CEBAF-PR-95-022

THE CEBAF CONTROL SYSTEM FOR THE CHL*

Marie S. Keesee, Brian S. Bevins

Continuous Electron Beam Accelerator Facility
Newport News, VA 23606-1909 USA

ABSTRACT

The CEBAF Central Helium Liquefier (CHL) control system consists of independent safety controls located at each subsystem, CAMAC computer interface hardware, and a CEBAF designed control software called Thaumaturgic Automated Control Logic (TACL). The paper describes how control software was interfaced with the subsystems of the Central Helium Liquefier. Topics of configuration, editing, operator interface, datalogging, and internal logic functions are presented as they relate to the operational needs of the helium plant. The paper will also describe the effort underway to convert from TACL to the Experimental Physics and Industrial Control System (EPICS), the new control system for the CEBAF accelerator. This software change will require customizing EPICS software to cryogenic process control.

SYSTEM DESCRIPTION

The CEBAF cryogenic system consists of three separate facilities - the Central Helium Liquefier (CHL), the End Station Refrigerator (ESR), and the Cryogenic Test Facility (CTF). The CTF provides refrigeration for use in CEBAF's test laboratory, the ESR provides refrigeration for the various cryogenic equipment in the experimental halls, and the CHL provides shield cooling and 2K refrigeration to components in CEBAF's injector and two superconducting linear accelerators. CEBAF's Cryogenic Scope is shown in Figure 1.

The CHL is a 4.8 kW, 2.0 K refrigerator and transfer line system which supplies the linacs with 2.0 K and 12 kW of 50 K shield refrigeration. The CHL also supplies 10 g/s liquid for the experimental physics halls. The system block diagram is shown in Figure 2. The main components of the system include two stages of warm helium screw compressors, a 4.5 K Cold Box, a 2.0 K Cold Box (Cold Compressors), and various support equipment.

* Supported by U.S. DOE contract DE-AC05-84ER40150

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

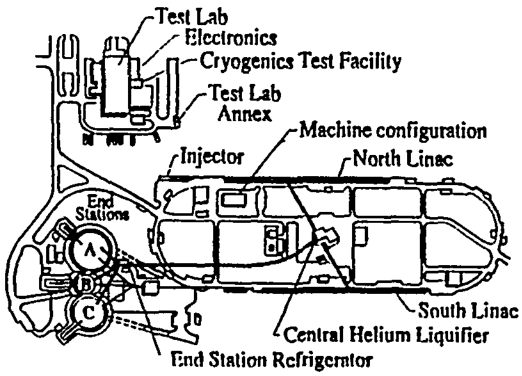

Figure 1. CEBAF Cryogenic Scope

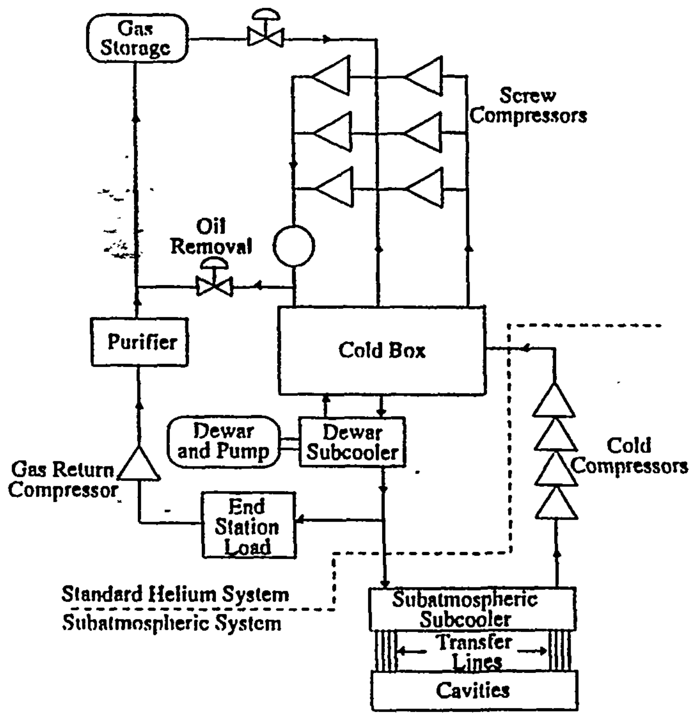

Figure 2. Block Diagram of CHL Refrigerator

INSTRUMENTATION AND INDEPENDENT SAFETY CONTROLS

The CEBAF cryogenic system has two levels of control. The first level of control is equipment protection and safety, and the second level is process control. The cryogenic group's philosophy is to separate the first level of control from the accelerator control system. Therefore, the CHL contract required that no piece of equipment shall depend on CEBAF's control system for equipment protection and safety. Each piece of equipment was supplied with all the instrumentation and controls required to protect the equipment in the event of equipment failure or off-design conditions that could damage the equipment. Most of this is accomplished with local instrumentation and relays, or programmable logic controllers.

