Drift-Chamber Gas System Controls Development for the CEBAF Large Acceptance Spectrometer

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ABSTRACT

The CEBAF Large Acceptance Spectrometer (CLAS) is a superconducting toroidal magnet with a large volume of drift chambers for charged particle tracking. The performance of these chambers depends on accurate monitoring and control of the mixture, flow rate, pressure, temperature, and contaminant levels of the gas. To meet these requirements, a control system is being developed with EPICS. The interface hardware consists of VME ADCs and three RS-232 low-level hardware controllers. The RS-232 instruments include MKS 647A mass flow controllers to control and monitor the gas mixture and flow, MKS 146B pressure gauge controllers to measure pressures, and a Panametrics hygrometer to monitor temperatures and the concentrations of oxygen, water vapor, and ethane. Many of the parameters are available as analog signals which will be monitored with XYCOM VME analog input cards and configured for alarms and data logging. The RS-232 interfaces will be used for remote control of the hardware and verification of the analog readings. Information will be passed quickly and efficiently to and from the user through a graphical user interface. A discussion of the requirements and design of the system is presented.

INTRODUCTION

The primary instrument in Hall B at the Continuous Electron Beam Accelerator Facility (CEBAF) is the CEBAF Large Acceptance Spectrometer (CLAS) shown in Fig. 1. This device is a toroidal multi-gap magnetic spectrometer and is described in detail in the Conceptual Design Report on CEBAF Basic Experimental Equipment [1]. The magnetic field is generated by six iron-free superconducting coils. The particle detection system consists of drift chambers to determine the trajectories of charged particles, Cerenkov detectors for the identification of electrons, scintillation counters for time-of-flight measurements and electromagnetic calorimeters to identify electrons and to detect photons and neutrons. The six segments will be instrumented individually to form six independent spectrometers. Commissioning of the CLAS will begin in the fall of 1996.

The tracking of charged particles is accomplished by three regions of drift chambers that are located at different radial positions from the target. The inner chambers, called “Region I”, surround the target in a region of low magnetic field. The “Region II” chambers are somewhat larger and are situated between the toroidal magnet coils in a region of high field, while “Region III” chambers are large devices located radially outward of the magnet. Achieving the design goals for an accuracy of better than 0.5% in momentum and angular resolution of $\approx$ 1 mrad requires tight constraints on the gas mixture within the chambers. These constraints are discussed in detail in the User Manual and Operation and Safety Procedures (OSP) for the Hall B Drift Chamber Gas System [2] and require control and/or monitoring of the flow rates, mixture, pressures, temperatures and contaminant levels of the gas.

There will be two levels of control in the gas system. The basic flow control loops and alarm system will be hardwired at one level. At a higher level, the system described in this paper will control and monitor the gas system in such a way as to allow:

- Safe operation of the gas system.
- Remote monitoring of signals.
- Remote control of system elements.
- Ease of use via a graphical user interface (GUI).
- Detection of anomalous operational modes, alerting the users of such situations and, where possible, executing automatic procedures to ensure personnel and hardware protection.
- Archiving operational parameters for future restoration and analysis.
- Automation to handle the processing of very large numbers of signals.

The drift chamber gas system control has been identified as one of the highest priority components of the Hall B control system [3, 4].

