

CLINICAL NEUTRON THERAPY SYSTEM
Control System Specification

PART II:
User Operations

Jonathan Jacky¹
Ruedi Risler
Ira Kalet
Peter Wootton
Jonathan Unger
Stan Brossard

Radiation Oncology Department
University of Washington
Seattle, WA 98195

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¹email jon@radonc.washington.edu, telephone (206)-548-4117

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Part I

User Operations

Chapter 1

About this document

The Clinical Neutron Therapy System (CNTS) at the University of Washington is a computer controlled cyclotron and neutron therapy treatment facility. This document is the second volume of the functional specification of the CNTS control system. The first volume [1] provides an overview of the CNTS facility and its control system.

This document contains detailed descriptions of the “user interface”: what the operators see and do at video terminals and control consoles to perform the operations that were described briefly in the first volume. Therefore, this document can be used as an authoritative and comprehensive operator’s reference manual, or as a source of material for a briefer user’s guide that might be easier to read.

The control system includes several terminals (also called workstations). Chapter 2 describes the characteristics and operations that are common to all of these terminals.

Chapter 3 describes the cyclotron control console.

Chapter 4 describes operations that are performed at the cyclotron operations terminal.

Chapter 5 describes the cyclotron status displays.

Chapter 6 describes the therapy control consoles.

Chapter 7 describes controls and indicators in the treatment rooms.

Chapter 8 describes the operations that are performed at each therapy operations terminal.

Chapter 9 describes the operations that are performed at the diagnostic terminals.

Chapter 10 describes how to start up and shut down the control system.

A forthcoming volume will contain detailed specifications of internal operations involving the cyclotron and therapy apparatus itself, which are only indirectly visible to users.

Chapter 2

Terminal operations

The control system includes several terminals. This chapter describes characteristics and operations that are common to all of these terminals. Subsequent chapters describe additional operations that are specific to cyclotron control, therapy control, clinical physics, and maintenance procedures.

In this document the word “terminal” is used for any device that provides the operator with a video screen and keyboard. This device may be a graphic workstation connected to an Ethernet; it need not be a character-oriented terminal connected to a serial line. Every operation described in this document could be implemented on a character-oriented terminal or a graphic workstation.

Some operations are provided at more than one terminal; these work the same way at any terminal at which they are available. For several practical reasons, each terminal only runs a particular subset of the available capabilities, but the underlying design does not impose this limitation. It is easy to modify the control programs to reallocate functions among terminals.

This document describes many operations that users perform at terminals. These descriptions should be considered samples or examples; it is not intended that all operations must take place exactly as described here. Latitude is allowed in the appearance of the displays, the exact wording of text on the screen, and choice of user interaction style (for example, whether options are selected by using the keyboard or a “mouse”). What is required is that the system provide the user with the same information, and obtain the same items from the user, as are described in this document.

This document does not specify the user interface mechanisms for invoking and performing

the operations; many acceptable alternatives are possible. Users might invoke operations by pressing function keys on the terminal keyboard, by selecting items from an on-screen menu using a graphic cursor and a “mouse,” or even by pressing dedicated buttons built into a control panel. Items might be edited by selecting options from a menu and typing responses to prompts, or by positioning a cursor over a displayed value and typing a new value, etc.

When the user interacts with the system, there is always a timely response; the user should be able to determine that the system detected his or her actions. Some operations take appreciable time (seconds or minutes) to complete; however, something on the display should always update immediately. The system also responds promptly and appropriately to invalid or erroneous input; it does not just ignore it. This lets the operator know that the control system is running and the terminal is working.

2.1 Notation and typing conventions

This section describes conventions used throughout this document to describe activities at terminals.

Text that appears on terminals is usually shown on a line by itself, printed in typewriter font. In this context, angle brackets enclose material that is not displayed literally, but is substituted with some actual value when the system is running. For example, in this document we usually use:

```
<date, time> <terminal> <operator-ID> logged out.
```

to indicate that a terminal will actually display something like:

```
8-Jul-1992 16:24:13 Cyclotron Operations RUEDI logged out.
```

Where such information is explicitly shown, as in the second example, it should be understood that the actual values of the date (etc.) may be different.

Sometimes in screen pictures, ellipses and etcetera appear. This does not mean that ... etc. ... literally appears on the screen; it indicates that some detail has been omitted.

2.2 The terminal display screen

This document includes many pictures of screen displays. These pictures should be considered samples or examples; it is not intended that the actual displays must appear exactly as shown here. The appearance of the actual displays may be designed to look better or take advantage of display attributes such as colors and highlighting that cannot be reproduced here. What is required is that the actual displays show the same data items as appear on the samples pictured in this document. All figures in this document illustrate sample displays that could be produced on character-oriented terminals.

Sometimes this specification requires that certain items on the display be highlighted. Highlighting can be accomplished using any available techniques, such as bold, or reverse-video, or different colors or fonts.

This document leaves the implementors considerable freedom to design screens, as long as they show the required data items. However, implementors should strive for a consistent design style. Many screen displays in this document use a screen design in which two screen regions are always shown — a status region and an operations region. An example is shown in figure 2.1. There are four other types of region: message regions, log regions, confirmation regions, and query regions, each of which may appear as needed and need not always be visible. None of the figures in this chapter show these regions.

2.2.1 Status Region

A status region displays information that pertains to the state of the terminal session as a whole, which only rarely changes when the operator invokes different operations. Examples include the operator's name, the cyclotron setting and the patient's name. In figure 2.1, there is a single status region that includes captions and five boxes or "lamps" that appear at the top of the screen.

2.2.2 Operations region

An operations region displays information associated with ongoing terminal operations. Typically, the contents of the operations region changes when the user selects a new terminal operation. For example, an operations region may display a list of patients and provide for the selection of one, or display the valves for a beam line and provide for the selection of a particular valve. The information is updated in an operations region more or less continuously as the indicated values and conditions change. The top of the operations

OPERATOR: Jon Jacky		PATIENT: None		FIELD: None	
GANTRY /PSA	FILTER /WEDGE	LEAF COLLIM	DOSI- METRY	THERAPY INTLKS	PROTON BEAM
PATIENTS					
243	Doe, Jane	17-Sep-1992	09:34	12-3456-78	
242	Smith, Adam	16-Sep-1992	15:01	23-4567-89	
241	Doaks, Joe	14-Sep-1992	08:12	34-5678-90	
			⋮		
			etc.		
			⋮		

Figure 2.1: Terminal screen showing status region (top) and operations region (remainder).

region shows a banner or title bar that describes the subsystem or information that is displayed. The operations region may be used for graphic user interactions, in which the operator uses an on-screen cursor to select displayed items. In figure 2.1, the operations region consists of the “Patients” title bar and the list of patient information beneath it.

2.2.3 Message region

A message region (not shown) simply displays some explanatory text to the operator, such as

```
SELECT PATIENT disabled - run in progress.
```

which appears if an operator attempts to select a patient while a treatment run is in progress.