Responsibility for the second level of control was split between CEBAF and the equipment supplier. All equipment was supplied with the vendor's recommended instrumentation. The vendor then wired the instrumentation to a designated location in the CEBAF supplied interface racks. CEBAF supplied the wiring from that interface location in the racks to the I/O crates and then to the control system computers.

CAMAC INTERFACE

The I/O crates that the cryogenic system uses are CAMAC crates. Off the shelf CAMAC modules are used whenever possible to encourage standardization. The standard CAMAC modules in use include Analog to Digital Converters, Digital to Analog Converters, Digital Input modules, and Digital Output modules.

Three custom-built CAMAC modules were necessary to support the needs of the cryogenic system. The first two custom CAMAC modules are electric and pneumatic valve drivers that were designed and built at CEBAF. The electric valve driver module sends DC signals to valve actuators driven by 24 volt DC motors. The pneumatic valve driver module sends 4-20mA signals for pneumatically actuated valves. These two modules also support an LVDT or a potentiometer (or voltage) valve position readback. The third custom module is a silicon diode and platinum resistor temperature scanner that was contracted to be designed and built for CEBAF. This module sends the appropriate current to the temperature resistor or diode, reads back the resulting voltage, and converts the voltage to a temperature using the proper calibration curve data.

There are over 1150 I/O channels currently interfaced through the CAMAC crates for the CHL system. The CHL building accounts for 770 I/O channels in five CAMAC crates. The CAMAC crates in the CHL building are connected to the control system in parallel by a GPIB interface. There are two crates for the compressor room, two crates for the cold box room, and one crate to support the 2.0 K cold box (cold compressors).

The cryogenic equipment in the two superconducting linacs accounts for 384 I/O channels distributed through fourteen CAMAC crates. These CAMAC crates connect to the control computers via two serial highways. There are 6 crates for each linac, and two crates for the injector area. The CAMAC crate layout is shown in Figure 3.

THE TACL SYSTEM

Overview

TACL is a logic-based software control system that was developed at CEBAF and has been in use since November, 1987[1]. TACL supports a CAMAC I/O interface, and provides for easy configuration of control logic databases and generation of custom screens for operator interface. The software runs on a distributed network of Hewlett-Packard UNIX workstations.

