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Program

Solenoidal Tracker at RHIC (STAR)

Subprogram

Time Projection Chamber - Gas System

Title

Gas System Operation at BNL

Abstract

The STAR TPC Gas System supplies either of two mixtures, P10 or 50% ethane in helium, to the STAR TPC at a controlled pressure. This system regulates the pressure and composition of the gas while monitoring gas temperature, oxygen'and moisture. A computer control/data acquisition system collects and logs the gas system operating parameters while providing a means of remotely controlling system valving. A separate alarm and interlock system prevents the TPC from operating under unsafe conditions.

Contents:

Introduction

The primary purpose of the STAR TPC GAS System (Fig. 1) is to provide either of two pure gas mixtures, P10 or helium + 50% ethane, to their at the correct temperature and pressure. Refer to Table 1 for a list of gas system parameters. A secondary function of the system is to cool the outer field cage resistor strings located in two channels at the top of the drift volume. The system operates nominally as a closed circuit gas system with the majority of gas recirculating through the TPC and delivery system. During normal operation a small amount of fresh gas is added and an equivalent quantity of the existing mixture is vented. The gas system can be operated in an open system configuration for purging.

The gas circulation rate is 36,000 1/hr which, given the 50 M3 volume of the TPC, is one volume change every 1.4 hours. The gas system contains two compressors, one active and one spare, each capable of 60,000 1/hr at 100 mbar gauge. The 100 mbar output pressure from the compressor is reduced to 30 mbar by the first pressure regulator and then to 2.4 mbar by a second regulator upstream of the TPC. A water cooled heat exchanger downstream of the compressors is used to remove the compression heat. The return gas manifold is maintained at 1.6 mbar above atmospheric pressure by a differential pressure transmitter and pneumatic (PID) controller that operates a bypass valve. The bypass shunts flow from the compressor discharge line directly back to the compressor's inlet. A second bypass valve is manually adjusted to enable the automatic control loop to be used within its optimum range.

The purity and composition of the TPC gas is monitored using oxygen, methane and humidity analyzers. A fraction of the recirculating gas can be passed through a dryer and purifier to remove moisture and contaminants as needed.

Table 1. Performance of Gas System is as follows:

TPC Volume	50,000 liters
Mixture	(10+/-O.2%)CH4 in Ar, (50+/-O.2%)C2H6 in He
Compressor pressure	90 - 100 mbar.
Supply pressure	2.2 -2.4 mbar.
Internal TPC pressure	2.+/-O.l mbar.
Return pressure	1.4 - 1.6 mbar.
Recirculation flow	36,000 1/h.
Purge flow	36,000 1/h.
Make-up gas flow	3.6 - 18 I/min, (36 I/min, He-Ethane)
Humidity analyzer flow	6 1/h.
Oxygen analyzer flow	12 1/h.
Oxygen content	< 10 ppm.
Water content	< 20 ppm.

An computer driven data acquisition/control system monitors all of the process variables and, through a feed-back loop, maintains a constant gas mixture. The computer system flags quantities which fall outside of predefined limits and initiates corrective action. However, where the safety of equipment or personnel are affected, a relay based, hard-wired interlock system connected to a redundant set of sensors control the action of all key valves. The relay based controls will bring the gas system to a safe state in the event the computer based controls fail.

It is imperative, for the safety of the device, that the TPC pressure accurately track ambient pressure. A rapid change in atmospheric pressure is typical preceding storms and hurricanes (ultimately the TPC will be located on the East Coast). To assure that the TPC follows a fast rise in ambient pressure, a relatively large flow of inert gas will admitted into the vessel in the event that normal pressure controls fail to keep up with "falling" internal pressure. The vent lines and associated valves are sized to allow for rapid venting of the TPC gas to prevent a high internal pressure should the ambient pressure fall faster than the closed system controls can accommodate. In addition to a large normally open vent valve, a bubbler connected to the TPC exhaust manifold will vent in the event that all other measures fail. A restrictive orifice has been placed upstream of the high pressure regulators to assure that the TPC and vent piping is not overwhelmed by a high inlet flow should a regulator fail.

Pressure Control

There are two sources of pressure in the gas system, the first is the compressors located at the exit of the TPC. The second is the flow of fresh gas through the mixing manifold. Nominally the pressure within the TPC is controlled by maintaining a constant pressure upstream of the TPC via a pressure reducing regulator and varying the pressure downstream of the TPC by regulating the amount of gas shunted from the compressor output to inlet. On a longer time scale the flow of fresh mixture is continually adjusted to compensate for varying atmospheric pressure.