2.2.4 Log region

A log region (not shown) displays information of sufficient importance that it is also logged to a log file. These are unsolicited messages from the system such as the timing out of an operation, or a report of some other sporadic or unpredictable event, particularly faults. A record of the event associated with the message is appended to the end of a log file, which is available in its entirety for later inspection. For example, during the automatic setup of the collimator, the message

```
<date, time> Leaf <nn> did not reach prescribed position
```

appears in a log region and is logged to a log file if collimator leaf **nn** does not reach its prescribed position within a given amount of time.

2.2.5 Confirmation region

A confirmation region (not shown) displays a warning message and requests a confirmation from the user before continuing. Some system operations result in major changes in the state of the controlled equipment. These can take considerable time to perform, and if they are invoked by mistake, recovering from them and restoring the preceding state can

require considerable time and effort. In these cases, the operator's attention is drawn to a confirmation region, before the requested operation is executed. For example, after selecting a cyclotron setting from the list of saved settings, the message

```

Saved setting number <nn>
<Operator-ID> <date, time> <particle, energy> <description>
Are you SURE you want to restore this setting?

```

appears in a confirmation region and the operator may opt to continue or to cancel the request. Confirmation regions are also used to request yes/no responses from an operator. For example, after selecting a new system setting from a file, if the main magnet setting is different than the current value, the message

```
Do you want the main magnet ramped through the top?
```

appears in a confirmation region; a yes/no response is requested from the operator.

2.2.6 Query region

A query region (not shown) gathers information from the user, such as a name, description, or a numerical value. A range of values and/or a default value may be provided. In the former case, range checking is performed to ensure that the value supplied falls within required limits. Input that is out of range is not accepted, and the operator must reenter the information. For example, the message:

```
Enter new state for SWM pump group
```

appears in a query region to change that pump group's state, with a request for the new input value. When there is a small number of options to choose from, the operator is presented with a list or "menu".

2.3 Different kinds of displays

This section describes three styles of display which may appear in an operations region: a list selection display, a control panel display, and a tabular display.

2.3.1 List selection displays

There are several displays whose purpose is to allow the user to choose one item from a list, where the number of items in the list is not known in advance; it may change from day to day. Moreover, the list may be too large to fit on a single screen. Examples of these displays include the list of saved settings at the cyclotron operations terminal, and the list of patients and stored treatment fields at the treatment operations terminal. Mechanisms exist for scrolling through the list if it is too large to fit on a single screen, and for selecting an item from the list — for example, a particular setting, patient, or treatment field.

OPERATOR: Jon Jacky		PARTICLE, ENERGY: 50.5 MeV Protons			
LAST LOADED SETTING:		28-Sep-1992 09:34 Ruedi Risler Morning startup			
SAVED SETTINGS					
1	50 MeV Protons	28-Sep-1992 09:34	Ruedi Risler	Morning startup	
37	50 MeV Protons	17-Oct-1992 15:01	Ruedi Risler	Isotope line	
36	50 MeV Protons	17-Oct-1992 13:25	Ruedi Risler	Isocentric room	
35	50 MeV Protons	14-Oct-1992 08:12	Ruedi Risler	Fixed beam room	
⋮					
etc.					
⋮					

Figure 2.2: Terminal screen showing list selection display.

In cases where a new selection would result in a lengthy or irreversible system response, as when selecting from the list of saved settings at the cyclotron console, a confirmation of the selection must be made in a confirmation region.

The

2.3.2 Control panel displays

There are several displays whose purpose is to present a small fixed collection of related items (where the contents of the collection is known when the system is configured) and offer the items to the operator for some purpose. The information is presented in a display that resembles a dedicated control panel with buttons and lamps. For example, the control panel display in Fig. 2.3 shows beam line valves and vacuum status against a simple graphic background that indicates the location of each component in the beam lines.

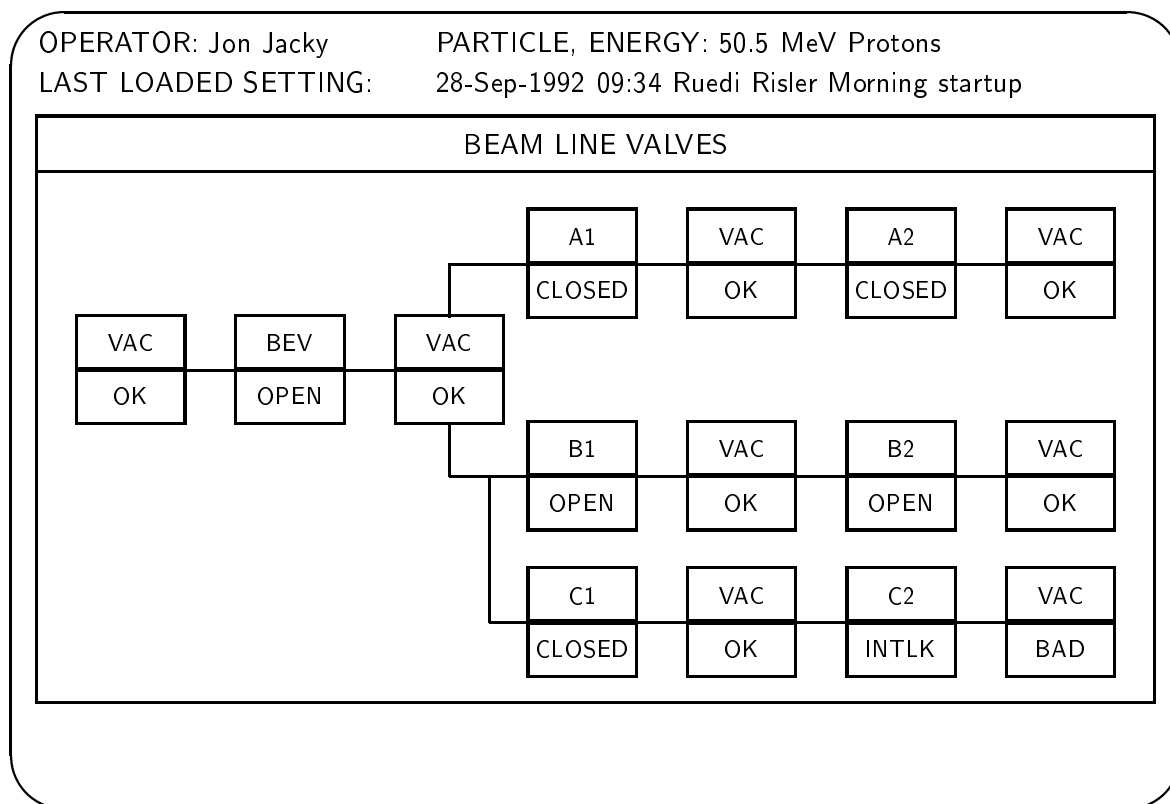


Figure 2.3: Terminal screen showing control panel display.