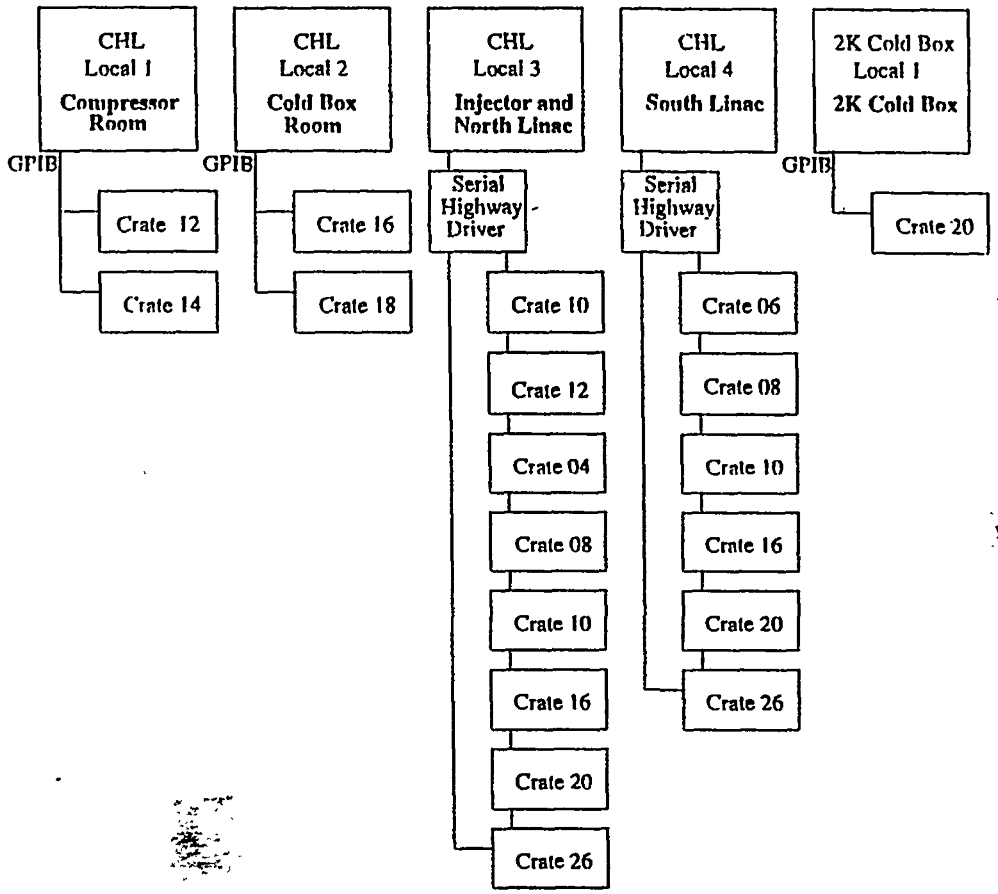

Figure 3. The CHL CAMAC Crate Layout

Configuration

The TACL control system for the CHL uses an architecture of 4 supervisor computers and 7 local computers. The control system layout is shown in Figure 4.

The supervisor computers handle the network communications between other supervisors and different parts of the control system, and run logic databases for necessary supervisory tasks.

The local computers run the logic databases that include most of the engineering conversions, control logic, PID calculations, and input/output operations with the CAMAC crates. The local computers only communicate with their own supervisor, and therefore are not overloaded by network traffic. The disadvantage of this layout is that the local computers cannot communicate with each other. They must communicate by way of their supervisors.

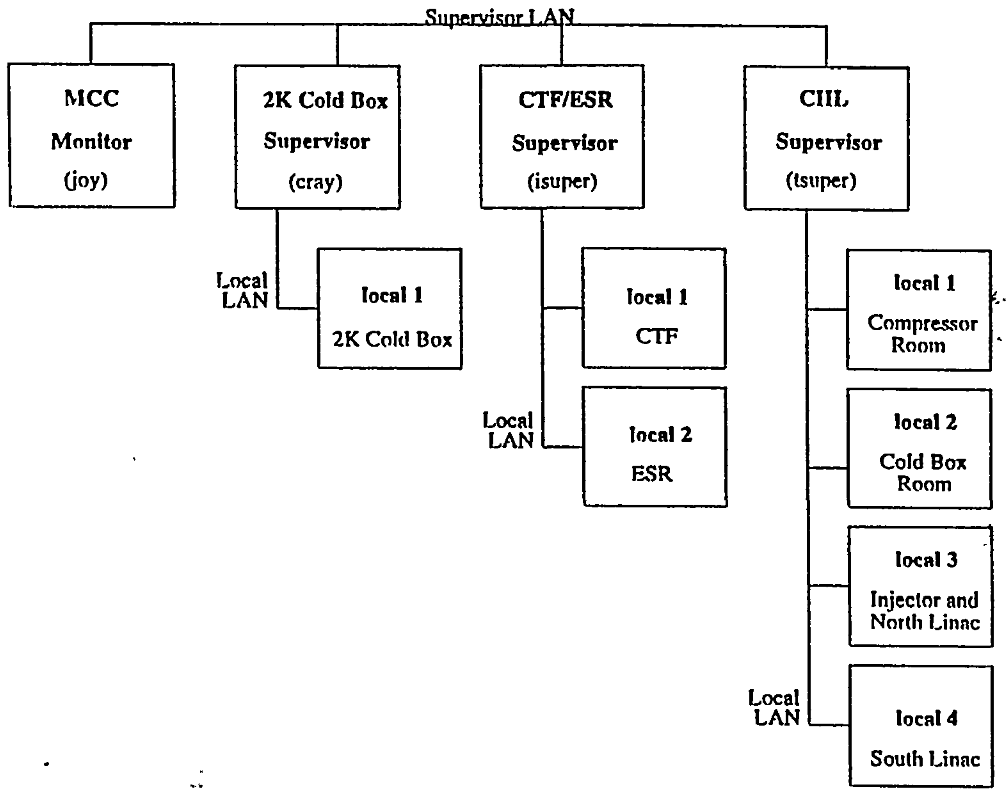

Figure 4. Cryogenic Control System Diagram

Editing and Operator Interface

TACL consists of tools that allow users to build the control logic databases and operator interface screens for their particular application. This reduces the load on the controls group staff, and allows the control system to be configured by users knowledgable in each application.

