EBR-II Cover Gas Cleanup System (CGCS) Upgrade
Graphical Interface Design

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ABSTRACT

Technology advances in the past few years have prompted an effort at Argonne National Laboratory to replace existing equipment with high performance digital computers and color graphic displays. Improved operation of process systems can be achieved by utilizing state-of-the-art computer technology in the areas of process control and process monitoring. The Cover Gas Cleanup System (CGCS) at EBR-II is the first system to be upgraded with high performance digital equipment. The upgrade consisted of a main control computer, a distributed control computer, a front end input/output computer, a main graphics interface terminal, and a remote graphics interface terminal. This paper describes the main control computer and the operator interface control software.

INTRODUCTION

Argonne National Laboratory's Experimental Breeder Reactor II (EBR-II) is a pool type nuclear reactor demonstration facility that uses liquid sodium as the primary system and secondary system coolant. The primary system tank contains 87,000 gallons of liquid sodium blanketed with an argon cover gas. Despite this inert atmosphere, the primary system requires a cover gas monitoring and cleanup system called the Cover Gas Cleanup System (CGCS). The CGCS maintains low levels of impurities in the cover gas so that even small levels of impurities can be detected to flag a failed fuel

element, and to support mass spectrometer analysis to identify a failed fuel element. Impurities can be introduced to the argon cover gas by the failure of fuel element cladding and the subsequent release of gaseous fission products, or xenon "tag gas" placed in the fuel elements for the purpose of signaling a fuel element breach. The CGCS consists of a main cleanup loop and a gas analysis system. See Figure 1.
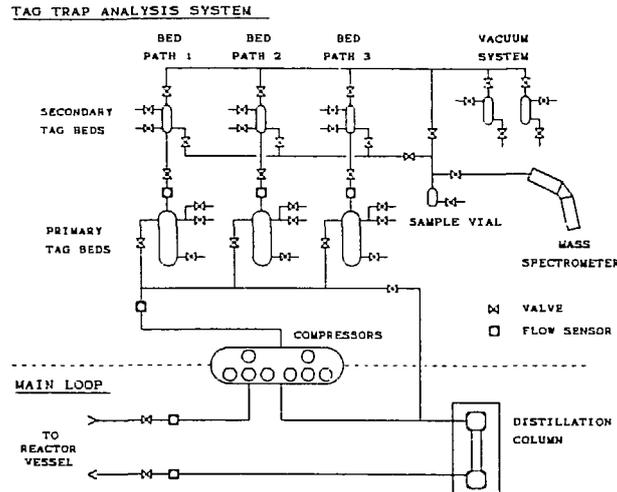

Figure 1. Cover Gas Cleanup System

The cleanup loop, called the Main Loop, takes argon cover gas from the primary tank, runs it through a cryogenic distillation column to clean it, and returns the clean gas to the primary tank. The gas analysis system, called the Tag System, takes a portion of gas from the cleanup loop, concentrates the impurities in the gas through a cryogenic adsorption/desorption process, and runs the gas through a mass spectrometer to determine the ratios of the xenon isotopes in the cover gas. Improvements in computer technology have prompted the upgrade of the CGCS control system to provide a more reliable and robust control strategy.

DESCRIPTION OF COMPUTER CONTROL SYSTEM

The layout of the CGCS computer control system is shown in Figure 2. The system consists of three computers: a main computer consisting of a Concurrent Computer Corporation MC6450 with RTU, Concurrent's real-time Unix operating system; an STD bus based distributed control computer; and an STD bus based front end computer. The operator interfaces with the system through two graphics terminals. A Main Loop backup control terminal and Tag System printer and optional maintenance terminal are driven directly from the STD bus computers.