In addition to the text identifying each item, there may be additional information describing the state of each item. When the state of an item changes (spontaneously or at the request of the operator), the corresponding information on the screen updates, much like the dedicated displays on a control panel.

It is possible to select items on the panel, one at a time, and perform commands that affect

them. Any command that the user requests (turning on a power supply, opening a valve) applies only to the currently selected item. The currently selected item may be indicated by highlighting or some other means. Selecting an item does not change the state of the controlled equipment, it merely identifies the item or component that will be affected by future commands.

2.3.3 Tabular displays

There are several displays whose purpose is to present a large fixed collection of related items, and offer the items to the operator for some purpose. Although the collection is large, the contents of the collection is known when the system is configured, and they can all be listed at once in a single operations display. An example of a tabular display is the cyclotron control parameters display on the cyclotron operations terminal (Fig. 2.4).

The operations region shows all the items in a two-dimensional table that resembles a spreadsheet. Each cell in the table is labeled with a number or letter combination. It is possible to select cells, one at a time, and perform operations that affect the items named in them.

2.4 Faults and errors

2.4.1 User input errors

The system responds promptly and appropriately to invalid or erroneous input; it does not just ignore it. This lets the operator know that the control system is running and the terminal is working. Furthermore, when input from a range of numerical values is requested, range checking is performed to ensure that the value supplied falls within required limits. Input that is out of range is not accepted, and the operator will be requested to reenter a valid value in this case.

2.4.2 Failed operations and equipment faults

It is possible that a requested operation might not be performed or completed, due to a fault in the controlled equipment. For example, the leaf collimator might not achieve the prescribed field shape because a leaf gets stuck, or a power supply might not turn on because

OPERATOR: Jon Jacky PARTICLE, ENERGY: 50.5 MeV Protons
 LAST LOADED SETTING: 28-Sep-1992 09:34 Ruedi Risler Morning startup

CYCLOTRON CONTROL PARAMETERS				
1 MAINFLD	2 MAINPRB	3 NMROFFS		
5 GRDCORR 1U	6 GRDCORR 1L	7 GRDCORR 2	8 GRDCORR 3	9 GRDCORR 4
10 GRDCORR 5	11 GRDCORR 6	12 GRDCORR 7	13 GRDCORR 8	14 GRDCORR 9
15 GRDCORR 10				
17 HRMCORR A1	18 HRMCORR A2	19 HRMCORR A3	20 HRMCORR B1	21 HRMCORR B2
: : etc. : :				

Figure 2.4: Terminal screen showing tabular display.

it has been left in local mode. Equipment faults are different from user input errors, where a user types invalid input.

When an equipment fault prevents some requested operation from completing successfully, a message appears in a log region. The same message is logged in a log file. This message always includes a timestamp and a brief description of the problem.

The terminal displays are designed to indicate equipment faults that could cause operations to fail. For example, the leaf collimator display at the therapy operator's terminal always shows the actual and prescribed positions of each leaf and highlights discrepancies. The various subsystem displays at the cyclotron status display terminal show whether each power supply is on or off and remote or local, and highlights conditions which are not appropriate for the current operating mode.

In some cases, equipment faults result in interlocks being set or other changes occurring that require the assistance of physics or engineering staff to clear the problem and proceed with turning on equipment or treating patients. These conditions are indicated on the displays.

The control system is designed to continue working despite faults in the controlled equipment. When equipment faults occur, the terminal session keeps running normally; it does not "crash" (terminate abruptly) or "hang" (become unresponsive to input). The operator can continue selecting operations in order to display the status of all subsystems and use equipment unaffected by the fault, as long as this is consistent with safety and equipment protection.

2.4.3 Control system errors

It is possible the control system itself might fail, due to computer hardware faults or software errors. These failures are different from faults in the controlled equipment and user input errors.

The control system is designed to detect certain failures in its own operation. For example, it can usually detect communication failures between the main control computer that drives all the terminals and other computers in the control system.

When the control system detects a failure in its own operation, a special system error display appears in an operations region of the affected terminals (Fig. 2.5).

When a system error display appears, operators should not attempt to proceed with treatments or other normal operations until the problem has been investigated and resolved. The

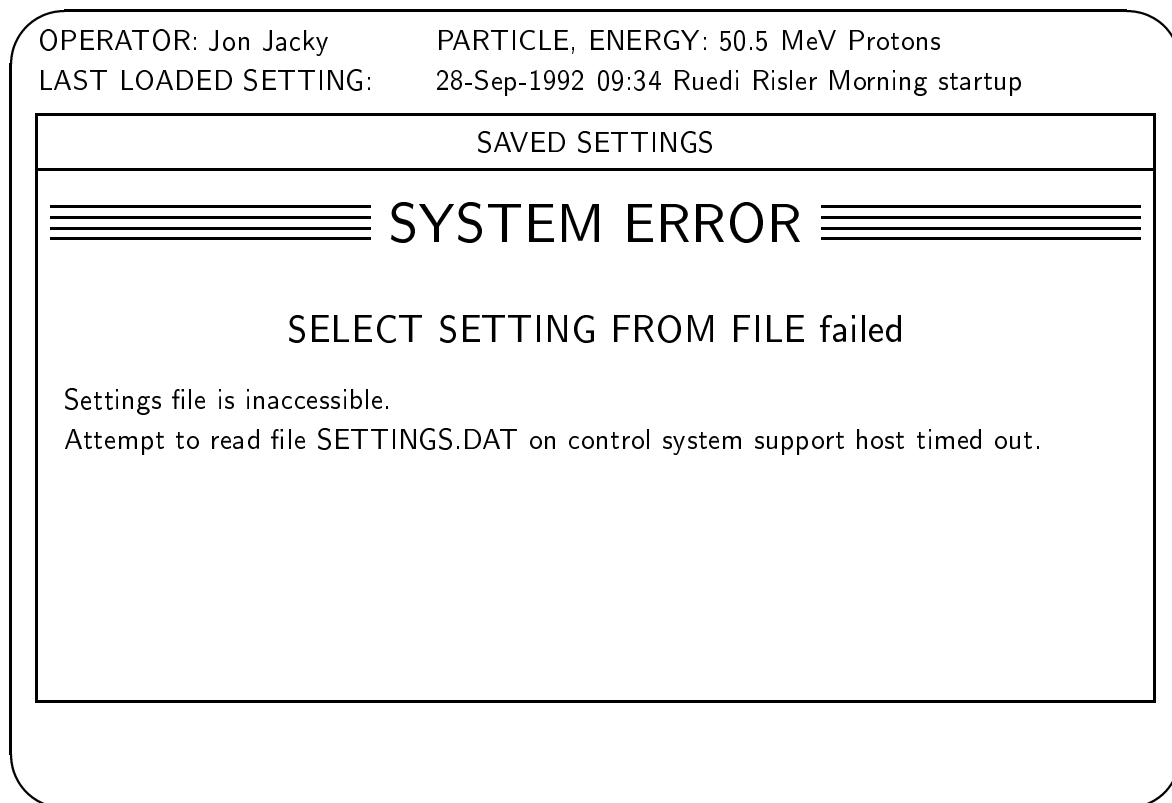


Figure 2.5: System error display

first thing they should do is write down the message that appears on the display, because subsequent activities may cause it to disappear or be overwritten and it may not be easy to reproduce the failure that invoked it. (The system also attempts to log these messages, but it may not always be possible to do so). There should be a manual of recommendations for dealing with various system errors. This manual should be in hardcopy, so that it can be used even if the control system computers and the control system support host are not working.