The output from the compressor is 60,000 1/hr at 100 mbar. A back pressure regulator (BPCV-1) in the outlet line is set to 100 mbar thus maintaining a maximum delivery pressure independent of the compressor output. This pressure is reduced to 30 mbar by the first pressure reducing regulator (PCV-1) and then to 2.4 mbar by a second regulator (PCV-4) upstream of the TPC. The TPC exhaust pressure, measured at the return gas manifold is maintained at 1.6 mbar by a Tescom electropneumatic PID controller (CNT1). A Dwyer 0-2.5 mbar differential pressure transmitter (PT-6) on the return manifold produces a 4-20 mA output that the PID controller (CNT-1) compares to a set point value. If the transmitter signal is different from the set point the controller sends a pneumatic output signal to the bypass control valve (FCV-1). The bypass shunts flow from the compressor discharge line directly back to the compressor's inlet. Opening the bypass valve causes the TPC's exhaust pressure to rise and closing the valve makes the pressure

fall. A second bypass valve (MV-9), manually adjusted during the initial system set-up, enables this automatic control loop to be used within its optimum range.
Gas is admitted to the system between the 30 mbar and 2.4 mbar pressure regulators, PCV-1 and PCV-4 respectively. The quantity of fresh mixture is 0.6 to 3.0% of the total flow, i.e. 3.6 to 18 I/min for P10 or up to 36 I/min for helium-ethane. Simultaneously, gas is removed from the system through the back pressure regulator (BPCV-1). Fresh gas input is regulated by the mass flow controllers in the argon (FM-3,4,5) and methane (FM1,2) supply lines. These units are normally remotely controlled by computer but may be controlled locally if necessary.

When the internal TPC pressure, as measured by PT-5 and PI-7, is more then 2.0 mbar above ambient, the gas control system will close the solenoid valve (SV-10 deenergized) in the gas supply line and open the vent valve (SV-18 de-energized) allowing gas to vent directly to the atmosphere. Should the pressure reach 4.5 mbar, the excess TPC gas will vent to the atmosphere through the bubbler. With this arrangement the TPC is protected from either flow controller malfunction, a rapid drop in atmospheric pressure and/or a failure of the back pressure regulator.

In the event of a rapid rise in atmospheric pressure, or effectively a fast drop in the TPC's internal pressure (up to 6 mbar/min), a dual set point Dwyer differential pressure transmitter (PT-5) in the return manifold will trip as the pressure falls below 0.5 mbar causing an audible and visual alarm. When the pressure at PT-5 falls below atmospheric (O gage) a second set-point trips and the computer control system will stop the compressor, shut-off the flow of methane and pass inert gas through the methane flow controllers by opening valves SV-22, closing SV-21 (refer to Fig. 2), open the fresh gas supply solenoid valves (SV-11,12) and maintain SV-10 in the open position to supply an additional 300 I/min of inert gas.
A pressure indicating switch (PI-7) with dual set points is also installed in the return manifold. This switch is not connected to the computer control system but instead is hardwired to perform the same functions as computer system in the event of a falling TPC pressure. Thus the system is equipped with two separate means of preventing the TPC field cage from experiencing an external over pressure.

In the event of a power failure, the solenoid valves SV-10,11,12 and SV-18 will open, or remain open. SV-22 and SV-20 will open, or remain open and SV-21 will close, causing 300 I/min of inert gas to flow through the TPC. This flow rate is adequate to assure that fluctuations in the atmospheric pressure will not result in an excessive external pressure in the field cage nor will the TPC gas be contaminated by air being drawn in. In the event that the argon (helium) supply is exhausted before power is restored, nitrogen will automatically flow into the system to assure an adequate purge of all flammable gases, see fig. 2. The nitrogen back-up of the argon (or helium) is provided by a completely passive system where the supply of nitrogen is maintained at a lower pressure than the argon (or helium) supply. As the primary gas runs out and the pressure falls, the nitrogen gas pressure exceeds the sum of the primary gas pressure and check valve cracking pressure and begins to flow. The check valve cracking and reseal pressures were selected in conjunction with the delivery pressure of the primary (argon or helium) gas and nitrogen to assure that back flow of either gas does not occur.

Temperature Measurement

Four temperature transmitters (TT-2, TT-3, TT-4, and TT-5) are used to measure the gas temperature within the TPC. A fifth temperature transmitter, TT-1, measures the gas temperature within the monitoring chamber. The temperature control of the TPC is a function of the cooling system and is independent of the gas system. The measured gas temperatures are logged for later use in data reduction.