The distributed control and front end computers communicate with the main control computer through serial fiber optic links. The main control room graphics terminal directly connects to the main control computer and the remote graphics terminal, an X-terminal, connects to the main control

computer through a fiber optic ethernet using a TCP/IP protocol. The main control computer contains four main tasks: the Operator Interface Task (OIT) that handles the main graphics terminal and the X-terminal, the Process Control Task (PCT) that controls the tag trapping system portion of the CGCS, the Mass Spectrometer Task (MST) that controls the mass spectrometer and analyzes the data it collects, and the Communications Task (CMT) that handles communications with the two STD bus based computers and the EBR-II DAS.
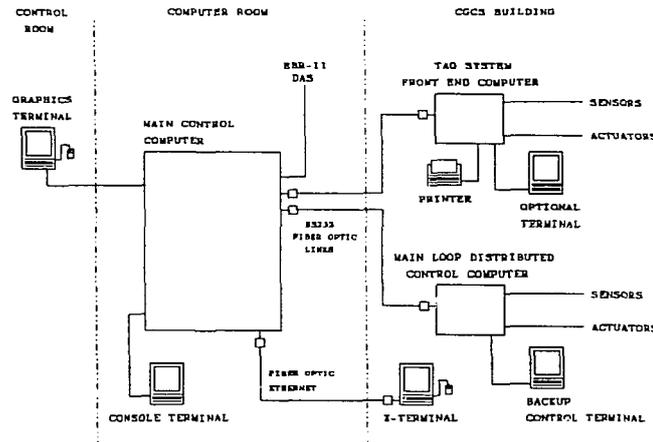

Figure 2. CGCS Computer Control System

DESCRIPTION OF COMPUTER SYSTEM SOFTWARE

System Software

The operating system on the main control computer is a real-time Unix. Real-time is achieved through the use of interrupts called Asynchronous System Traps (AST) and a dual CPU architecture. The master CPU processes the interrupts so that normal program flow is not disturbed. This technique allows the software engineer to be guaranteed a specific period of time to elapse before the interrupt is processed. Since ASTs are different than the standard Unix signals, they can be queued and can carry information with them.

The graphics system software uses X Windows and a product called Dataviews. X Windows is used as the vehicle for creating the network connection between the main control computer and the high resolution color graphics X-terminal. The inherent networking characteristics of X-Windows allowed multiple graphical devices to be developed on the main control computer and then distribute the graphical information to the remote X-terminal. Dataviews is a graphics package which was purchased from V.I.Corporation. It contains a graphics editor and a library of subroutines. The editor, DVdraw, allows the developer to rapidly create a picture containing graphical objects that can be linked to local program variables and dynamically updated with respect to changing data. The

subroutines, DVtools, are the mechanisms for handling the operator interaction and for updating the graphical objects.

Application Software

The CGCS application software is in multiple tasks that share a common data segment called Shared Memory. The software structure is shown in figure 3.
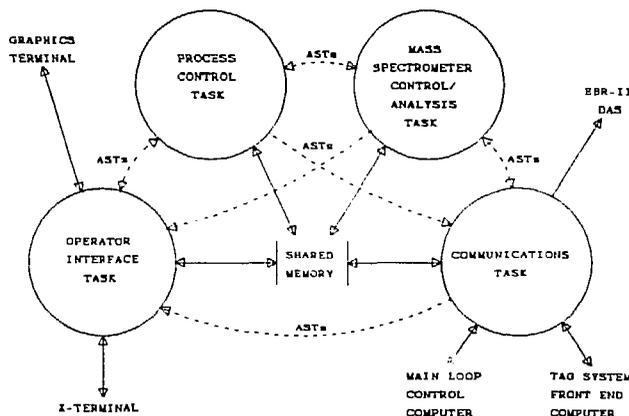

Figure 3. Task Structure

Shared memory is a method of mapping a computer's memory segment into multiple program data segments. This allows any process attached to this memory segment to use and share the segment with other tasks as easily as using a local program variable. This is currently the most efficient interprocess communication technique available on Unix systems.

ASTs are used to interrupt a task's normal flow. CGCS tasks signal each other and pass control information to cause specific functions within the task to be executed. This is done by posting the AST interrupt handler's address in shared memory so that other tasks can send the AST and cause execution of the receiving task to halt and proceed at the address of the interrupt handler. At this point, all other ASTs are queued until the interrupt handler is finished.