There are some system errors where most functions continue to work normally, and it is possible to continue selecting operating modes and issuing commands. For example, if one of the attached processors (such as the leaf collimator controller) fails, operations that do not require the failed processor will continue to work. However, after the system error display has appeared, the behavior of the terminal session may be unpredictable, and many functions may not work.

When a system error has been detected, the system attempts to set interlocks that disable motions and prevent the beam from being turned on. Intervention by engineering or physics staff is required to clear these interlocks.

A list of system errors which the system is designed to detect appears in another volume. It is not possible to detect all system errors. It cannot be assumed that the control system has not failed just because no system error display has appeared.

2.5 Common operations

Now that the user interface conventions have been explained, particular operations can be described in detail.

Most operations described in this section are available at any logged in terminal in the cyclotron control system.

2.5.1 WRITE LOG MESSAGE

When this function is selected, the operator may type a line of text into a query region. This text is then written to the operator log file; the log entry consists of the date, time, terminal name and operator ID, all assigned by the system, followed by the operator's text. It is necessary to include the terminal name since this operation is available from several terminals.

2.5.2 LOGOUT

When this function is selected, the current operator is logged out from the terminal from which the LOGOUT command was given, and the login sequence is begun at that terminal (there is no need for a separate LOGIN operation).

After the LOGOUT command is given, the operations region clears and the message:

```
<date and time> <terminal> <operator-ID> logged out.
```

appears in a message region and is also written to the operations log file. Then the LOGIN sequence begins (see Section 2.5.3 for details). All terminal operations are disabled. Console switches or other devices associated with the terminal may also be disabled.

2.5.3 Login procedure

At almost all the terminals in the control system, in order to perform operations at the terminal, a cyclotron operator or therapy technologist must log in, analogous to the login procedure for access to a timesharing computer system. Note that the CNTS Control System is *not* a timesharing computer system and this procedure is built in to control access to the equipment and keep records of who was on duty, rather than to simply authorize general access to a computer system.

The login sequence begins after an operator invokes the LOGOUT operation, or when the console keyswitch is turned on and there is no operator logged in. When the system first starts up, no operator is logged in, so the login sequence begins immediately if the console keyswitch is turned on. Whenever the console keyswitch is off, the operations region of the display clears and this message appears:

```
THIS CONSOLE HAS BEEN DISABLED  
TURN KEYSWITCH TO ENABLE CONTROLS
```

In this condition, turning on the key clears the operations region of the display. If no operator is logged in, the login display appears in the operations region (fig. 2.6) and the new operator is requested to supply his or her ID and password into a query region. The password is not echoed to the screen. If either the ID or password is not valid, the message

Invalid login

appears in a message region and the operator's ID and password must be resupplied. This continues until a valid ID and password are entered. When a valid ID and password are entered, the operations region is cleared. The following message is written to a message region and is also written to the operator log file:

```
<date and time> <terminal> <operator-ID> logged in
```

OPERATOR: None		PATIENT: None		FIELD: None	
GANTRY /PSA	FILTER /WEDGE	LEAF COLLIM	DOSI- METRY	THERAPY INTLKS	PROTON BEAM
LOGIN					
UNIVERSITY OF WASHINGTON CLINICAL NEUTRON THERAPY SYSTEM TREATMENT OPERATIONS TERMINAL LOG IN					

Figure 2.6: Terminal screen during login operation

The terminal name must appear in the log file because the operation may take place at any terminal.

A message of the day appears in the operations region. The message is read from a file on the control system support host. The message remains in the operations region until the operator selects another operation.

If a terminal is associated with a console or other special devices, usually some of the devices which are disabled when the terminal is logged out become enabled when the terminal is logged in. Specifics are described in the appropriate sections.

Chapter 3

Cyclotron control console

This chapter describes the cyclotron control console, also called the *control desk* (CD). The cyclotron control console (Fig. 3.1) houses several panels, each holding a functionally related set of controls and indicators. The console also houses two terminals, the Cyclotron Operations Terminal and the Cyclotron Status Terminal. The operations performed at these two terminals are described in chapters 4 and 5.

The following sections describe each of the controls and indicators on the following panels, most of which are shown in Fig. 3.1.

- On/off control and system status
- Beam line selection and status
- Faraday cups
- Ion source
- Beam probes
- Harmonic coils
- Beam current display
- Tuning modules
- NMR magnet control
- Isotope targets

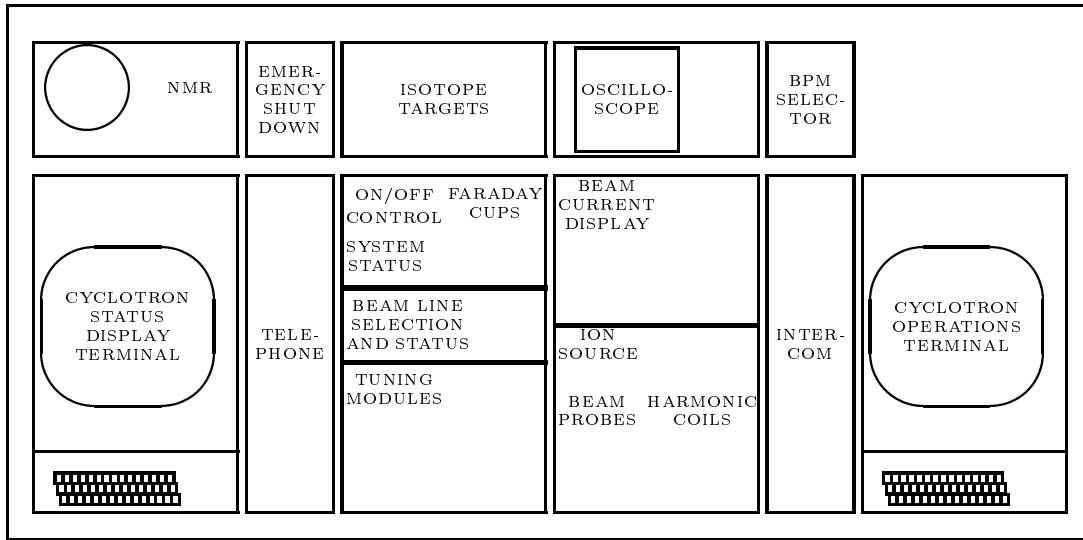


Figure 3.1: Cyclotron control console

Other panels shown in Fig. 3.1 are not described; their functions are not considered part of the control system.