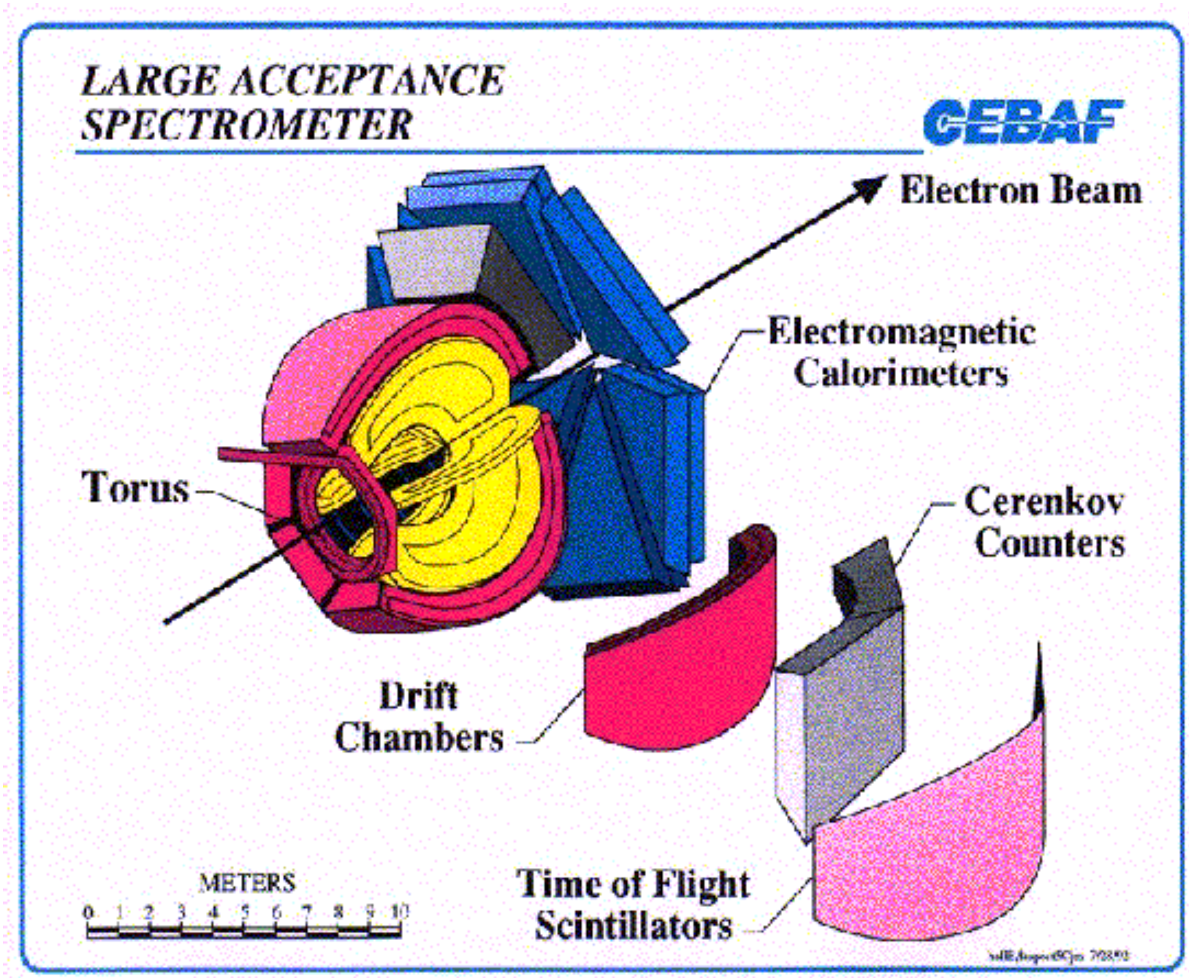

Figure 1. Exploded view of the CLAS showing the magnet and the various detector components.