OPERATOR INTERFACE DESIGN

Screen Layout Methodology

The basic structure of the screen layout is shown in figure 4. It is comprised of functional areas on the display called "viewports". The "Main" viewport is where the CGCS diagrams called "views" are displayed. These views display real-time data and handle operator interaction for system

modifications and alarm acknowledgement. Operator interaction is performed with an attached mouse. The design of the views is discussed in the next section.
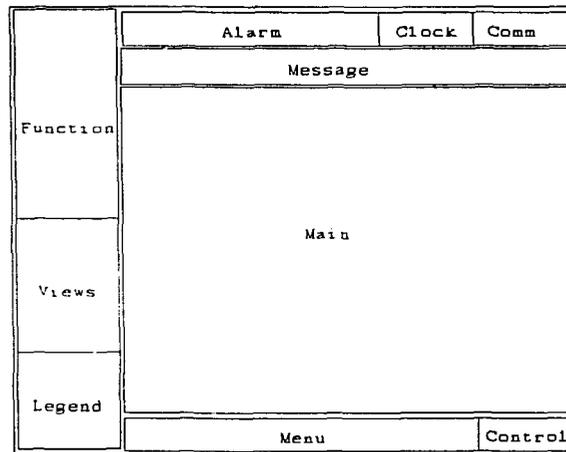

Figure 4. Display Viewport Layout

The "Functions" viewport is a menu that lists the main functions of the CGCS. There are six (6) functions available. They are: 1) Setup, 2) Main Loop, 3) General Status, 4) Bed Paths, 5) Vacuum System, and 6) Mass Spectrometer System. Operator interaction in this viewport causes the selection to be high-lighted and the view associated with the selection to be displayed in the "Main" viewport. If there is more than one view associated with the selected function, a pre-determined view is displayed.

The "Views" viewport lists the available views pertaining to the current function selected in the "Functions" viewport. In figure 5, the "Setup" function is selected and the three views associated with setup are 1) Main Loop, 2) Bed Paths, and 3) State Definitions. The pre-determined view to be displayed in the "Main" viewport is the "Main Loop'. The other views may be selected and displayed.

The "Menu" viewport is used to process any modifications made to the CGCS system. Interaction in this viewport sends an AST to the appropriate task on the main control computer. Typically, changes are made to the system in the "Main" viewport and reviewed for accuracy. The changes will not be processed by the main control computer until operator interaction in the "Menu" viewport requests the Process Control Task to process the changes.

The "Control" viewport is used to pass control to and from the remote X-terminal. The ability to make modifications to the CGCS is restricted to one display terminal at a time. The Control Room display terminal is the Master display terminal. It can relinquish or regain control back at any time. The X-terminal is a Slave terminal and can only relinquish control. Control is passed by clicking on the "Control" viewport with the mouse. While CGCS modifications are restricted to one display terminal, both terminals can be used simultaneously to monitor different parts of the CGCS.
The "Alarm" viewport is used to signal the operator that there are active alarms in the system or

alarms that have not yet been acknowledged by the CGCS operator. If the system is normal then the "Alarm" viewport is green indicating a normal status. If an alarm occurs, an audible signal alerts the operator and the "Alarm" viewport turns red to indicate an alarm condition.
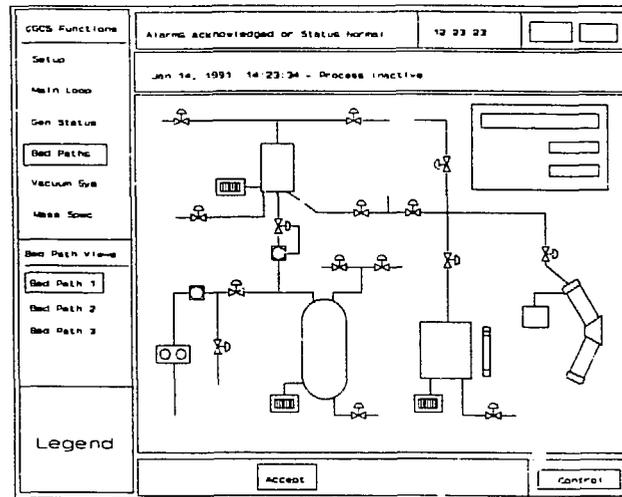

Figure 5. Sample View Layout

The "Comm" viewport is used to show the activity status of the "Main Loop" and "Tag System" communication lines. If for any reason there is a loss of communication through the fiber links to the STD bus computers, the "Comm" viewport status changes to red indicating which line has failed.
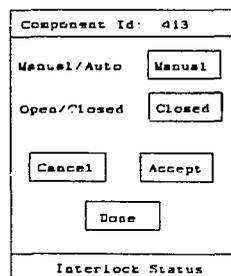

Figure 6. Manual Operation Menu

The "Message" viewport is used to display error messages along with a time/date stamp. Error messages are received, displayed, and then stored in a message que. Up to 30 error messages can

be placed in the message que. Operator interaction in this viewport leads the operator through the stored messages.