The TACL Logic Editor is an icon-based database editor. Menus are used to select and describe all the hardware interfaces in the system. This editor also allows the user to symbolically define the logical flow of control. The editor generates a database from the user defined information that is executed at run-time.

The TACL Display Editor allows the user to create control screens for operator interface using a wide variety of drawing tools. The user may create custom symbols to supplement the available drawing functions. A custom symbol was created and added to the drawing functions list for monitoring and operating the many PID loops in the cryogenic system. Most of the control screens for the CHL were created to look like the system process diagrams. This makes it easier for the engineers and technicians familiar with the hardware to monitor and control the system.

Special Logic Functions

Since the CHL is a process control application, PID loops are widely used in the system. PID loops are software proportional, integral, and differential feedback loops. The CHL control system uses over 125 PID loops to control the cryogenic equipment in the CHL building and in the two linacs. A special PID logic function was added to TACL for the CEBAF cryogenic systems. This PID loop allows for all of its parameters, including gains and limits, to be changed during runtime, allowing for easy runtime tuning of the loops.

Utility Programs

Utility programs have been written to perform datalogging, strip chart graphing, and saving and restoring settings.

The datalogger allows periodic logging of process signals in samples from one second and up in one second increments. A menu driven editor is supplied to configure the datalogging file.

The graphs program plots process signals in strip chart format. Up to ten signals may be plotted on one graph. Each signal may have its own range, and the time between plotted samples may be changed. This program can plot signals in real time or can plot datalogged signals.

There is also a program that can save current operational settings so that they can be restored after a computer reboot or failure, or to support a different operational mode. Restoration of PID settings is very important to a process control system like the CHL.

THE EPICS CONVERSION EFFORT

EPICS is a control system toolkit being developed by a collaboration of several DOE laboratories[2]. EPICS will support existing CAMAC hardware through serial highway to VME based I/O Controllers (IOC) that run the EPICS software. UNIX workstations are used to execute high level applications, and XWindows format is used for the operator interface. The differences between TACL and EPICS and reasons for CEBAF's conversion of control systems from TACL to EPICS are discussed in references 2 and 3.

The CHL system will be converted to EPICS late in 1996, after the Cryogenic Test Facility (CTF) is successfully converted. CTF will be used as a test bed for the CHL conversion to work out conversion details relating to cryogenics.

A new EPICS PID is currently being written to support CEBAF's needs. The new PID will act like the TACL PID, so that all of the CEBAF cryogenic PIDs will not have to be retuned.

A graphs program is also being developed to support the cryogenic conversion to EPICS. Since most cryogenic processes are relatively slow, a good real-time graphs program assists the operators in monitoring the system.

CTF is scheduled to be converted to the EPICS control system in August of this year. The programming and configuration for the control system is 75% complete and is waiting on completion of the new PID. All of the existing instrumentation and CAMAC hardware will be used under the EPICS system with the exception of the CAMAC crate controllers. The crate controllers will be changed to serial controllers to support the serial highway mentioned above. The operator interface screens are in the process of being redone since EPICS uses an XWindows operator interface.

Since most of the control system runs on VME based IOCs, the computers used for the operator interface will be X-terminals. These X-terminals will run off of one workstation that will also run the higher level applications such as graphs, archiving, and save/restore programs.

REFERENCES

1. E. Navarro, M. Keesee, R. Bork, C. Grubb, G. Lahti, J. Sage, Use of the TACL System at CEBAF for Control of the Cryogenic Test Facility, *Proc. 1989 Conference on Real-Time Computer Applications in Nuclear, Particle, and Plasma Physics*, June (1989).
2. K. White, et. al., *The Migration of the CEBAF Accelerator Control System from TACL to EPICS*, CEBAF Control System Review, May (1994).
3. S. Schaffner, et. al., *Device Control at CEBAF*, Particle Accelerator Conference, May (1995).