THE DRIFT-CHAMBER GAS SYSTEM

The gas system has been designed to meet the stringent requirements outlined in the User Manual and OSP for the Hall B Drift Chamber Gas System [2]. A schematic of the system is shown in Fig. 2. The basic gas system operation consists of mixing, filtering, monitoring, and recirculating (Regions II and III) the gas. When raw gas arrives on site, it is analyzed using a residual gas analyzer (RGA). Once accepted, it is cleared for use with the CLAS drift chambers. During steady state operation, two fresh gases are precisely mixed to achieve the correct relative fraction. The newly mixed gas is stored in large buffer volumes that supply the process loop that contains the CLAS drift chambers. The pressure and percentage of ethane in the gas in the buffer tanks are continuously monitored. As the mixed gas enters the loop, it is first filtered to remove contaminants. An adjustable orifice then drops the pressure and controls the flow. For fine tuning of the gas mixture, additive bubblers are then provided as an option. Directly following the bubblers the oxygen and water content and the temperature and flow rate are monitored before the gas leaves the shed for the hall. As the gas enters the hall, it passes through heat exchangers to damp temperature fluctuations. The gas then enters the chambers where it serves its purpose. At the chamber exit manifolds, the gas passes by safety bubblers. Downstream of the manifolds, the gas temperature and differential pressure with respect to atmosphere are monitored. This pressure reading is transmitted back to the shed where it controls a proportioning solenoid valve in front of a pump. The pump and “throttle valve” pull gas out of the hall while controlling the pressure in the chambers. Once back at high pressure again in the shed, oxygen and water monitors continuously monitor contaminant levels. Finally, a fraction of the gas is exhausted and the rest reenters the cycle above the filters (Regions II and III).