Subsequent sections describe how the controls on these panels are used together to run the cyclotron in different modes.

3.1 On/off control and system status

The On/off control panel is pictured in Fig. 3.2. The right side of this panel connects with the Faraday cups panel (Fig. 3.4).

3.1.1 Keyswitch

When the keyswitch is turned off, some console functions are disabled. This provides some security: cyclotron operators can prevent some tampering with the controls by taking the key along if they have to leave the control room. The key can only be removed from the switch in the OFF position.

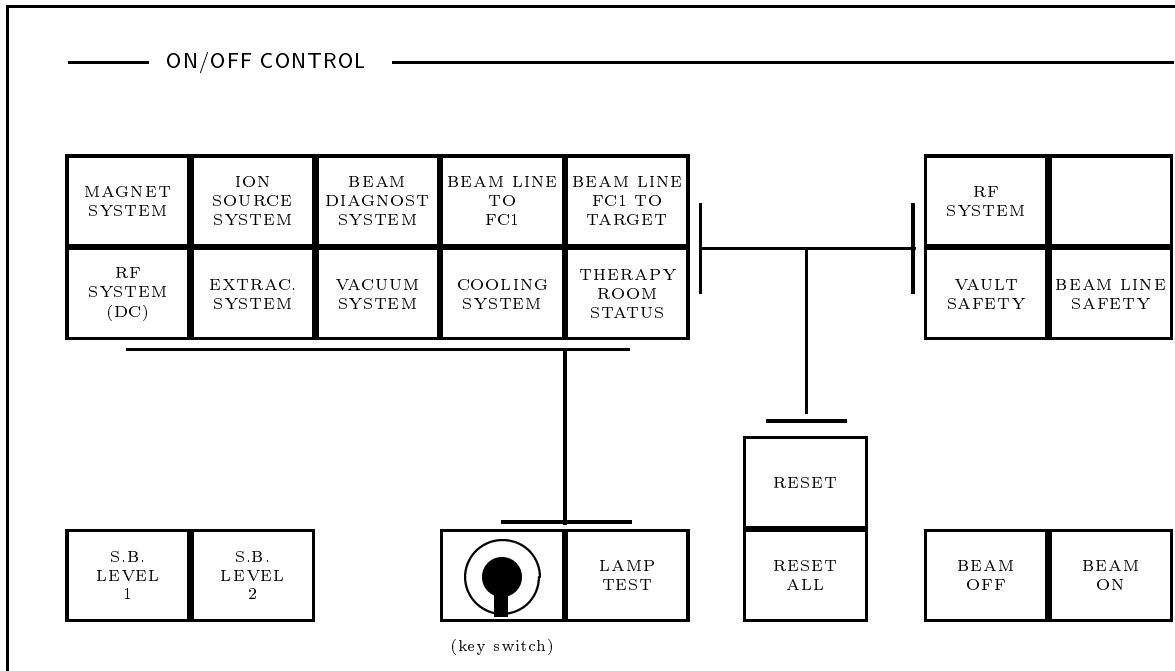


Figure 3.2: On/off control and system status panel

If the beam is on when the keyswitch is turned off, the beam remains on (until some other event causes it to turn off). This permits a certain level of unattended operation, for example during overnight experiments or isotope production runs. Turning off the keyswitch does not affect line selection (it does not release the currently selected line).

Controls disabled by the keyswitch

These are the console controls which are *disabled* when the keyswitch is off:

- On the On/off control and system status panel:
 - Standby Level 1
 - Standby Level 2
 - Reset
 - Global reset
 - Beam on
- On the Faraday cup panel, the IN and OUT buttons for all three cups are disabled.
- On the beam line status panel, all controls including line selection controls, beam path controls and CYCLOTRON READY FOR TREATMENT are disabled. If CYCLOTRON READY FOR TREATMENT is cleared it remains cleared to allow therapy operation.
- On the tuning module panel, the tuning modules are disabled.

Controls not disabled by the keyswitch

Even when the keyswitch is off, some controls remain enabled. These include all controls not explicitly listed in the preceding section. In particular, they are:

- On the on/off control panel, the BEAM OFF button remains enabled. All of the subsystem status display buttons remain enabled.
- On the ion source panel, the arc current control remains enabled.
- On the beam probe panel, all of the main probe controls and the deflector probe control buttons remain enabled.

- On the harmonic coils panel, all harmonic coil azimuth controls remain enabled.
- On the beam current panel, all of the meter selection buttons remain enabled.

Interactions with cyclotron operations terminal

Turning off the keyswitch disables almost all operations provided at the cyclotron operations terminal, including LOGIN and LOGOUT. If the keyswitch is on and the beam is on but no operator is logged in, then if the keyswitch is turned off the beam turns off.

The LOGIN and LOGOUT operations at the operations terminal have a similar effect on the console controls as turning the console keyswitch on and off. When no operator is logged in at the operations terminal, the same computer-controlled functions as are listed above are disabled. Table 3.1 summarizes the effects of the cyclotron console keyswitch and operator login/logout. Note that No Key/Operator logged in is *not* the same as Key/No Operator logged in.

LOGOUT is disabled when the keyswitch is off, so the keyswitch must remain on to enable operators to change. Operator changes can occur during regular therapy operations: the first operator logs out and then the second operator logs in.

Interactions between the keyswitch and the operations terminal are described in more detail in chapter 4.

3.1.2 Standby 1 and Standby 2

These are two momentary pushbuttons with lamps behind them.

Standby 1 (SB1) is a state in which the cyclotron subsystems are largely shut off. In the *Standby 2* (SB2) state most subsystem power supplies are on and the system is capable of producing beam on target. The system is also considered to be in the Standby 2 state when the beam is actually on. The complete definitions of these states appear in another volume.

The two buttons together function similarly to a two position toggle switch. Pressing the SB2 button initiates an attempt by the control system to set the cyclotron equipment in the Standby Level 2 state. Pressing the SB1 button initiates an attempt to set the equipment in the Standby Level 1 state.

The two lamps indicate which way this toggle was set, and whether the state of the system is

KEYSWITCH	OPERATOR	FUNCTIONALITY
No key	No operator logged in	Beam off Some console controls disabled Operations terminal mostly disabled
No key	Operator logged in	Beam may remain on (cannot be turned on) Some console controls disabled Operations terminal mostly disabled LOGOUT at operations terminal disabled Nighttime runs, unattended Therapy runs from treatment console possible
Key	No operator logged in	Beam may remain on (cannot be turned on) Some console controls disabled Operations terminal mostly disabled; LOGIN enabled Between operator change
Key	Operator logged in	Full functionality

Table 3.1: Effect of keyswitch and operator login on cyclotron console

in agreement with the toggle position. In other words, if the toggle is set to STANDBY 2 an indication of that toggle position is needed. Since the toggle is implemented by momentary pushbuttons the lamps have to show this virtual toggle switch position. A blinking lamp indicates that the corresponding state was requested (is in that toggle position) but the system is not in that state.