The "Legend" viewport performs two functions. Under normal operation it displays the color identification table used in the CGCS views. When an operator selects a component to be placed in manual, the Manual Operations menu pertaining to the selected component is displayed in the "Legend" viewport. See Figure 6.

The "Clock" viewport is used to display the current time.

Careful consideration was taken during the design of the screen layout to provide the operator with, traceability of his position within the hierarchy of views, rapid location of alarming components, and location of components which have been placed in manual.

View Design Methodology

The CGCS views are standard piping and instrument diagrams that have been modified to depict an overall representation of process flow through the system. This design method was chosen to maintain continuity between CGCS system drawings, and operating and training procedures. It gives the operator the ability to quickly assess alarm situations, locate components which have been placed in manual, or follow the progress of a "tag gas" through the CGCS. The views are broken up into two types of components, major and minor. Major components are the Distillation Column, the Main Loop and Tag System Compressors, the Tag Beds, the Sample Vial, and the Mass Spectrometer. Minor components are heaters, valves, controllers, pressure transducers, temperature indicators, and flow meters. Each major and minor component is a "dynamic object" that have attributes encoded with the graphics editor, DVdraw. The dynamic attributes enable the component to change state with respect to data. In the case of valves, the component changes both in color and appearance depending on the situation. If the valve state is "open", the valve appears solid or filled, and hollow or unfilled if the valve is "closed".

Valve
Open

Valve
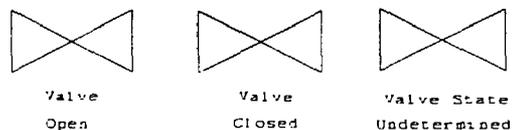Closed

Valve State
Undetermined

Figure 7. Valve Status

Figure 7 shows the different valve states. The color of the valve is dependant on the type of gas or liquid that is flowing through it. Green is used to depict argon cover gas, brown for exhaust gas, violet for vacuum, and blue for liquid nitrogen. Color is used substantially in the CGCS to indicate current process and component status. In some cases, component color indicates the desired range rather than the current range. Flow and temperature controllers are examples of this. In the Tag System, Tag Beds, which are used to cryogenically adsorb and desorb gasses, go through many

different temperature ranges. The process of changing the range from one to the other can take hours. For this reason the desired temperature is indicated on the controller's color and the current temperature is indicated by the Tag Bed's color. When the Tag Bed gets to the desired temperature range then the colors match. Color shading is used to indicate small temperature changes. This works well in determining the proximity of the current range to the desired range. The color "red" is reserved for Alarm Conditions and to indicate that a component has been placed in manual. In the case of alarms, the alarming component is displayed in red along with a red arrow pointing to the component. The red arrow serves as an indicator that a component has alarmed. There may be circumstances where a component may alarm for a short period of time and then return to normal. In this case, the component's color returns to normal but the red arrow continues to point to the component. The operator must acknowledge the alarm even though the component is no longer alarming. If the alarming component is not in the view currently being displayed, the operator can trace the alarm by interacting with the "Functions" and "Views" viewports. The menu item in these viewports turn red indicating an alarm condition. This helps the operator quickly determine where to look for the alarming component and isolate it.
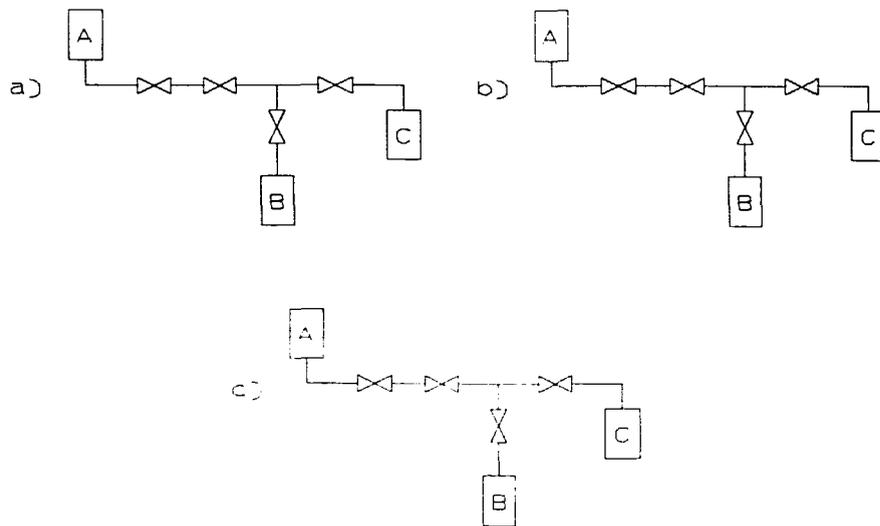