Mixture Control

Along with automated valve control, the gas system's dedicated computer controlled data acquisition provides constant monitoring of the gas mixture composition via a methane (or ethane) monitor. The mixture ratio is fixed by the mass flow controllers with the inert gas 'slaved" to the methane (or ethane) flow controller. The stability of the flow controllers is sufficient to make variation in the mixture negligible in comparison to atmospheric pressure variations. Since both gas mixture and pressure affect the drift velocity a single correction via real-time control of the field cage potential will be used to stabilize this parameter.

Drift and Gas Gain Monitoring

Drift and gas gain measurements are provided by a separate specially constructed chamber built and tested by Purdue University for this application. Output from this chamber will be read and evaluated by the gas system's data acquisition unit and archived for future reference.

Gas Sampling

The gas system is equipped with oxygen, moisture and methane (or ethane) monitors plumbed such that each section of the gas system can be selected separately for evaluation. A second oxygen monitor upstream of the 30 mbar pressure regulator, PCV-1 continuously samples the recirculating gas. If the oxygen content exceeds the 0.1% set point, the flow of flammable gas will be shut off and inert gas will flow in its place. As an added precaution, during P10 running, a dedicated gas monitor at the output of the mixing manifold continuously measures the methane content of incoming gas. In the event that the methane content exceeds 10% the monitor will trip and shut-off the flow of methane to the system.

All analyzers, mass flow controllers, monitoring chamber output and instruments are read and archived by this unit. Sensor outputs can be selected and viewed from the terminal.

Gas Purification

A gas dryer and purifier withdraws a portion of the flow upstream of the 30 mbar regulator and delivers the conditioned gas to the recirculating flow upstream of the 2.4 mbar regulator. This loop is used only as needed. The dryer is made from a stainless steel tube containing 10 lbs of molecular sieve (zeolite) (13X) adsorbent. This amount permits the removal of about 3 lbs of water vapor to a level of 1 ppm at room temperature. Filters are installed upstream and downstream of the adsorbent to prevent particles from entering the gas stream. A heating coil is wound around the outside of the tube and covered with glass insulation and an aluminum cover for heating (regenerating) the absorbent. The dryer is regenerated by heating to 300 'C will purging with helium or argon gas. The purge gas enters at the top of the dryer and exits at the bottom carrying with it the water vapor. A temperature transmitter installed on the outside of the tube and connected to controller (TIC-1) regulates the coil temperature. Solenoid valves installed at the inlet and outlet of the dryer isolate the unit from the main circuit when its not in use.

A moisture analyzer is used to measure the quantity of water in the circuit before and after the dryer to determine when the absorbent is saturated.

The purifier is similar to the dryer except that it is filled with a catalyzer that permits the oxidization of CH4 (C2H6) by the oxygen, present as an impurity, to form alcohol. The alcohol is subsequently removed by the dryer. The catalyzed oxidization process takes place at 200'C. This purifier does not require regeneration but must work in conjunction with the dryer. The dryer can be used separately as required. In normal operation neither unit is used. A 10 micron filter is installed after the purifier/dryer to prevent dust from passing into the main gas supply line. Two safety valves, PSV-1 and PSV-2 are used to prevent inadvertent over pressurization of the dryer and purifier during purging.

Computer Control and Data Acquisition

The gas system includes a computer driven data acquisition and control system. The controlling computer is a dedicated PC with a Intel 486 processor with a custom built I/O board and separate, shared, solid state relay chassis. This computerized system is programmed to acquire the signals from the various temperature, pressure, flow and gas measuring devices and issue warnings and/or take corrective action in the event that predetemined levels are exceeded. In addition, the gas monitoring chamber output is read and archived by the computer. All acquired values can be selected and viewed on the terminal. The interface of the gas system with the STAR level controls will be accomplished by an EPICS interface which will be restricted to the higher level functions such as purge, fill and stop and a subset of the most important measured quantities such as TPC pressure mixture and temperature.

Interlock and Alarm

An solid state relay driven interlock system is installed to warn of fault conditions and to take corrective action automatically if specified limits are exceeded. These actions include stopping the gas system compressor and shutting off the high voltage to the TPC. The interlock system is parallel and, in many cases, redundant to the computer control system. A partial list of fault conditions and the system's response is contained in Table 2 below.

