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GAS MIXING SYSTEM FOR DRIFT CHAMBERS USING SOLENOID VALVES

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ABSTRACT

We describe an inexpensive system for mixing argon and ethane drift chamber gas which is used for the E-605 experiment at Fermilab. This system is based on the idea of intermittent mixing of gases with fixed mixing flow rates. A dual-action pressure switch senses the pressure in a mixed gas reservoir tank and operates solenoid valves to control mixing action and regulate reservoir pressure. This system has the advantages that simple controls accurately regulate the mixing ratio and that the mixing ratio is nearly flow rate independent.

We also report the results of the gas analysis of various samplings, and the reliability of the system in long-term running.

Introduction

We previously used an argon/ethane gas mixing system for drift chambers which mixed the two gases continuously according to the total flow of gas into the chambers. The mixing ratio was determined by comparing the readings of two flowmeters which had been calibrated for argon and ethane gases by the manufacturer. There were three major problems in our old system:

1. For fixed flowmeter needle valve adjustments, the mixing ratio varies with total system flow. This means that each flowmeter must be readjusted when the total system flow is changed. The non-linear calibration characteristics of the flowmeters require that calibration curves be consulted each time this is done.

2. We often need a large flow rate such as ten times more than in normal operation in order to purge chamber gas after repairing broken wires. It is difficult to obtain flowmeters which have this dynamic range without sacrificing accuracy.

3. It takes about an hour for the mixing flowmeters to settle down to the final reading once the flow rate has been changed. This is due to the volume and the low conductivity of the line from the gas mixing hut to the chambers.

The new system which is described below has solved the above mentioned problems. It is based on the idea of intermittent mixing with constant flow rates at the flowmeters using simple solenoid valves. The simplicity of this system has permitted its construction at a cost of less the $1,000.

Description of the System

The main part of this system consists of two solenoid valves, two flowmeters, a reservoir tank, and a dual-action pressure switch as shown in Fig. 1.

If the pressure of the reservoir tank falls below a certain threshold, the pressure switch is activated and it opens the solenoid valves simultaneously permitting flow of argon and ethane gases. Both of the gases start flowing through flowmeters and mix together in a mixing tube. The ratio of mixing is controlled by precision needle valves and is monitored by the flowmeter indicators. The flow rate of each flowmeter is set slightly higher than the maximum necessary flow of the gas into all the chambers during a rapid gas purging. The mixed gas goes into the reservoir tank and its pressure builds up to exceed the upper threshold eventually, which resets the pressure switch and shuts the solenoid valves to stop mixing. The system repeats this cycle with a time constant determined by the consumption rate of the gas from the reservoir tank.

We chose the following values as the parameters according to the needs of our experiment.

The lower threshold of the pressure switch is 14 psi and the upper threshold 16 psi. The reservoir tank is 4 cubic foot in volume and is made of a modified cylinder for argon/ethane premixed gas. The mixing flow rates are 14 SCFH for both argon and ethane under 25 psi at the input of the flowmeters. The flowmeter readings were first set to the values of approximately 50%-50% mixture using the typical calibration curves provided by the manufacturer and then one of them was re-adjusted later according to the gas analysis. The typical requirement of the gas flow into all the chambers of our experiment is about 2 SCFH under a normal operating condition and about 20 SCFH under rapid purging condition.

The input pressures of the flowmeters are regulated to 25 psi by the regulators R-3 and R-4 in Fig. 1.

The diaphragm relief valve D-1 is used to maintain a constant back pressure on the flowmeter outlet which otherwise would be affected by the reservoir tank pressure which varies within a 2 psi range.

The flow restrictors are used to minimize the over-shoot of the balls in the flowmeter tubes due to the initial surge when the solenoid valves open. The regulator R-5 used to minimize the effect of the pressure cycle on flow rate to the chambers.

We use liquid ethane cylinders and liquid argon dewars for the sources of gases in order to reduce the frequency of the bottle changes.