Figure 8. Flow Path Examples

To provide a means for the operator to follow progress of the system, flow path indications were developed. As the system sequences through the different stages of the process, it is desirable that the operator be able to quickly identify the configuration of the system. The flow path is determined by the open valves in the system. Graphically, the flow path is shown by highlighting the pathway where the gas is flowing using brighter colored lines. Figure 8 illustrates several possible combinations of valve alignment and how the flow path is shown. In Figure 8-a flow is from point A to point B; in Figure 8-b flow is from point B to point C; and in Figure 8-c there is no flow. The flow is shown only when the pathway is complete.

SYSTEM OPERATION

The entire operation of the CGCS is far too complicated to describe in this paper. For that reason the Tag System will be briefly discussed to illustrate placing components in manual and alarm acknowledgement. Under normal operating conditions of the Tag System, the operator simply needs to set the desired configuration using the Setup Views located in the Setup function of the "Functions" viewport. When the configuration is correct, the "accept" command in the "Menu" viewport sends that setup configuration to the Process Control Task. From that point on, the system automatically transitions through the required states. During this time period the operator can query the different Tag System views to follow its progress. If however the system fails at any point during the process, the system will "hold", the problem component will alarm and the operator will be notified. A "hold" condition is indicated in the "Functions" and "Views" viewports by the word "Holding" displayed next to the menu item. This leads the operator quickly to the view and component causing the hold condition. In some cases, the component causing the problem can simply be operated manually to release the hold condition. After the problem has be corrected the operator must send the "Continue" command to the Process Control Task by clicking on the "Continue" button in the "Menu" viewport.

To place a component in "Manual", the operator clicks on that component with the mouse. This places a green "M" next to the component showing that it has been selected to be placed in manual and displays the Manual Operations menu in the "Legend" viewport, Figure 6. The Auto/Manual button is selected so that it displays "Manual" and then select the appropriate state. The operator then selects "Accept" to send the request to the Process Control Task. At this point the green "M" next to the selected component turns red to indicate that the component has been placed in manual and the word "Manual" appears next to the menu item in the "Functions" and "Views" viewports to indicate which view and function contains a manually operated component. The method of indicating this condition in the "Functions" and "Views" viewports gives the operator the capability to rapidly find a manually operated component. To return a component to automatic, the component is selected with the mouse. The Auto/Manual button in the Manual Operations menu is selected and returned to "Auto" and then the "Accept" button is selected. The red "M" disappears and the component is returned to automatic operation.

When a component alarms, the indicators described earlier set up a condition which allows the operator to quickly determine the cause of the alarm. As alarms come in, they are stored and a counter increments to keep track of the number of active alarms. In order for the alarm condition to be reset, all of the components must return to normal status and each one must be acknowledged. To acknowledge an alarm, the operator clicks on the alarming component with the mouse. This causes the red arrow to disappear and the alarm count to be decreased by one. When all alarms have been cleared and acknowledged, the "Alarm" viewport turns green and all menu items in the "Functions" and "Views" viewports return to the normal display color.

CONCLUSIONS

The CGCS upgrade was the first major modification made to EBR-II using advanced digital computers and high resolution color graphic displays. All of the upgrade system design and programming was performed in-house and took approximately 3 man-years of effort. This system has been on-line since September 1991 and has had favorable reviews from operations personnel.

REFERENCES

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