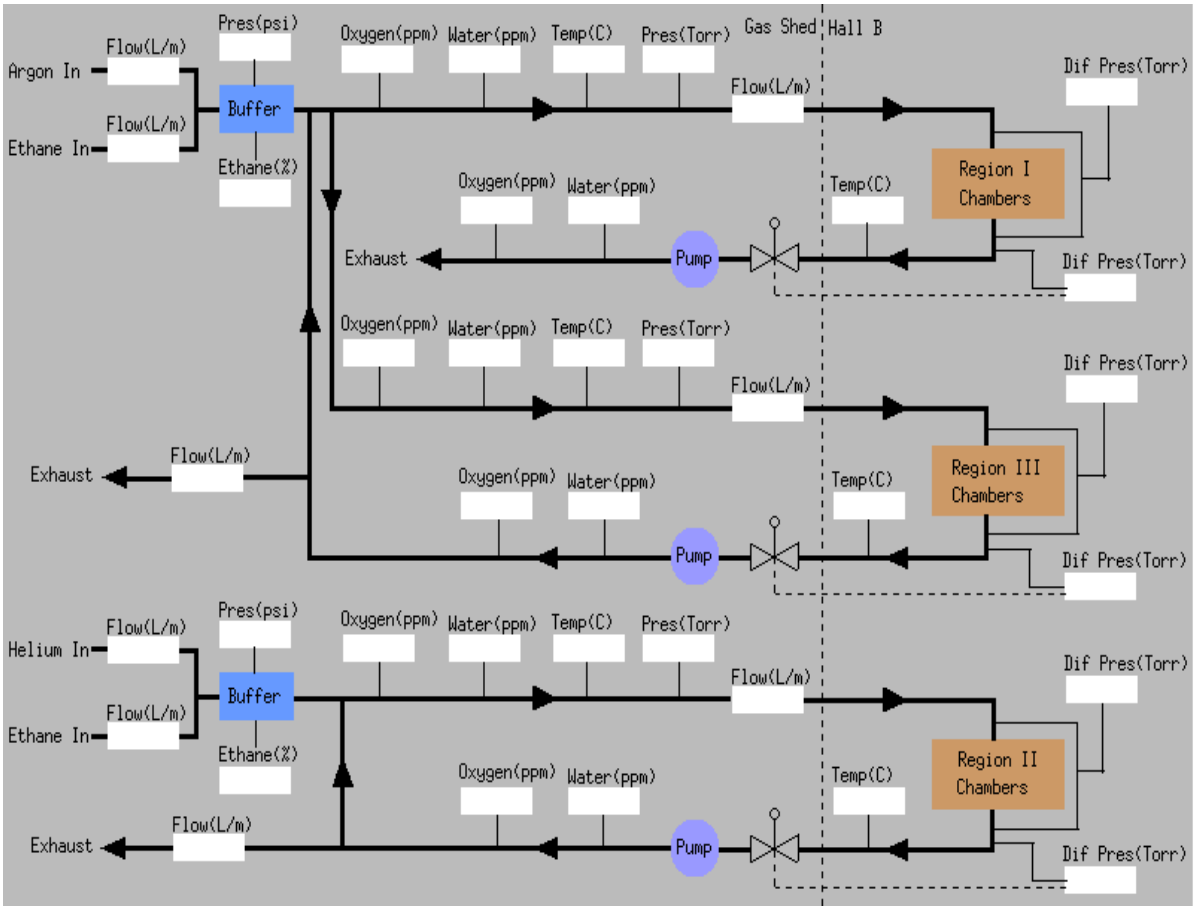

Figure 2. Prototype of the main window of the graphical user interface for the CLAS drift chamber gas system controls. A schematic of the gas system is shown with digital displays to present the analog information.

The various sensors are powered and monitored with three different hardware controllers that have local readout and programming capabilities. The flow controllers and transducers are operated with two MKS 647A mass flow controllers. Pressure sensors are controlled with three MKS 146B pressure gauge controllers. A Panametrics hygrometer is used to monitor temperatures and the concentrations of oxygen, water, and ethane. All of these instruments have RS-232 interfaces for remote control and monitoring. Analog signals are also available for many of the parameters. The instruments have programmable alarms that produce signals that are used to bypass or shut down portions of the gas system. In the event of a failure due to any of a number of conditions, the chamber is bypassed automatically with electronically actuated valves immediately before and after the chambers. These safety features are hardwired and under no software control. The computer control system is needed to monitor parameters and alert the operator of abnormal conditions so that they may be corrected to avoid hardware-activated shut downs. The system is also needed for remote control of the hardware and archiving of parameters for analysis.

THE CONTROL SYSTEM

The control system is being developed within the framework of the Experimental Physics and Industrial Control System (EPICS) [5]. A schematic of the control system hardware is shown in Fig. 3. The operator interface (OPI) is a Hewlett Packard workstation with an X-windows GUI. The input/output controller (IOC) is a Motorola MV 162 single board computer running the VxWorks operating system and mounted in a VME crate. The crate also contains two XYCOM XVME-560 analog input cards and a Green Spring IP-octal 232 industry pack. Communication between the OPI and the IOC is accomplished through ethernet with the EPICS network communication software called Channel Access. The system includes RS-232 interfaces to the two mass flow controllers (MFC), the three pressure controllers (PC), and the hygrometer (HYG).

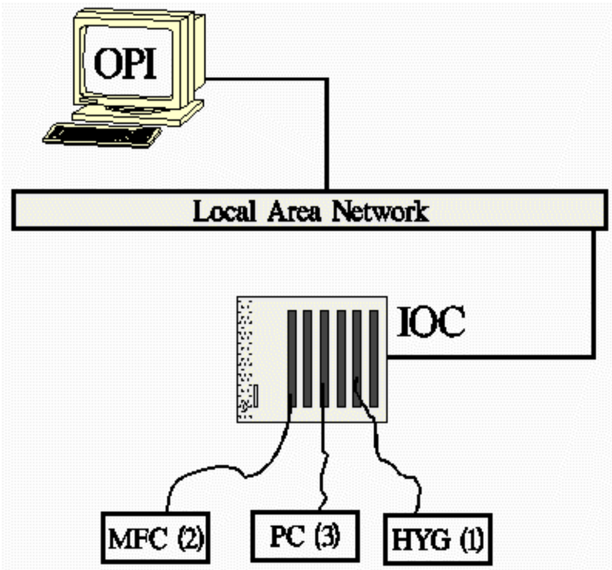

Figure 3. A schematic of the control system hardware showing the operator interface (OPI), the input/output controller (IOC) and the low-level hardware controllers.