The final flow rates into the chambers are controlled individually by flowmeters near the chambers.

Operation of the System

Under a flow rate to the chambers of 2.1 SCFH, the system has cycle times of 1.2 minutes for filling the reservoir tank from 14 psi to 16 psi and 15 minutes for discharging the tank from 16 psi to 14 psi as shown in Fig. 2(a). Figure 2(b) shows the time cycle of the reservoir tank pressure under a flow rate of 12.5 SCFH. It is possible to make the cycle time longer by adding more volume to the reservoir tank, but we have chosen not to do this because there is no obvious advantage in it and the shorter time helps ensure more uniform mixtures.

The 2 psi change in reservoir tank pressure during filling results in a 2% change in both argon and ethane flows. This is the result of imperfect control of pressures before and after the mixing control flowmeters.

The mixture ratio of argon and ethane was commercially analyzed by the thermal conductivity method against a known reference gas. Several samplings were taken under different conditions such as different settings of the flowmeter readings and different flow rate for the chambers. First we set the mixing ratio according to the typical calibration curves of the flowmeters which were provided by a manufacturer. The estimated ethane contents were 46.0%, 50.4%, and 54.6% while the results of the analyses were 46.76%, 50.47%, and 54.98%, respectively. The relative calibration scales for argon and ethane are accurate within an error of 1%. The final setting was done by interpolating these data.

The flow rate dependence of the ethane percentage was less than 0.5%, which is satisfactory for our experiment. The actual gas analysis showed 50.63% of ethane for the flow rate of 12.5 SCFH, and 50.47% at 2.1 SCFH under the same settings of the flowmeters.

The system has been run for about five months without failure. The drift of the flowmeter readings is less than 2%. As both of the flowmeters tend to move to the same direction, the actual drift of the mixture is less than 0.5%.

Conclusions

We have built and tested an inexpensive gas mixing system for drift chambers, based on the idea of intermittent mixing using solenoid valves. The system has shown a great capability to follow the changing demands of the gas flow and has worked stably for five months. The mixing ratio has been constant within ± 0.25%.

We thank the members of Experiment #605 for discussions.

FIGURE CAPTIONS

Fig. 1. Schematic diagram for the gas mixing system.

Fig. 2(a). Diagram of the time cycle of the reservoir tank pressure under the condition of 2.1 SCFH flow to the chambers.

Fig. 2(b). Same as Fig. 2(a) under the condition of 12.5 SCFH flow to the chambers.