Only one of the two lamps can be on or blinking at any time. If a lamp is on or blinking, the toggle is set to that position, i.e., if the SB2 lamp is on, the operator had pushed the SB2 button to set the system in Standby 2. The lamp blinks during the transition into the state, which typically takes several minutes (while magnet power supplies ramp, etc.). A steady light indicates that the state was requested and achieved. The lamp also blinks after the requested state has been successfully achieved, when some fault condition causes the system to leave the state. The lamp also blinks when the state was requested but could not be achieved because of some fault, and the attempt to achieve the state has timed out.

If the operator pushes the other button before the transition completes, the lamp goes out.

When the operator first pushes one of the buttons a message is written to the operations log file (this series of messages shows SB2 but a corresponding set of messages is written for SB1):

```
<date and time> Standby 2 requested with setting ...
```

If the operation completes successfully the following message is written to the operations log file:

```
<date and time> Attained Standby 2 with setting ...
```

If the operation fails for any reason, the following message is written to the operations log file:

```
<date and time> Failed to attain Standby 2 with setting ... because ...
```

3.1.3 Subsystems

For each of several subsystems, there is a momentary pushbutton with a lamp behind it. The subsystems are:

- Magnet system
- RF system (DC)
- RF system
- Ion source system
- Extraction system
- Beam diagnostic system
- Vacuum system
- Beam line to FC1
- Beam line FC1 to target
- Cooling system
- Vault safety
- Beam line safety
- Therapy room status

Pressing any subsystem status button causes the display for that subsystem to appear on the status display terminal built into the cyclotron control console. That display continues to update on that terminal until another is selected. The contents and design of each display are described in more detail in chapter 5.

Pressing the button for BEAM LINE FC1 TO TARGET calls up the display for the currently selected beam line, or if no line is selected, the line which was most recently released. Before any line is selected (after the control system programs are started up) it calls up the display for the A line. Displays for beam lines not presently selected can be called up by using the status display terminal keypad, as described in chapter 5. Similarly, the VAULT SAFETY, BEAM LINE SAFETY, and THERAPY ROOM STATUS displays for beam lines and treatment room not presently selected can be invoked from the status display terminal keypad.

When a subsystem status lamp is on, the corresponding subsystem is in the correct state for the current position of the SB1/SB2 toggle, i.e., if the SB2 lamp is on or blinking, and the subsystem lamp is on, it is in the correct state for Standby 2. If the SB1 lamp is on or blinking, and the subsystem lamp is on, the subsystem is in the correct state for Standby 1.

When a lamp is off, the corresponding subsystem is not in the correct state for the current position of the SB1/SB2 toggle.

The complete definitions of the correct state of each subsystem for SB1 and SB2 appear in another volume.

3.1.4 Reset and Reset All

These are momentary pushbuttons.

Pressing RESET clears all remotely resettable interlocks whose triggering condition was corrected, for the subsystem currently displayed on the status display terminal. This may include interlocks which do not explicitly appear on the status display. For example, sometimes only the “sum” interlock (which is set when one or more of some collection of interlocks is set) is shown on the display, but any of the interlocks that contribute to the sum can be reset.

Pressing RESET ALL clears all remote (resettable) interlocks whose triggering condition was corrected, for all subsystems.

The complete list of resettable interlocks for each subsystem appears in another volume.

If the current subsystem displayed is FAULT CONDITIONS, all those are cleared. In this case RESET and RESET ALL have the same effect.

3.1.5 Beam on

This is a momentary pushbutton with a lamp behind it. Pushing this button requests both RF systems to turn on in their normal drive mode. In order for beam to actually be present when the RF drive is on, other conditions must also be satisfied. For example, ion source gas flow must be on, ion source current must be on, the cyclotron must be reasonably well tuned, etc.

Pressing the BEAM ON button begins the sequence to turn on the RF drive, if interlocks and other conditions permit. The turn on sequence typically takes 1 to 2 seconds if the RF systems are well tuned.

This button is disabled if the BEAM TURN-ON ALLOWED conditions are not met (see

chapter 5.5). The complete list of conditions that is required to allow the RF drive to turn on appears in another volume.

The BEAM ON lamp indicates that at least one of the RF systems is running in a high power mode¹. The condition indicated by this lamp being on is not the same as indicated by the RF subsystem lamp; in particular, it is possible for this lamp to be on when the RF subsystem lamp is off (for example, if only one of the two RF systems is running).

If the CYCLOTRON READY FOR TREATMENT condition is true (3.2.2), pressing BEAM ON makes it false and turns that lamp off, because pressing BEAM ON indicates that the cyclotron operator has taken control over the machine and it is up to him to authorize resumption of therapy by pressing CYCLOTRON READY FOR TREATMENT.

3.1.6 Beam off

Pressing this button immediately and unconditionally turns off the drive to both RF subsystems.

If the CYCLOTRON READY FOR TREATMENT condition is true, pressing BEAM OFF makes it false and turns that lamp off, to indicate that the cyclotron operator has taken control over the machine.

3.1.7 Vault Safety

When this lamp is lit the system is ready to produce beam to FC1, or is producing beam. The cyclotron operator's BEAM ON button is enabled. If this lamp is on, then the system is in Standby 2, both beam plugs are closed, and many other conditions are satisfied (e.g. the cyclotron vault door is closed etc.). Faraday Cup 1 is closed, or the beam is allowed to reach a cup or target downstream of Faraday Cup 1. The exact definition of this condition appears in another volume (see also chapter 5.5).

Pressing this button displays the vault safety system status display, including any components pertinent to the selected beam line (see chapter 5.5).

¹It is on exactly when the BEAM ON flasher at the vault door is on.

3.2 Beam line status

The beam line status panel is pictured in Fig. 3.3.

