correctly. These correction factors can be found in the manual.

Correction factors for pure gases are built into the software or the controller. Correction factors for gas mixtures must be calculated using the procedure described in the manual and then entered under the user gas type. The factors for ArCO2 mixtures are as follows;
Ar 1.370, CO2 0.700, and ArCO2 1.300.

Mode Selection: The MFCs can be operated in several different modes. The CO2 MFCs are operated in slave mode to the Ar MFCs. Thus on both #1 and #2 MGCs CH#2 is a slave to CH#1. All other MFCs are set to operate in the independent mode.

Zero Adjust: The method of gas flow measurement through the MFC is dependent on a heated sensor. Each sensor is slightly different. The zero is adjusted such that a zero flow reading corresponds to zero flow. The zero offset is dependent on ambient temperature. The zero of the instrument changes according to ambient temperature. Temperature changes of only a few degrees can change the zero by 10% or more. The zero should only be set after the MFC has been operating at the same ambient temperature for at least an hour. The gas supply to the MFC must be isolated and the MFC should be set to flow zero. Then adjust the zero such that it reads zero at zero flow.

None of the other display screens are used in our application.

WARNING

Improper use could cause gas system malfunction and detector damage. Only properly trained and authorized personnel are permitted to operate these controllers.

Operating the MKS Type 146 Vacuum Control System

The MKS type 146 unit is the most complicated controller used in the gas system. Most of the technical manual is not applicable for our application. I will discuss the basics of operation relating to our specific application. I have included the applicable page numbers from the technical manual to simplify things.

Operation in Normal Mode - (MKS manual Operation in Normal Mode pp. 75-81) The only time this mode is used is when the operating channel must be chosen and the control valve must be turned on or off. Pages 75-81 of the MKS technical manual describe these operations in detail. Care must be taken such that only Channel 1 is used in all cases and the channel must be turned on in order to operate.

Operation in Tuning Mode - (MKS manual Operation in Tuning Mode pp.125-152) Tuning mode is the normal mode of operation. Valve control settings can be changed in this mode and control operation can be monitored. Settings for each Region are different. (SEE NORMAL OPERATING PARAMETERS listed in this manual) Pages 125-152 of the technical manual describes these operations in detail. Care must be taken when entering values such that an error is not made.

Operation in Control Mode - (MKS manual Operation in Control Mode pp.213-220) Control mode is used to control the proportional solenoid valve on the inlet side of the vacuum pumps in the gas shed. Control mode must be used to recover from an automatic bypass condition under certain circumstances. (**WARNING! Operation in this mode must never be performed unless the chambers are bypassed)** Pages 213-220 in the technical manual describe these operations in detail.

WARNING

Improper use could cause gas system malfunction and detector damage. Only properly trained and authorized personnel are permitted to operate these controllers.

Operating the OMEGA DP25-E Process Controllers

These units have a menu system. All functions can be setup using the controls on the front panel. The operators manual should be used as a guide to operations.

These units are the heart of the over pressure and under pressure protection system of the detectors.

Each unit has 2 relays.
----The under pressure protection relay is configured to be active, closed, above the setpoint.
----The over pressure protection relay is configured to be active, closed, below the setpoint.

Both relays must be active in order for the bypass control solenoids to be energized. If either relay trips, the solenoids will be de-energized and the chambers will be bypassed.

Each Region has different set points. (SEE NORMAL OPERATING PARAMETERS)

WARNING

Improper use could cause gas system malfunction and detector damage. Only properly trained and authorized personnel are permitted to operate these controllers.

Calibrating the Panametrics TCUs

There are 2 types of calibrations performed, a DAILY calibration and a FULL calibration. The DAILY calibration is used to make small adjustments to the mix. The FULL calibration is used to set the zero and span of the units and prepare calibration charts.