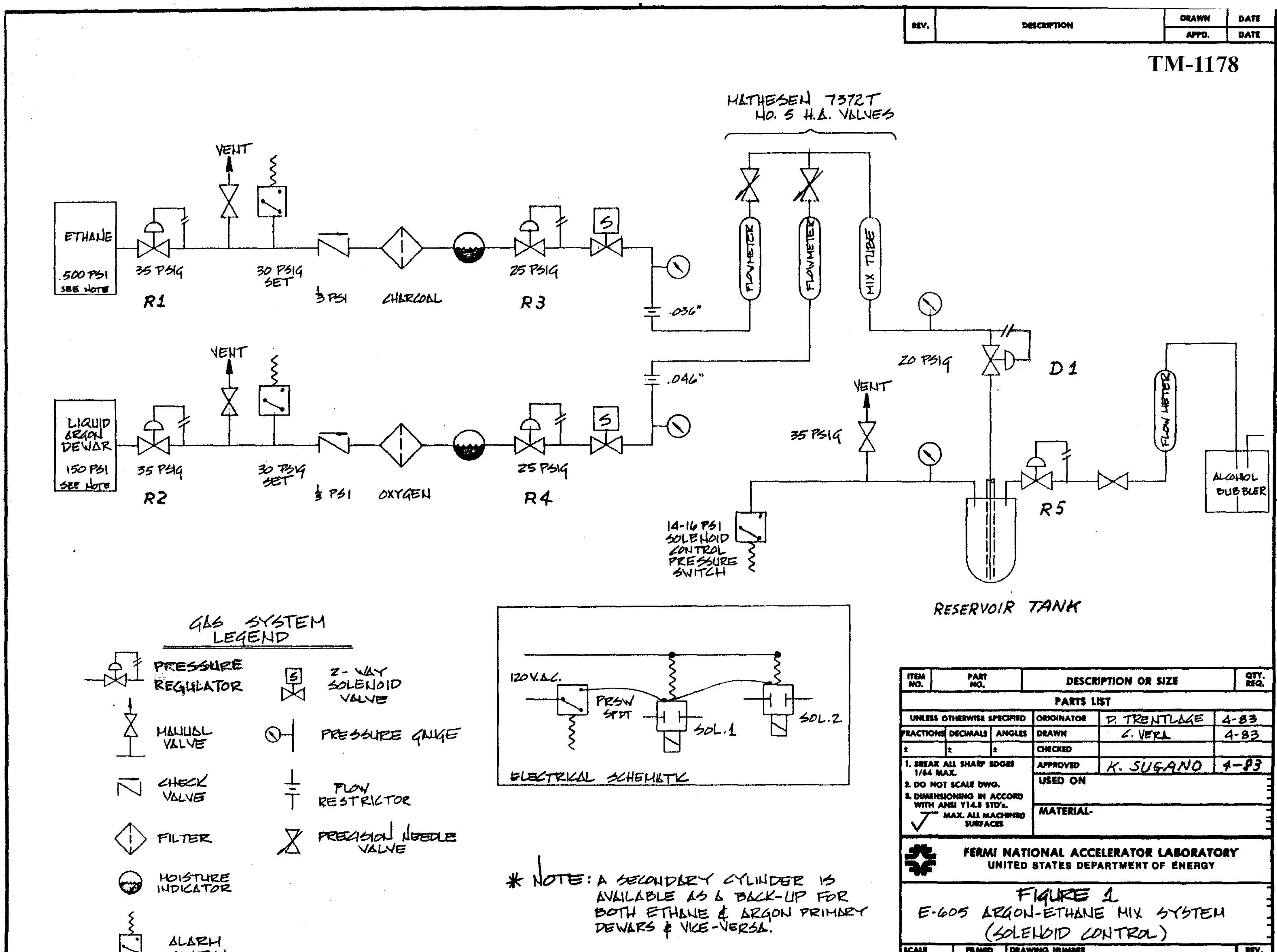
REV.
DESCRIPTION
DRAWN
DATE
APPD.
DATE
MATHESEN 7372T
NO. 5 H.A. VALVES
VENT
ETHANE
500 PSI
SEE NOTE
35 PSIG
R1
30 PSIG
SET
1/3 PSI
CHARCOAL
25 PSIG
R3
.036"
FLOWMETER
FLOWMETER
MIX TUBE
LIQUID ARGON DEWAR
150 PSI
SEE NOTE
35 PSIG
R2
30 PSIG
SET
1/3 PSI
OXYGEN
25 PSIG
R4
.046"
20 PSIG
D 1
VENT
35 PSIG
FLOW METER
ALCOHOL BUBBLER
R5
14-16 PSI
SOLENOID
CONTROL
PRESSURE
SWITCH
RESERVOIR TANK
GAS SYSTEM LEGEND
PRESSURE REGULATOR
2-WAY SOLENOID VALVE
MANUAL VALVE
PRESSURE GAUGE
CHECK VALVE
FLOW RESTRICTOR
FILTER
PRECISION NEEDLE VALVE
MOISTURE INDICATOR
ALARM SWITCH
120 V.A.C.
PRSW SPDT
SOL. 1
SOL. 2
ELECTRICAL SCHEMATIC
* NOTE: A SECONDARY CYLINDER IS AVAILABLE AS A BACK-UP FOR BOTH ETHANE & ARGON PRIMARY DEWARS & VICE-VERSA.
ITEM NO.
PART NO.
DESCRIPTION OR SIZE
QTY. REQ.
PARTS LIST
UNLESS OTHERWISE SPECIFIED
FRACTIONS
DECIMALS
ANGLES
±
±
±
1. BREAK ALL SHARP EDGES 1/64 MAX.
2. DO NOT SCALE DWG.
3. DIMENSIONING IN ACCORD WITH ANSI Y14.5 STD's.
MAX. ALL MACHINED SURFACES
ORIGINATOR
D. TRENTLAGE
4-83
DRAWN
C. VERA
4-83
CHECKED
APPROVED
K. SUGANO
4-83
USED ON
MATERIAL-
FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY
FIGURE 1
E-605 ARGON-ETHANE MIX SYSTEM
(SOLENOID CONTROL)
SCALE
None
FILMED
DRAWING NUMBER
REV.