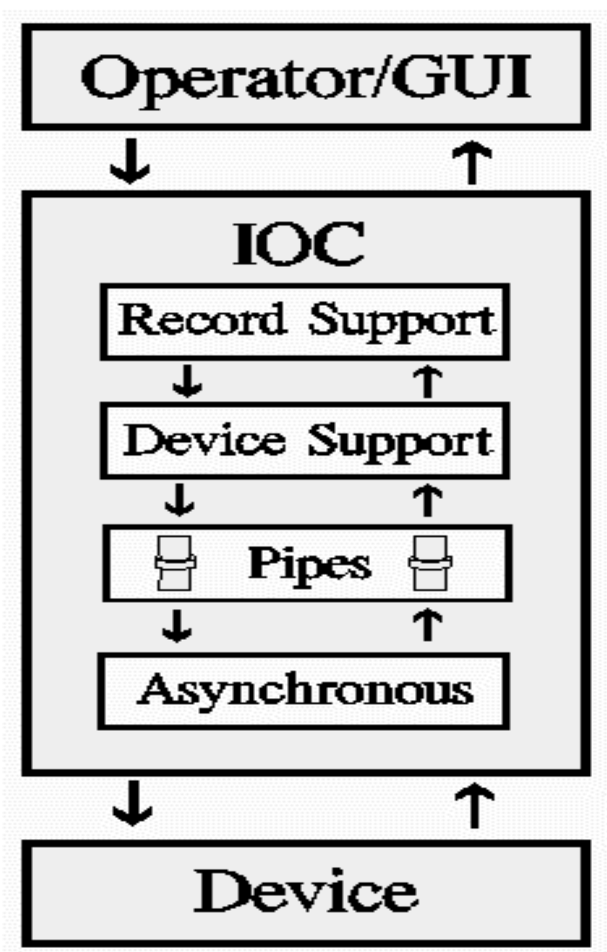

Figure 4: A schematic of the RS232 software interface

Analog Signals

The analog signals from the gas system instrumentation will be continuously monitored with the VME ADCs operating in the 32-channel differential input mode. Device and driver support routines for the XYCOM XVME-560 have been obtained from the SSC and are running on our EPICS development system after some modifications. All of the analog signals are being configured for data logging and many for alarms.

RS-232 Interfaces

Remote control of the hardware and verification of the analog readings will be accomplished through the RS-232 interfaces. The RS-232 device support software has been written and tested for the flow and pressure controllers. The device support for the Panametrics hygrometer will be developed in the near future. An overview of the RS-232 software interface is illustrated in Fig. 4. Standard EPICS analog output records are used to send commands to the device support. Commands without special parameters use a common analog output record, while those with special parameters each have their own analog output record. The device support is split into synchronous and asynchronous parts. This is necessary because EPICS is a synchronous system that cannot wait for a slow asynchronous device to process commands and respond. The synchronous device support is essentially a simulated synchronous device. It utilizes two Tx pipes, which are standard data structures in the VxWorks environment; one to send commands and one to receive responses. These pipes communicate with the asynchronous device support, which is essentially an infinite loop that continuously checks the output pipe for a command. The asychronous device support is spawned as a task in VxWorks, and it is what actually communicates with the device. Once a command is found, it is converted into an ASCII string of a format acceptable to the device. The asynchronous support then waits for a response from the device. Once it is received, the response is placed in the other of the Tx pipes, where it can then be removed by the synchronous device support. Having been removed, the response is placed in a standard EPICS string input record. If any errors are encountered, the device support will instead place an appropriate error string into the record. Once in this record, the response can then be accessed by the GUI.

Graphical User Interface

The GUI is being developed using an EPICS tool called the Motif Edit and Display Manager (MEDM). The main screen of the GUI will consist of a schematic of the gas system with the analog information presented in digital displays. A prototype of this window is shown in Fig. 1. Along the bottom of the main screen will be a menu to bring up windows for the different RS-232 instruments. These lower level screens include buttons, which are connected to the analog output records and send commands and text displays connected to the string input records for the responses. Examples of these screens are shown in Figs. 5 and 6.