The Panametrics TCUs tend to drift randomly over time and are temperature sensitive. We use the units to maintain a 10.0% mixture of CO2 in Argon. These units use a reference leg of Argon to compare to the mixed leg. The gas flow through each leg must be equal. There is a large piping volume which must be purged through the unit before an equilibrium reading can be obtained from the unit. A 10-20 minute time lag to equilibrium in unit readout is typical.

The Panametrics TCU technical manual contains a detailed procedure for setting the zeros on the unit. There is a problem with the procedure described in the manual. In our particular case a DMM cannot be used. The output display is used instead. The DMM produces offsets, which cannot be removed or taken into account through the rest of the calibration.

The following procedure is used to perform a FULL calibration.

----The first step in calibrating the units is to set the zero point. This is accomplished by isolating the CO 2 supply from the mixing MFC. The zero is found by comparing pure argon with pure argon. The display rapidly reaches an equilibrium value in this case due to the mix ratio. A 20 min flow should be used before setting the zero. The zero potentiometer in the unit is adjusted such that the digital readout is 3.950 to 4.050 ma. (The zero pot is next to the dip switches under the cover of the unit) Turning the adjusting screw clockwise decreases the current flow while turning it counterclockwise will increase current.

----The second step is to set the 100% CO 2 reading at 20ma. The CO2 supply valves must be opened and the argon supply valves closed. The CO 2 MFC must be changed to independent mode IAW the MKS manual. A 20 minute flow should be used before setting the 100% point. This is a good time to set the zero offsets for the Argon MFC units. The 100% or 20ma pot is adjusted to between 19.900 and 20.100 ma.

----The third step is to open the Argon supply valves and place the CO 2 MFCs back into slave mode operation IAW the MKS manual. This will flow gas in a normal mode at the correct ratio according to the previous calibration.

----The 4rth step is run calibration gases through the Panametrics TCUs and record the output current for each mixture. Several different mixtures are used to produce a calibration curve for each unit. The 3 way selector valve on the mixing panel is turned to the calibration position. Each calibration gas must flow for at least 10 minutes before a reading is taken. Points at 0%, 8%, 10%, 11%, 12%, 13%, 15%, 20%, and 100% are used to determine the calibration of the unit. A curve is fitted to the data points using a nth degree polynomial fit.

----GNUPLOT is used to produce the graphs and GGV or GSVIEW is used to preview them and print hard copies for posting.

GNUPLOT instructions are available on line.

The following procedure is used to perform the DAILY calibration checks.

Preliminary Discussion

This procedure compares the 10% calibration standard to the mix. This procedure must be performed prior to any adjustment to the mix.

Procedure

1) Switch the TCU selector valve to calibration gas 10%
2) After a 10-12 minute window record the TCU outputs.
3) Switch the TCU selector to the mix
4) Adjust the mix to match the 10% standard
5) Switch to calibration gas buffer 1 and compare the result to the calibration value
6) Switch to calibration gas buffer 2 and compare the result to the calibration value
7) Repeat the above steps as necessary

Setting the Zero on a MFC

The zero on a MFC must be set by an expert only. It must be set when first installed and periodically between factory calibrations. The zero on a MFC tends to drift over time. This is due to the properties of the heating element used in the unit. The effect is most pronounced in the gas mixing MFCs because they operate at high pressure. High pressure MFC units have special internal parts which are more sensitive to ambient temperature changes in addition to the drift associated with time for the heating element. The zero is performed IAW the MKS manual.

OPERATING THE GAS SYSTEM

The DC GAS SYSTEM is not a 100% automatically controlled system. There are some parameters which must be manually controlled and as such must be monitored frequently.

Maintaining the Supply Buffer Tank Pressure

Overview

The pressure in the supply buffer tanks is controlled by varying the volumetric flow rate of gas being mixed. To increase buffer tank pressure you must increase the volumetric flow rate of mixed gas supplying the buffer tanks. To decrease buffer pressure you must decrease the volumetric flow rate of mixed gas to the buffer. This relationship can be described as follows:

Flow Rate IN - Flow Rate OUT = Differential Flow Rate

If the differential flow rate is positive the pressure in the tank will increase. If the differential flow rate is negative the pressure will decrease.

