CONTROLLED MIXER FOR THE GAS TO THE DRIFT CHAMBERS IN THE AXIAL FIELD SPECTROMETER IN THE CERN INTERSECTING STORAGE RINGS

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Received 30 April 1981

This report describes a continuous mixing system used to supply a very stable gas mixture to the central detector of the Axial Field Spectrometer. The way in which the mixture is measured and controlled is described. A particular feature of this system is the careful minimization of effects due to variations in atmospheric pressure, inlet pressure and inlet temperature.

1. Introduction

The central detector of the Axial Field Spectrometer in the ISR is formed of two hemi-cylindrical drift chambers each of a volume of 1.8 m^3 .

For the drift chambers it is essential to work with a stable gas mixture in order to maintain a constant gas gain [1]. The performance of the electronic read-out can be adversely affected by changes in gas gain, and in particular a reliable particle identification by measurement of the total ionization becomes very difficult. In order to work continuously with a stable gas mixture a controlled mixer has been designed and put in operation in the system.

In the following the main problems in obtaining a stable mixture are described, and then the operating principles in other known systems and in the constructed system are discussed. Finally, some results from the operation of the system are given, and possible improvements are pointed out.

2. The problem

The gas mixture presently chosen for the drift-chambers is 50% argon and 50% ethane.

It is desired to supply the mixture at variable flow rates and it is a great help to be able to supply a fixed flow rate to one chamber when changing (or even connecting or disconnecting) the flow rate to the other chamber. This can be obtained if the output pressure from the mixer can be controlled. Also should it be possible to accept variations in input pressure, particularly changes due to automatic switching of gas bottle batteries. It is also required that changes in temperature due to start-up of new bottles and due to storage at different temperatures should not influence the gas mixture.

In short, the mixer should supply as precisely as possible the desired mixture at a controlled pressure regardless of changes in input pressures, input temperatures and output flow rate.

Fig. 1. CERN standard rack mixer.

Fig. 2. Mixer using thermal flow meters and flow control.

Other known methods of preparing binary mixtures present disadvantages in the present situation:

a) The classical set-up (shown in fig. 1) is known

from the CERN standard rack. The mixture stability relies on the proportional pressure controllers and on the input gas temperature. When mixing argon with

Fig. 3. Pressure and mixture controller measuring volume flow by flanges.

Fig. 4. Mixture control loop.

ethane from bottles of pure components a change in input pressure and temperature will occur because argon is gaseous and ethane liquid in the bottle. The output pressure from the proportional pressure controllers (pressure reducers) will depend on input pressure and output flow rate. Also the output pressure from the mixer cannot be controlled [2].

b) A system using thermal flow meters (commercial name: mass flow meters) to control the flow of each components is shown in fig. 2. Such a system, however cannot control the output pressure. Also explosion proof thermal flow controllers are expensive and have long delivery times [3].

c) In fig. 3 is shown a system where the output pressure is controlled. The mixture is obtained by measuring the flow in each stream by means of measuring flanges, and regulating one flow proportionally to the other. The use of metering flanges presents

Fig. 5. Pressure control loop.

the disadvantage of being sensitive to input pressure and temperature [4].

d) Another possibility is to prepare a batch in a pressure vessel large enough to give flow for one physics run. This solution gives the possibility of mixing more than two components, and ensures a constant mixture during the particular run. Analysis can be carried out before the use of each batch [5]. In

Fig. 6. Mixer hardware diagram.

our situation the size of the vessel would be prohibitive.

3. The solution

The chosen solution was to control the ethane flow by a measurement of the output mixture. When measuring the *mixture* no difference in temperature or pressure between the components can occur. The argon flow is controlled so that the desired output pressure is obtained.

In block diagram terms there are two control loops: a mixture control loop shown in fig. 4 and a pressure control loop shown in fig. 5.

The hardware diagram (piping and signals) is shown as fig. 6.

4. Mixture transmitter

A choice of instruments exists to measure the composition of a binary mixture. The principle is to use a physical quantity that is different for each of the two components, thereby making that quantity a function of the mixture. Examples of such physical quantities are: density, speed of sound, infrared absorption, thermal conductivity and heat capacity.

The analyser used in this system works with thermal conductivity. It compares the thermal conductivities of pure argon and of the mixture. The analyzer cell contains four filaments that change their resistance with temperature. The filaments are built in as shown in fig. 7. They are heated electrically, and the thermal conductivity of the gas determines the temperature of each filament. The gas streams and the electric coupling in a Wheatstone bridge are shown in fig. 8. The thermal conductivity depends not only on the gas but also on pressure and temperature. Therefore the pressure in the two streams is kept constant compared to the atmospheric pressure. The fact of

Fig. 7. Thermal conductivity cell.

Fig. 8. Mixture measuring principle.

having a reference gas stream (and not a sealed reference) minimizes the effect of atmospheric pressure variations (which are of the order of 5–10%) on the measurement of the mixture. Effects of changes in mixture measurement due to changes in temperature are minimized by having heat exchangers at laboratory temperature through which the sample and reference gas streams pass en route to the analyzer. The installed version uses ~8 m of copper pipe ϕ 6 mm passing through the air conditioned room.

With the above mentioned precautions the voltage difference in the Wheatstone bridge becomes a good measure of the mixture in the sample stream.

Calibration is carried out by means of four known gas "mixtures": (a) pure argon, (b) 44.1% ethane in argon, (c) 51.2% ethane in argon, (d) pure ethane. The calibration curve is shown in fig. 9. It is seen that the output voltage is almost a linear function of the mixture.

Fig. 9. Mixture transmitter calibration.

5. The controller

The output voltage from the mixture transmitter is converted into a standard control signal as shown in fig. 10. This standard signal is fed into a standard PID controller (Proportional Integral Derivative controller). The output control signal is used to position a pneumatically controlled valve.

Pneumatic control is chosen in order to meet the safety requirements for flammable gases.

6. The mixture stability

Because of the length of the copper piping between the mixer and the mixture transmitter the control system cannot be very rapid in its action. This fact leads to oscillations in the output from the mixer. However the integrating controller assures a constant mean value in time. Furthermore the buffer barrel after the mixer radically reduces these oscillations in the gas sent to the chambers.

7. Operation

The mixer operates at a flow rate of about 12 l/min (STP) and an output pressure of 200 mbar rel. The sample flow rate to the mixture transmitter is about 0.25 l/min (STP), and the volume of the pipes can be estimated to 0.5 l. The controller is set to an integration time of about 3 min. Typical oscillations in the mixture under these operating conditions can be seen in fig. 11. The variations at the output of the 250 l barrel (i.e. input to chambers) also are shown in fig. 11, and are seen to be of the order of 10^{-3} .

Fig. 10. Mixer transmitter signal conditioning.

Fig. 11. Operation performance.

8. Improvements

In order to further improve the mixture stability the following points deserve a further study:

(a) If the pipe length between the mixer and the mixture transmitter is reduced the amplitude of the oscillations could be reduced. In the present situation this would require the construction of a new mixture transmitter to be mounted in the flammable gas zone.

b) A mixture transmitter with another measuring principle mentioned in sect. 4 to choose the best should be carried out.

The authors would like to express their gratitude to all those who have contributed by encouragement, and/or criticism, to this work. Especially we would like to thank C.W. Fabjan, H.J. Hilke, K. Ley, P.

Quéru and E. Rosso. Also we thank N.A. McCubbin for his aid and remarks on the draft report.

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