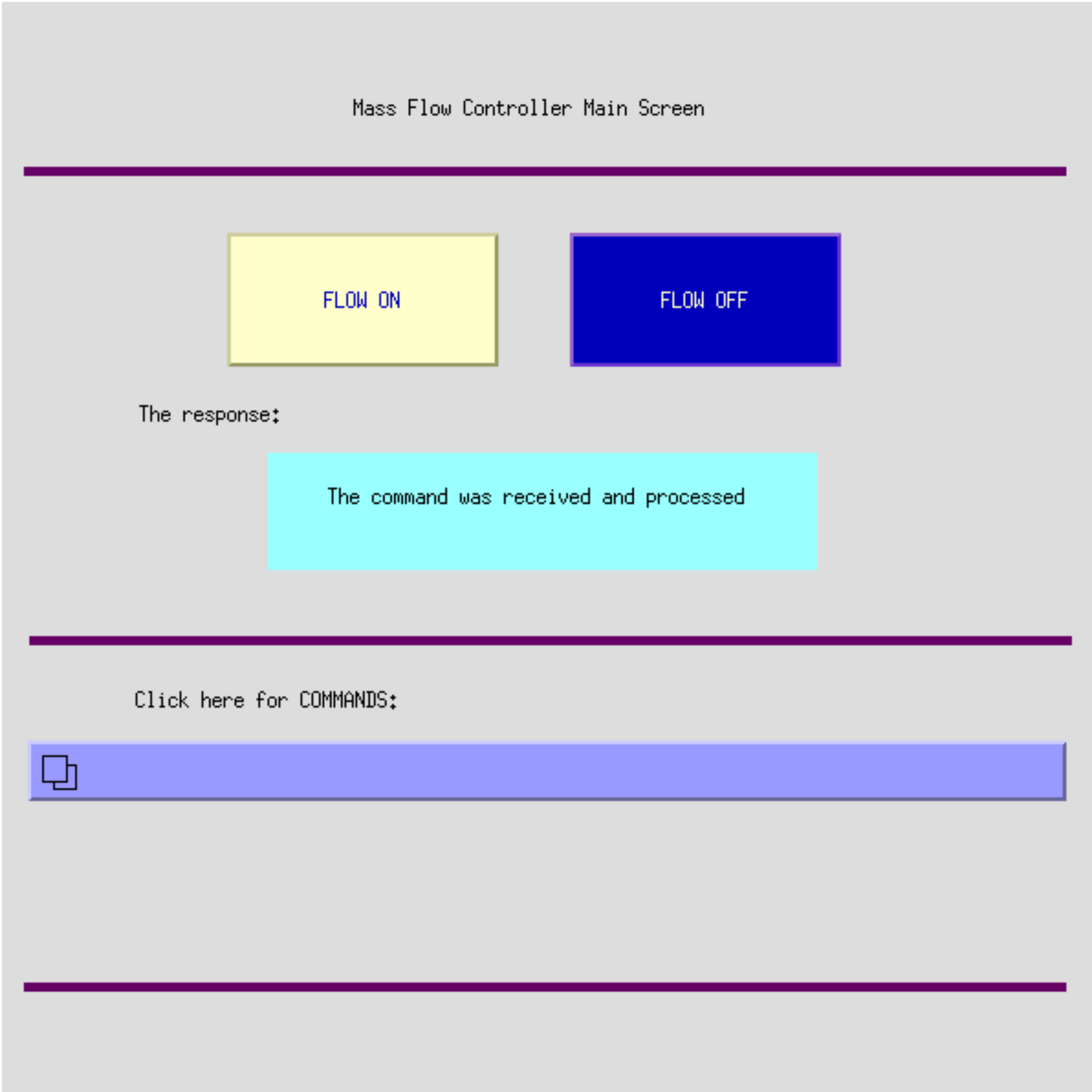

Figure 5: The GUI screen for the mass flow controller.