Flow Rate IN = Ar Flow Rate + CO2 Flow Rate = Mixed Gas Flow Rate

Flow Rate OUT = R1 Supply Flow Rate + R3 Supply Flow Rate + Instrumentation Supply Flow Rate + Atmospheric Leak Rate

For Buffer #1, Region 1 and 3 supply buffer, channels 1 and 2 on MFC 1 control the mix.

For Buffer #2, Region 2 supply buffer, channels 1 and 2 on MFC 2 control the mix.

Pressure in the Supply Buffer Tanks should be maintained 125psig +/-25psig.

Due to Temperature effects, leakage, and varying Instrumentation Supply Flow Rates, it is not possible to exactly match Flow Rate IN to Flow Rate OUT.

The goal is to be able to control the pressure by only making small changes in Flow Rate IN. The CO2 flow rate is a slave to the Ar flow rate during normal operation. This maintains the flow ratio as measured by the MKS MFC units. This works only if small changes in the flow are made. This does not work well if a more than 10% change in flow is performed. This is due to the inherent nonlinear characteristics of the MKS MFC units when used to flow CO2 gas. The Panametrics TCU monitors the gas mix. When any change is made to Flow Rate IN, the TCU must be monitored and the CO2 flow must be adjusted to maintain the proper mix ratio.

The basis for the operating pressure range of the tanks is to ensure detector gas supply in case of gas delivery problems or problems with the gas mixing equipment. For example the capacity of R3 tanks is 23,000 liters. Using the relationships defined by the ideal gas law the gas supply can be calculated. At 140psig the buffer can supply ~230,000 liters of mixed gas. R3 uses ~15,000 liters/day. That is ~2 week supply for R3. For R2 the capacity is ~8,000 liters. At 140psig the buffer can supply ~80,000 liters of mixed gas. R2 uses ~20,000 liters/day. Currently, that is only a 4 day supply of gas for R2 at the current gas consumption rate. At lower buffer pressures a smaller gas supply would be available.

There are some operating limitations associated with the buffer tanks. The Gas supply to the gas mixing MFC units is regulated at 155psig. The units will not operate beyond a 150psid across inlet to outlet, while the maximum operating pressure of the units is rated at 200psig.

There is a problem associated with too high a pressure in the buffers. As buffer pressure increases the differential pressure between the gas mixing MFC gas supply and the Buffer decreases. As this occurs the MFC control valves open to compensate. Eventually this valve will open to 100%. Then the flow through the MFC will begin to decrease. As this occurs the mix ratio of the gas will change. This is a short term problem if corrective action is taken, but can have a long term effect if left unattended.

The Supply Buffer tank pressures can be monitored at the tanks themselves, by reading the pressure gages. They can also be monitored indirectly by monitoring the pressure of the mixed gas from the MKS Multi Gas Controllers.

(The buffer tanks are cross connected just prior to the hall supply panels. This setup results in pressure equalization between the buffers. The buffers were cross connected when the flow rates were increased for R3. Now both mixing systems supply the tanks.)

PROCEDURE

To increase Buffer tank pressure you must increase Flow Rate IN. --To increase Flow Rate IN -- the Ar MFC is adjusted to flow more gas. The Ar MFC flow rate is increased, the CO_2 MFC will follow because it is in slave mode.

To decrease Buffer tank pressure you must decrease Flow Rate IN. --To decrease Flow Rate IN-- the Ar MFC is adjusted to flow less gas. As the Ar MFC flow rate is decreased, the CO_2 MFC will follow because it is in slave mode.

Buffer tank pressures do not change rapidly. The best way to increase or decrease pressure is to do it slowly. Small iterative changes allow positive pressure control and do not cause large changes in the gas mix ratio. The Panametrics TCU reading must be monitored. The Ar-CO_2 mix ratio may need to be adjusted. If the Ar-CO_2 mix ratio needs adjusted follow the procedure outlined in the next section.