Table 2. Example Fault Conditions

FAULT	LEVEL =>ACTION
1. PT-5	< 0 mbar =>Stop compressor & HV, inert gas purge
2. PT-5	< 0.5 mbar => Alarm
3. PI-10	< 2.2 bar => Stop HV, alarm
4. (CHI) C2H	< (9.8) 49.8% => Alarm
5. (CHI) C2H	> (10.2) 50.2% => Alarm
6. (CH,) C,H6	> (10.4) 50.4% =>Stop compressor & HV, inert gas purge, alarm
7. 02 and H 20	> 80 ppm =>Stop compressor & HV, alarm
8. 02 and H20	> 25 ppm => Alarm
8. Compressor outlet	< 60 mbar => Alarm
9. Vent pressure	>-O.5 mbar => Alarm
10. CH,* conc.	>(ll) 51% =>Stop HV, inert gas purge, alarm
11. Oxygen conc.	> 0.1% => Stop HV, inert gas purge, alarm

*Measured at fresh (make-up) gas supply line.

To restart the TPC Gas System after fault conditions it is necessary to:

FAULT 1,2	raise the TPC pressure to normal levels of >0.5 mbar using a fresh mixture and switch on the compressor.
FAULT 6	lock off (acknowledge) the alarm correct the source of the problem and switch on the compressor to circulate mixture through the monitoring loop
FAULT 7	lock off (acknowledge) the alarm and switch on the compressor to circulate the mixture through the purification loop. When the mixture parameters return to normal the alarm must be unlocked (reset).
FAULT 10,11	Same as 7 but no need to switch on the compressor.