Fig. 1

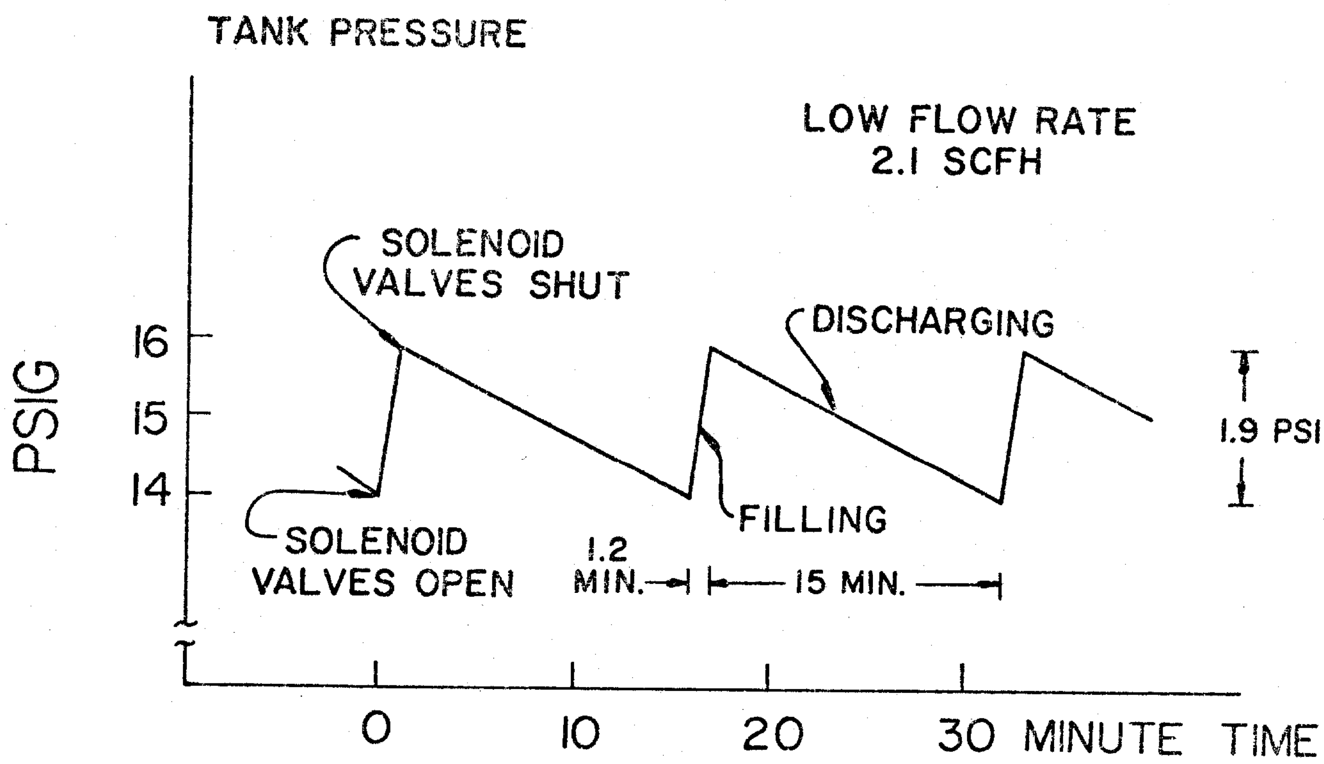

Fig. 2a TIME CYCLE OF TANK PRESSURE