Maintaining the Ar-CO2 MIX RATIO

The gas mixture composition directly effects detector operation. The gas mix is controlled to maintain a 10% +/-0.3% drift of CO2 in Ar gas mixture. The Ar-CO 2 mix ratio is controlled by varying the CO 2 flow rate. The CO2 MFC is in slave mode to the Ar MFC. The CO2 MFC will adjust CO2 flow to maintain a set ratio of flows. Due to the inherent nonlinearity of the CO2 MFC, the ratio changes with flow.

The Panametrics TCU is used to maintain the proper gas mix. The Panametrics TCU has a 4-20ma output. This is read out on the Panametrics Series 3 Moisture Monitor. The reading units are ma (milli-amps). Weekly calibrations are performed and graphs are produced which are representative of the relationship between the gas mixture and the Panametrics TCU output signal. The mixture of the gas is adjusted such that a 10.0% mixture of CO2 in Ar gas is achieved at the time immediately following the calibration procedure.

Daily calibration checks are performed with the 10.0% CO2 in Argon calibration standard and adjustments are made on a daily basis. The mixture should not be adjusted between calibrations, except when required due to a change in the flow rate of mixed gas. Then it should only be adjusted to reproduce the TCU reading present before the change. The reasoning behind this is that the MFC units drift less than the TCU.

PROCEDURE

--To increase the percentage of CO 2 in the mix, the current output signal must be increased. To increase the current output signal, the CO 2 MFC must be adjusted to flow more gas.
--To decrease the percentage of CO 2 in the mix, the current output signal must be decreased. To decrease the current output signal, the CO 2 MFC must be adjusted to flow less gas.
--Small incremental adjustments work best. A 5% change in CO2 flow will change the mix by ~ 0.5%. That is a large change. A very good estimate of the change required can be easily calculated as follows. Take a reading from the Panametrics TCU. Use the TCU calibration graph to determine the gas mix. The difference between that result and 10% will determine the change required. For example, a 10.3% result is 3% from 10%. So a decrease in CO2 flow would then be the first incremental change. If 5.5 SLM is the current CO2 flow, then the new flow should be set to 5.335 SLM. 10-20 minutes should be allowed for the TCU to stabilize. Then the mix can be adjusted again in a similar manner. This process is repeated until the mix is exactly 10% CO2 in Ar as indicated by the Panametrics TCU.

Changing the Flow Rate to the Drift Chambers.

Overview

The DCGAS system consists of several independently controlled individual gas systems integrated into a larger system.

The individual systems are as follows;
-The R2 Buffer tank supply mixing system
-The R3 Buffer tank supply mixing system
-The R1 Supply flow controller
-The R2 Supply flow controller
-The R3 Supply flow controller
-The R1 Pressure control system
-The R2 Pressure control system
-The R3 Pressure control system

Each of these gas sub-systems is operated independently but must operate in a compatible manner with the others. The mixing system must mix at the correct ratio and maintain supply buffer tank pressure within the operating band. The detector supply controllers must maintain the proper supply flow volume to the detectors. The pressure control system must maintain constant pressure in the detectors by removing the correct volumetric rate of gas from the detectors. Each of these systems must operate within the proper control parameters.

Preliminary Discussion

The detector gas supply mass flow controllers meter gas from the supply buffer tanks to the detectors. If the mixing supply input to the buffers exactly matches the output flow, the pressure in the buffer is constant. Whenever the output from the buffers to the detectors is changed, the input to the buffers from the mixing system must also be changed in order to maintain buffer pressure. The Ar-CO2 ratio is manually controlled to match a reference value determined by a calibration gas. The total flow into the buffer must equal the total flow out over time or the pressure will either increase or decrease outside of the normal operational range. The flow controllers are sensitive to temperature and pressure, operation at different temperatures and pressures requires manual adjustment to mixing flows to match the calibration value or the mixture ratio will drift.