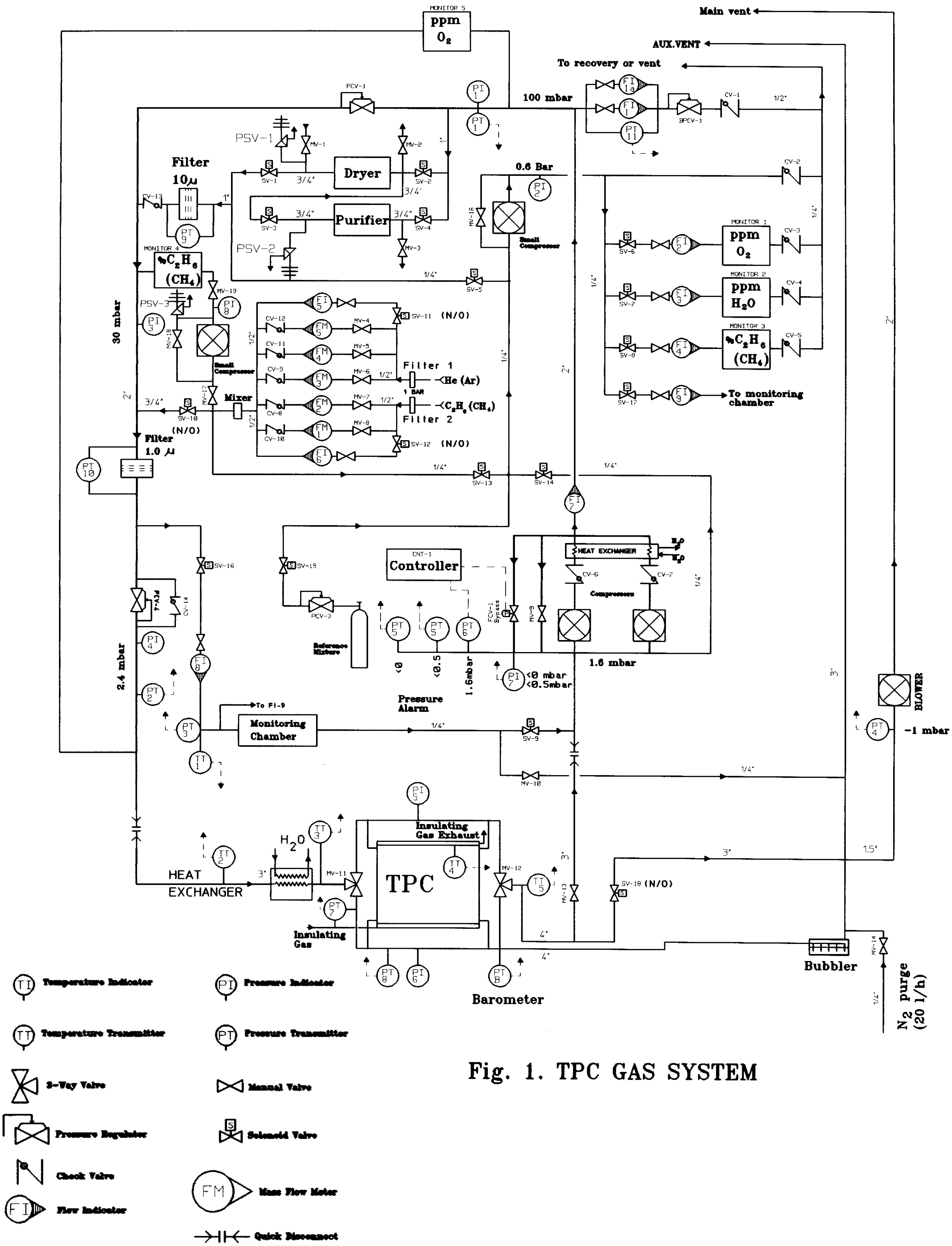
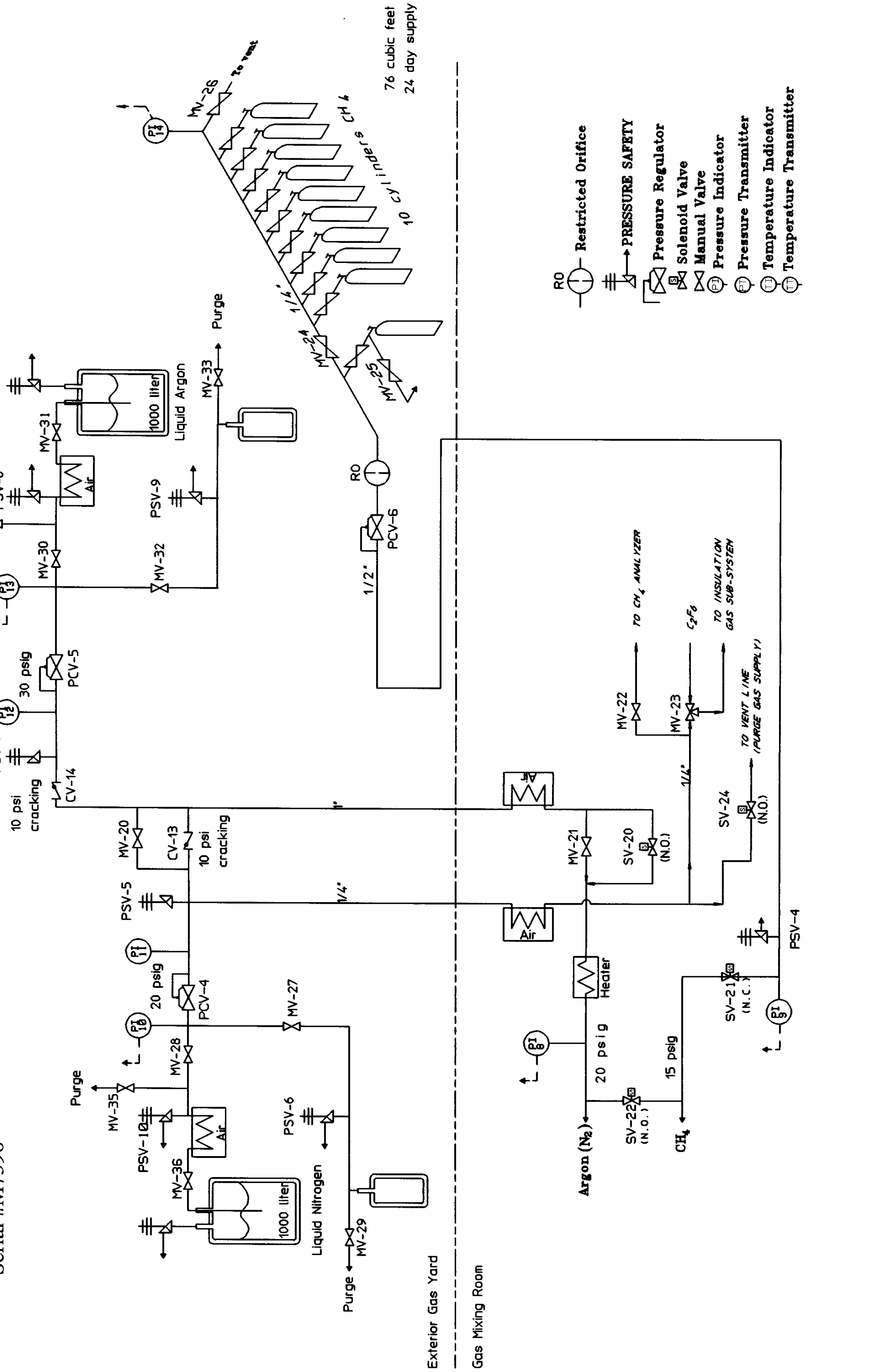


Fig. 1. TPC GAS SYSTEM



FILE:Gas_System_TPC_BNLrevB

Fig. 2. TPC GAS SUPPLY SYSTEM (BNL)

Serial #M7596