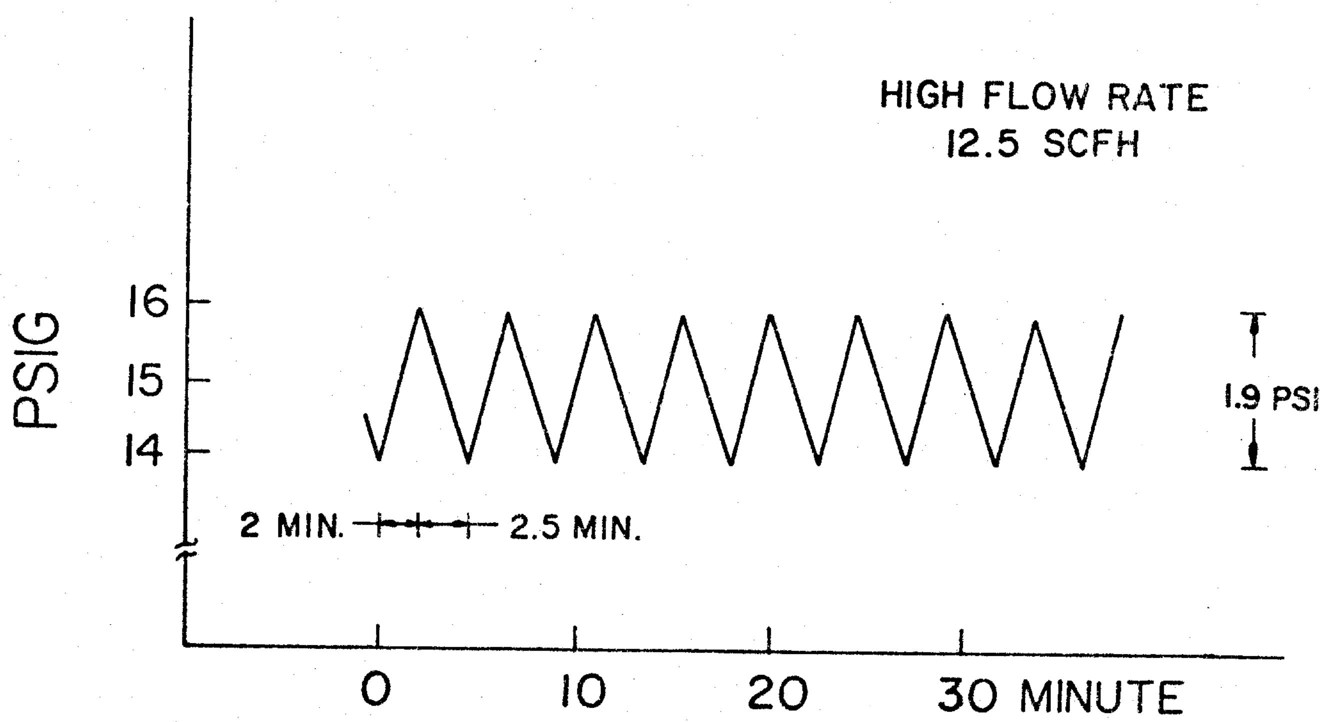

Fig. 2b TIME CYCLE OF TANK PRESSURE