One purpose of the supply buffer tanks is to average out any fluctuation in the mix over time and to minimize the effect of any short term error in the mix. If detector flow is increased without also increasing the mixing flow, pressure in the buffers will begin to decrease. As the pressure decreases, the amount of gas in the buffers is reduced, and the efficiency of the buffer to buffer out fluctuations in the mix is reduced. At some point the pressure will decrease below that required to maintain flow to the detectors.

If the flow to the detectors is reduced without also reducing mix flow, the pressure in the buffers will increase. Eventually, the mixing system will no longer be able to flow at the set points. The mixture in the buffer will drift until manual adjustments are made in the relative flows to correct the mis match. The ratio of the Ar and CO2 mixing flows may deviate enough to produce an EPICS alarm.

Changing the flow rate of the supply gas to a detector region requires the pressure control system to respond to a transient. Changes should be made slowly. Changes should be made in gradual steps over a period of time. There should be sufficient time between steps for the system to stabilize. Steps should be limited to a maximum change of 10slm in a 10 minute period.

CAUTION

IMPROPER OPERATION OF THIS SYSTEM CAN RESULT IN CATASTROPHIC DAMAGE TO THE CLAS DETECTOR.

ONLY PROPERLY TRAINED AND AUTHORIZED INDIVIDUALS ARE PERMITTED TO OPERATE DCGAS FLOW AND PRESSURE CONTROL SYSTEMS.

Procedures

Procedure to Decrease Flow

1) Determine what the final flow rate will be, V_{fin}
2) Calculate the change in flow to the detector region and determine the number N of flow change steps required. $V_{init} - V_{fin} = \Delta V$ and then $\Delta V / 10 = N$
3) Reduce total mixing flow by ΔV. $\Delta V_{Argon} + \Delta V_{CO2} = \Delta V$
4) Reduce detector flow no more than 10 slm per 10 minutes while monitoring pressure controls.
5) After the final flow adjustment, monitor all flow and pressure control parameters until they have stabilized.
6) Periodically monitor Buffer tank pressure and adjust the mixing flow as necessary to maintain pressure.

Procedure to Increase Flow

1) Determine what the final flow rate will be, V_{fin}
2) Calculate the change in flow to the detector region and determine the number N of flow change steps required. $V_{fin} - V_{init} = \Delta V$ and then $\Delta V / 10 = N$
3) Increase total mixing flow by ΔV. $\Delta V_{Argon} + \Delta V_{CO2} = \Delta V$
4) Increase detector flow no more than 10 slm per 10 minutes while monitoring pressure controls.
5) After the final flow adjustment, monitor all flow and pressure control parameters until they have stabilized.
6) Periodically monitor Buffer tank pressure and adjust the mixing flow as necessary to maintain pressure.

MKS Type 146 Controller Under Range Failure

The MKS Type 146 Vacuum Gauge Measurement and Control System has a failure mode which requires a manual system recovery. Under certain conditions the system is unable to keep up with a rapid pressure transient. When this occurs the system pressure exceeds the range of the DPT. When this occurs the controller signals the control valve to open completely. The valve does not begin to close until the DPT signal is normal. By then the valve is unable to close fast enough to prevent an under-range condition for the DPT. The Type 146 controller has only one response to a pressure which is out of range of the DPT. It opens the control valve fully. This action allows the vacuum pumps to pump down the gas lines.

As soon as the pressure left the allowable range the detector protection solenoids isolated the detector from the gas system. The detectors have the gas shut off and can only be operated for a short period of time before HV must be secured. The Gas system will not recover from this fault without manual intervention.

INDICATIONS
-There is a DC GAS bypass condition.
-The Type 146 controller shows a flat line on the pressure display.
-The Type 146 controller has the word under-range in the top right of the display.

Preliminary Discussion

The goal is to recover the system. The system is best recovered when placed into a normal condition. The MKS Type 146 controller must be recovered. Then gas flow can be restarted and slowly increased as needed. Recovery is safest and simplest from base startup parameters or all zeros.