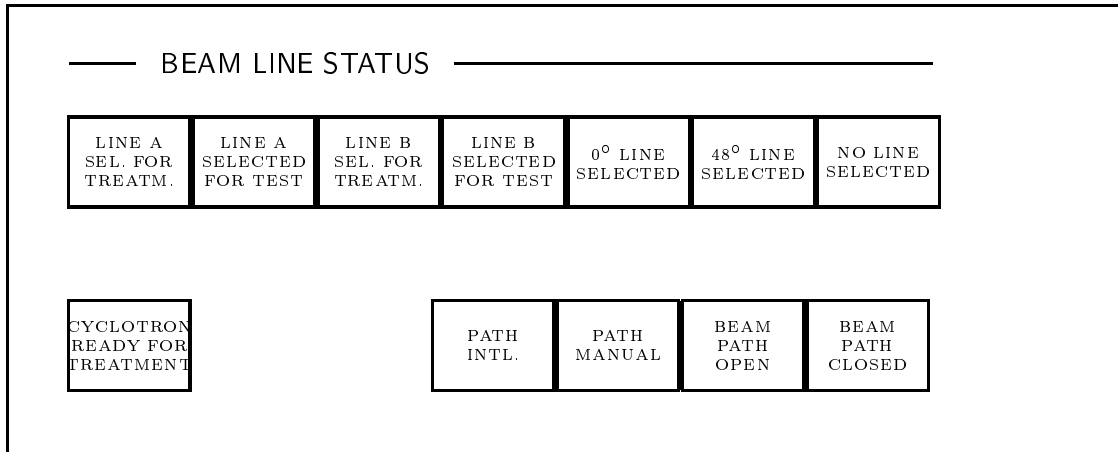


Figure 3.3: Beam line selection and status panel

3.2.1 Line selection

There are three beam lines. Each line carries the beam to a different destination. The *A line* or *isocentric line* carries the beam to the isocentric treatment room. The *B line* or *fixed beam line* carries the beam to the fixed beam treatment room. The *C line*, also called the *48 degree line* or the *isotope line*, carries the beam to the isotope production station in the cyclotron vault.

There is also provision for a *zero degree line*, but this line is not currently installed.

The A and B lines have two modes, test mode and treat mode. *TEST mode* allows the beam to be turned on in the treatment room from the cyclotron console, and in this mode the beam may remain on target indefinitely. This is the mode usually used for tuning the beam. It is also used for some experimental runs. The beam cannot be turned on in the treatment room from the treatment console in TEST mode.

TREAT mode is used for treating patients, and for experimental runs which involve the dosimetry system. In TREAT mode, the beam can only be turned on in the treatment room from the therapy console; the beam cannot be turned on in the treatment room from

the cyclotron console. In this mode additional safety conditions must be satisfied before the beam can reach the target. In particular, the *check and confirm* facility checks that the treatment room equipment is set up to conform to a treatment prescription, and the *dosimetry system* automatically turns off the beam when the prescribed dose is delivered.

The line selection panel houses several momentary pushbuttons and lamps. They are used to select (and indicate) the beam line and mode:

- LINE A SEL. FOR TREATMENT
- LINE A SELECTED FOR TEST
- LINE B SEL. FOR TREATMENT
- LINE B SELECTED FOR TEST
- 0° LINE SELECTED
- 48° LINE SELECTED
- NO LINE SELECTED

LINE A SELECTED FOR TEST and LINE B SELECTED FOR TEST are indicators only; these units do not include pushbuttons. The other units include both momentary pushbuttons and indicator lights.

Line selection buttons

The cyclotron operator selects a line and mode by pressing one of the buttons. Pressing 48° LINE SEL prepares the system for isotope production. Pressing LINE A SEL FOR TREAT or LINE B SEL FOR TREAT prepares the system for therapy in the corresponding treatment room. (Lines A and B can also be selected in treat mode from their respective treatment consoles.) In order to select one of the treatment lines, the console enable key at the appropriate treatment console must be turned on.

There are no buttons for LINE A SEL FOR TEST or LINE B SEL FOR TEST. For safety reasons, it is not possible to put these lines in test mode from the cyclotron console. Lines A and B can *only* be selected in test mode from their respective treatment consoles. If it is necessary for cyclotron operators to run the beam on target in TEST mode, they must request that the therapy technologist select the line, or go to the treatment console to select the line themselves. Either option requires cooperation between operators and helps to

ensure that a line will not be placed in TEST mode when a patient is in the treatment room.

A line and mode can only be selected when all other lines are released, that is, when there is NO LINE SELECTED. Pressing one of the line select buttons when another line is already selected has no effect.

When a line is selected for the first time after the Standby 2 toggle is in effect (e.g. the SB2 lamp is on or blinking), the system attempts to turn on all power supplies associated with that line that are not already on, and bring their parameters to the values that have been assigned for this line. The method for assigning parameter values is described in chapter 4. The power supplies associated with each line are listed in another volume.

Some parameters take different values, depending on which line is selected. If the Standby 2 toggle is in effect when a line is selected, the system attempts to change these parameters to their appropriate values. The method for assigning the different parameter values is described in chapter 4. The parameters whose values depend on the line selection are listed in another volume.

A line can be selected while the Standby 2 toggle is not in effect (the SB2 lamp is off), but in that case no power supplies turn on. If Standby 2 is pressed when a line is selected, the appropriate power supplies turn on.

Selecting a line in TREAT mode opens Faraday cups 2 and 3 in that line. Faraday cup 3 remains open the entire time the line is selected in TREAT mode. Faraday cup 2 is usually open during TREAT mode but can be closed from the cyclotron control console as long as a treatment run is not in progress.

Selecting the A line or B line opens all the beam line valves in the selected line that are not already open. Selecting the C line opens only the C1 valve; the Nuclear Medicine radiochemistry laboratory staff always have control over the C2 valve in that line.

Selecting a line closes the first valve past the switching magnet in both of the other lines, if they are not already closed. So, selecting the A line closes the B1 and C1 valves, etc. This prevents a vacuum accident in the selected line from affecting the other lines and vice versa.

Release Button

The operator can de-select or *release* any of the lines by pressing the NO LINE SELECTED button.

Pressing NO LINE SELECTED while the beam is on and running into a line beyond Faraday Cup 1 has no effect. A line can be released only when there is no beam in the line (Faraday Cup 1 is closed). However, it is possible to release the line when the beam is on, but is not in the line. In other words, it is always possible to release the line when Faraday Cup 1 is closed, even when the beam is on.

Releasing a line does not turn off any power supplies; all power supplies that were on, remain on.

Releasing a line closes the beam path (section 3.2.3) in that line, if it is not already closed.

Releasing a line does not change the condition of any beam line valves.

Lamps

Exactly one of the lamps is on at any time, to indicate which line and mode are selected (or that none are selected).

3.2.2 Cyclotron Ready for Treatment

This is a momentary pushbutton with a lamp behind it. The CYCLOTRON READY FOR TREATMENT condition must be true to turn on the beam in the treatment room from the therapy console without the assistance of the cyclotron operator.

Cyclotron operators press CYCLOTRON READY FOR TREATMENT to indicate their judgment that the cyclotron and the beam line system is ready to produce a beam suitable for therapy. Typically, an operator does this after achieving a satisfactory beam tuning. If all other preconditions are satisfied when the button is pressed, the CYCLOTRON READY FOR TREATMENT CONDITION becomes true.

If Faraday Cup 2 is closed when the operator presses CYCLOTRON READY FOR TREATMENT, but all other preconditions are satisfied, then that cup opens automatically and the condition becomes true. About two seconds elapse before the lamp turns on, while the cup

moves out of the way.

CYCLOTRON READY FOR TREATMENT can only be true when one of the lines has been selected for treatment. Pressing the button in TEST mode, or when the isotope line is selected or no line is selected, has no effect.