SUMMARY

A control system is being developed with EPICS for the drift-chamber gas system for the CLAS detector at CEBAF. The gas parameters will be continuously monitored and configured for alarms and data logging. Remote control of system elements will be accomplished through RS-232 interfaces to low-level hardware controllers. Information will be passed efficiently to and from the operator via a GUI. The design of the system is nearly complete. Device support software has been written and tested for all the hardware except the Panametrics hygrometer, and prototype

GUI screens have been developed. Future work includes device support development for the hygrometer, implementation of valve status monitoring, and integration with other components of the Hall B control system.

ACKNOWLEDGEMENTS

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REFERENCES

[1] Conceptual Design Report, Basic Experimental Equipment, CEBAF Report, April, 1990.

[2] User Manual and OSP for the Hall B Drift Chamber Gas System, S. Christo,W. Major, M. Mestayer, R. Wines, and Pete Woods, Working Draft CEBAF Report, June, 1995.

[3] Hall B Slow Controls System Requirements Document Overview (SRD), D. Barker and the Hall B Controls Group, Draft CEBAF Report, June, 1995. Information on the system can be found on the World Wide Web at https://www.urich.edu/~vineyard /SRD.book_1.html.

[4] Commissioning the Hall B Experimental Equipment, Draft CEBAF Report, June, 1995.

[5] The Experimental Physics and Industrial Control System (EPICS) is a set of software tools originally developed by Argonne National Laboratory and Los Alamos National Laboratory for the purpose of building distributed control systems. Information on EPICS can be found on the World Wide Web at https://www.aps.anl.gov/asd/controls/epics_home.html.

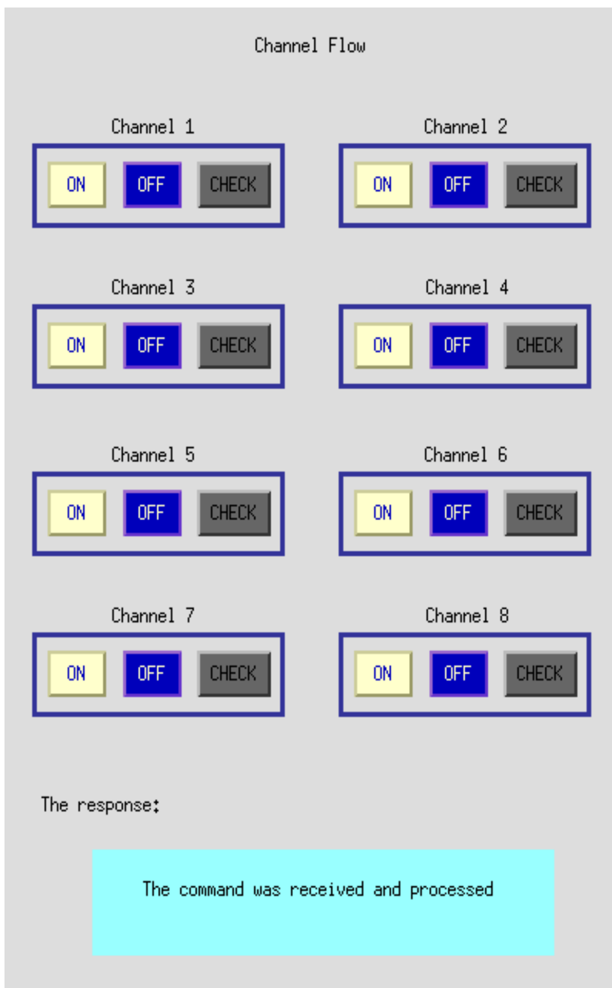

Figure 6: The command subscreen for the mass flow controller.