RECOVERY PROCEDURE

Verify that the failure has occurred by checking the indications.
If the failure has occurred perform the following steps exactly.

1) Set the gas supply to the effected region to zero
2) Unplug the pump or pumps for the effected region.
3) Adjust gas flow to bring the MKS type 146 display into the normal range and then set to zero.
4) Press the CONTROL MODE key
5) Using the arrow keys scroll down to select CLOSE and press ENTER.
6) Verify the valve is at it's base setting.
7) Using the arrow keys scroll up to select AUTO and press ENTER
8) Verify the valve remains at the base position and the pressure reading on the controller is normal and the under range indication has cleared.

9) Switch to Protection OFF on the DCGAS Master control box to override the protection system
10) Restart gas flow slowly.
11) Verify that the controller does control at the setpoint.
12) Switch to Protection ON on the DCGAS Master control box to enable the protection system
13) Increase gas flow slowly as required
14) Monitor the system to verify normal operation.

Recovery of the Gas System Following a UPS Failure

When a UPS fails, the system controls powered by it fail. This may leave the system in an abnormal configuration. The following components are powered by UPS. MKS type 146 controllers, DC GAS Master Control, DC GAS pressure panel and Protection Circuit. There are 2 basic scenarios to this type of failure, each requiring a very careful approach to system recovery.

SCENEREO #1
A UPS failure which is the result of a long term power outage is the most likely scenario. Once power is restored, the pumps will energize, the MKS type 146 controllers will turn on and begin controlling using whatever parameters they power up with. These parameters may or may not be correct. The MKS type 146 controllers will need to be reprogrammed with the correct parameters prior to restoring gas flow. The MKS type 647B Multi Gas Controller will power up by default with all MFCs off. The DC GAS protection system will power up and operate according to it's previously programmed set points. Once the MKS type 146 controllers have been programmed with the correct parameters, gas flow can be restored. Then each Region must be recovered from a protection system bypass.

SCENEREO #2
A UPS failure which is not caused by a complete power failure will result in the system failing to an abnormal mode with the chambers bypassed, gas still flowing, pumps still running, and the pressure control valves on the pumps suctions closed. This means that within a short period of time the pressure in the gas lines would increase as the MFCs flow until the differential pressure across them goes to zero. This should not present any problems as long as the system is started up properly. However, in the worse case scenario, if the operator were to prematurely attempt to recover normal operations by turning to protection off on the Master Control Panel, then the gas in the system would flow to the bubblers and chambers. If this is done while the lines and buffer tanks are pressurized to 15 psig, it could cause catastrophic window damage if the bubblers are unable to exhaust the gas fast enough. Hence the reason for this recovery procedure.

RECOVERY PROCEDURE (Each Step Must be followed in Sequence)

1) If the control system (MKS 146 controllers) or the protection system (Omega DP25EAR and DC GAS Master Control) has lost power, then turn off the MKS Multi Gas Controllers 647B.
2) Turn off the power switch on the DC GAS Master Control Panel.
3) Restore power to the pressure monitoring and protection system first, the Omega DP25EAR units.
4) Restore power to the MKS type 146 controllers.
5) Verify all set points on the MKS 146 controllers and reload values as required..
6) Turn on the power switch on the DC GAS Master Control Panel.
7) Continue to restore gas flow IAW the chapter for recovery from a power outage.

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.

When power is restored the gas system will restart with the exception of gas flow. The MKS Multi Gas Controller powers up with all MFC units turned off. Each MFC must be turned on in order for gas to flow. The main menu will be present on the screen at power up. You must select the extended display from this menu. You must press the number 2 key on the keypad to have the extended display appear on the screen. Once the extended display has been selected you must turn on each MFC by turning on each channel.

Procedure to Restore Gas Flow

1) Using the keypad on the MKS Multi Gas Controller, press the number 2 to bring up the extended display.
2) Using the keypad on the MKS Multi Gas Controller, press the ON key followed by the channel you which to turn on. Repeat this until all channels you wish to turn on are turned on. Take care in pressing the keys as they are rather sensitive. Please refer to page 12 and 13 of this manual for more details on operating the MKS Multi Gas Controllers.

Spares

There are certain major components which must operate properly for the gas system to function. It is possible to operate the system with scaled back controls. I will describe the requisite minimum configuration.

Pressure Control

In any eventuality, the MKS Vacuum Control System must be operational in order to supply gas to the detectors. There are sufficient spares on hand to replace all the components for one region.

MKS Type 146 Vacuum system controller
2 MKS Type 154A-200SV Vacuum control valve
3 MKS Baratron Type 223BD-00010AAB 0-10v output
1 Metal Bellows Pump (R3)
2 GAST diaphragm pump (R1 and R2)
Rebuilt kits for GAST pumps

Flow Control

MKS Multi Gas Controllers control the MKS Mass Flow Controllers. There are sufficient spares on hand to replace any single failed component.

1 MKS Type 647B 8 channel Multi Gas Controller (MGC)
1 MKS Type 1559A- 12178 200slm HP MFC
1 MKS Type 1559A-12797 50slm HP MFC (CO2 Supply Only)
1 MKS Type 1559A-050L-SV 50 slm MFC (R1 Supply Only)

Mixture Monitoring

A Panametrics Thermal Conductivity Unit (TCU) monitors the thermal conductivity of the gas as it is mixed. This allows for precise control of the ArCO2 mixture using a calibration gas as a reference. We have a spare TCU on hand. The output of the unit is a standard 4-20ma output. Replacement power supplies are available in the stock room. The unit is replaced IAW the Panametrics manual.

The Jan 2006 System Upgrade

The system has undergone a comprehensive upgrade to allow higher gas flow rates to the detectors. The modifications made to the system were required in order to increase the system mixing capacity, increase the detector supply flow capacity, increase the exhaust gas return capacity, and to decrease the differential pressure between the detectors and the pressure control point.

Mixing System

The 2 parallel ArCO2 mixing systems were upgraded by replacing the Mass Flow Controllers with higher capacity units. The Argon MKS type 1559A-12178 -50 slm MFCs were replaced with new MKS type 1559A-12797 200slm MFCs. The CO2 MKS type 1359C-10000-SV 10 slm MFCs were replaced with the old Argon controllers, the MKS type 1559A-21178 50slm MFCs

Detector Supply

The R2 and R3 supply MKS type 1559A-050L-SV units were replaced by new MKS type 1559A-12797 200slm MFCs. The R1 MKS type 1359C-5000-SV 5 slm MFC was replaced by the old R3 MKS type 1559A-050L-SV 50 slm MFC. The MFC supply piping had to be modified in order to increase the capacity of the supply pressure reducers. Gas is supplied to the detectors from the buffer tanks through a pressure reducer and them metered by the MFC. The pressure reducer capacity at it's maximum pressure setting was 80 slm. I used the unused recirculation pressure reducers in parallel with the supply reducers to double the supply capacity. The individual flow rotometers for each sector had to be replaced with larger ones. The R2 and R3 rotometers were replaced with new larger ones. R1 needed a supply manifold in addition to larger rotometers. The R1supply manifold was the old R3 exhaust manifold and the new R1 rotometers were the old R3 rotometers. The R2 and R3 supply lines were replaced with 1/2” nylon tubing from the manifold to the upstream end of the detectors.

Detector to Control Point Differential Pressure

The differential pressure between the detector and the pressure control point, the exhaust manifolds was reduced by changes in the number of or size of the exhaust lines between the detectors and the manifolds.

R1 lines were increased in size to 1” OD from 1/2” and ran to a new manifold with 1” tubing connections. The lines were routed differently permitting them to be nearly half the previous lengths. S4 has the longest exhaust line so a magnahelic gauge was attached to this sector to measure the worse case pressure differential at a given flow rate and setpoint.

R2 had the most changes. The old exhaust lines were abandoned and capped off. New 1” lines attach to a new cover plate mounted over where the upstream observation window used to be. Each sector has 2 lines out of the cover that then split into 3 lines using 3 “tee” fittings at the detector that then run to the exhaust manifold. The lines were routed differently permitting them to be about a third less length than previous. S3 has the longest lines, so a magnahelic gauge was attached to this sector to measure the worse case pressure differential at a given flow rate and setpoint. The new exhaust manifold has 18 individual 1” connections compared to the 6 small 1/2” connections on the old one.

R3 has 2 additional 1” lines per sector for a total of 3 lines per sector. The 1/2” connections on the detector were replaced with bored out versions that directly connect the 1” lines to the detector gas volume. The new exhaust manifold has 18 individual 1” connections compared to the 6 small 1/2” connections on the old one. S4 has the longest lines, so a magnahelic gauge was attached to this sector to measure the worse case pressure differential at a given flow rate and setpoint.

Exhaust Gas Return Capacity and Pressure Control

R1 needed a new pressure control valve to replace the MKS type248A-10000-SV 10 slm capacity valve. I cannibalized the MKS type 154A-050L-SV valve from the old R2 supply MKS type 1559A-050-SV 50 slm MFC. I then used the transducer portion of the MFC as the R1 return flow transducer.

R2 required a 2nd pump to be added in parallel to increase system capacity. Due to limited space, the R1 and R2 pumps were moved onto a shelf above the old location to make room for the 2nd R3 pump on the floor level. The unused MKS type 358C-50000 transducer from the unimplemented R2 recirculation piping was used in parallel to the original to monitor return flow.

R3 required the most return and control modifications. The R3 return lines in the gas shed now consists of 2 separate parallel paths each with a control valve, pump, and flow transducer. A 2nd control valve, pump, and flow transducer was installed in parallel to the first. This valve is controlled by the same MKS type 146 controller. By tapping off the valve output signal from the MKS type146 controller through a voltage divider and then input to a MKS type 1249A valve driver module which then drives the valve with it's own +/-15 vdc power supply. The voltage divider was adjusted such that each valve has equal flows at high flow rates. Separate pumps and transducers were used for each valve so flows could be equalized. The unused MKS type 358C-50000 transducer from the unimplemented R3 recirculation piping was used in the 2nd line to monitor return flow.

Modifications Still Unfinished

R2 S5 still needs new supply lines between the upstream end of the detector and the gas inlet. The ¼" OD tubing limits the supply flow. CLAS must be dissassembled and the corresponding R3 must be pulled out to gain access to attach the line.

MKS 647B

MFC1				***MFC2***		
CH1	Ar mix1	84.0		CH1	Ar mix2	90.0
CH2	CO2 mix1	~9.45		CH2	CO2 mix2	~10.35
CH3	R1 supply	12.0		CH3	R2 supply	102.0
CH4	R3 supply	84.0		CH4	R2 return1	varies
CH5	R3 return1	varies		CH5	R2 return2	varies
CH6	R3 return2	varies		CH6	unused	unused
CH7	R1 return	varies		CH7	N2 Dist	110.0-140.0
CH8	unused	unused		CH8	C4F10 Dist	4.00

MKS 146C

Parameters	***R1***	***R2***	***R3***
SETPOINT	0.060	0.060	0.060
LEAD	0.5	0.05	0.05
GAIN	5	20	20
INTEGRAL	1	3	3
BASE	25	25	25
START	45	50	45
PRESET	50	50	45
ALPHA	20	20	20
UNITS	torr	torr	torr
SENSOR CAL	ln	ln	ln
SENSOR RANGE	10 torr	1 torr	1 torr
SENSOR RESOLUTION	10^{-3}	10^{-3}	10^{-3}
DISPLAY LAG	5.00	15.00	15.00