Any proton beam related interlock will turn off the CYCLOTRON READY FOR TREATMENT indicator. The cyclotron operator has to take care of all of these before he can declare the system ready. The complete definition of the conditions required for CYCLOTRON READY FOR TREATMENT appears in another volume.

The lamp behind the button turns on to indicate that the cyclotron operator has pressed the button and that all other requirements of the CYCLOTRON READY FOR TREATMENT condition are met.

There is no single button dedicated to turning off CYCLOTRON READY FOR TREATMENT (there is no CYCLOTRON NOT READY ...). Instead, the cyclotron operator can turn off this condition by pressing one of the following buttons on the cyclotron console:

- BEAM ON. The CYCLOTRON READY... condition turns off whether or not the beam was already on.
- BEAM OFF
- FARADAY CUP 2 IN (described in section 3.2.4)
- NO LINE SELECTED
- STANDBY 1

Pressing any of these buttons indicates that the cyclotron operator requires control of the beam. Therefore, it must no longer be possible for the therapy technologist to turn on the beam in the treatment room without the cyclotron operator's assistance.

CYCLOTRON READY FOR TREATMENT does *not* turn off when a treatment technologist presses the BEAM OFF button on a therapy console.

3.2.3 Beam path

The "Beam path" refers to three barriers that normally occlude the beam lines: the beam plug, the X-ray drawer, and the glass stop. (Only line A has a glass stop; there is no glass

stop in the fixed beam room). The beam plugs keep stray radiation from the cyclotron vault out of the treatment rooms, and the X-ray drawer and glass stop help limit radiation from the target and collimator in the treatment head. Before the beam can be turned on in a treatment room, these barriers must be moved; the beam plug and glass stop are opened, and the X-ray drawer is moved to its TREAT position. These operations together are called “opening the beam path.”

In TEST mode, the cyclotron operator can open and close the path by using buttons on the cyclotron console, interlocks permitting. In TREAT mode the path is only opened and closed under automatic control, as a result of activities at the therapy console. The cyclotron operator cannot control the path in TREAT mode.

The path always closes automatically whenever the beam turns off for any reason. This prevents radiation from the cyclotron vault from reaching the treatment room and also limits radiation from the treatment head.

The cyclotron console houses four lamps and two momentary pushbuttons for controlling and indicating the beam path. These are multiplexed between lines A and B, so they show the condition for the path of the currently selected line. When neither line A nor line B is selected, all the lamps are off and there is no effect of pressing any of the buttons.

Path interlock

This lamp is on when an interlock condition exists that prevents the path from being opened manually or automatically.

Path manual

This lamp is on when either the A or B line is selected in TEST mode, to indicate that the cyclotron operator has control over the path in these modes. However, if the PATH INTERLOCK lamp is also on, the path cannot be opened.

Beam path open

The cyclotron operator presses the BEAM PATH OPEN button to open the path. If the PATH MANUAL lamp is on and the PATH INTERLOCK lamp is off, the path will begin

to open. It normally takes about 8 seconds for the path to open. If this button is pressed when the PATH MANUAL lamp is off, there is no effect.

The BEAM PATH OPEN lamp is on when the beam plug and the glass stop are open and the X-ray drawer is in the TREAT position. A flashing lamp indicates that the path has been manually or automatically commanded to open but not all of the three devices are in the open position.

Beam path closed

The cyclotron operator presses the BEAM PATH CLOSED button to close the path. If the PATH MANUAL lamp is on, the path will begin to close. It normally takes several seconds for the path to close. If this button is pressed when the PATH MANUAL lamp is off, there is no effect.

The BEAM PATH CLOSED lamp is on when the beam plug and the glass stop are closed and the X-ray drawer is in the SAFE position. A flashing lamp indicates that the path has been manually or automatically commanded to close but not all the devices is are in the closed (SAFE) position.

3.2.4 Faraday cups

The Faraday cups are beam stops that can be placed into a beam line. A cup is closed when it is occluding the line. The cups are closed to prevent the beam from reaching a part of the beam line which is not ready to accept it; for example, closing a Faraday cup in the vault permits the cyclotron operator to turn on and tune the beam while therapy technologists are in the treatment room with the patient. The cyclotron console houses a set of lamps and momentary pushbuttons for controlling and indicating the Faraday cups. They are on the right side of the same panel that houses the On/off/status controls, and are pictured in Fig. 3.4.

In TEST mode, the cyclotron operator can open and close any of the Faraday cups by using buttons on the cyclotron console, interlocks permitting.

In TREAT mode the cups are automatically controlled and the cyclotron operator has less direct control. In TREAT mode cup 3 is always open, because running the beam into cup 3 creates radiation in the treatment room. Cups 1 and 2 are in located in the cyclotron vault, so the cyclotron operator may close them in TREAT mode, as long as the beam plug is closed. It is useful to tune the beam while it is running up to cup 2, particularly

for adjusting the switching magnet current after switching the beam back from the isotope production line. Radiation from cup 2 does not reach the treatment room when the beam plug is closed.

The interlocks are designed so that the beam cannot turn on unless Faraday cup 1 is closed; the beam must always be stopped by Faraday cup 1 when it is first turned on. The cyclotron operator may open Faraday cup 1 after the beam is on, if safety conditions permit. For example, cup 2 must be closed when the beam plug is closed. The cups are interlocked so that it is not possible to open cup 1 unless cup 2 is closed. This prevents the beam from striking the plug.

When the therapy console operator begins a run by pressing START on the therapy console, control of the cups from the cyclotron console is disabled and is not re-enabled until cup 1 closes at the end of the run. The cups are controlled automatically during therapy runs.

Faraday cup 1 always closes automatically whenever the beam turns off for any reason. This helps ensure that the beam cannot strike beam path components and cannot reach a treatment room except during a proper test or treatment sequence.

There is only one Faraday Cup 1, which is nearest to the cyclotron in the main beam line, and the first row of controls is always connected to it, regardless of line selection. The other rows of controls are multiplexed between beam lines, and apply to the cups in the currently selected line. The second row is attached to Faraday Cup 2 in the currently selected line; when there is no line selected, all FC2 lamps are off and the buttons do nothing. The third row is attached to Faraday Cup 3A (only the A line includes a cup 3). When there is no line selected, or when the B or C line is selected, all FC3 lamps are off and the buttons do nothing.

Faraday Cup Interlock

This lamp is on when an interlock condition exists that prevents the particular cup from being moved manually or automatically from its present position, either to open it or close it. For example, if the beam plug is closed, the last remaining cup that is closed cannot be opened (otherwise the beam might strike the plug). Or, if the cooling for cup 2 or cup 3 has failed, the cup cannot be closed (otherwise the beam might damage it). For safety reasons, Faraday Cup 1 cannot be interlocked in the OUT position; it is always possible to close cup 1. The complete list of conditions that disable cup motion is given in another volume.

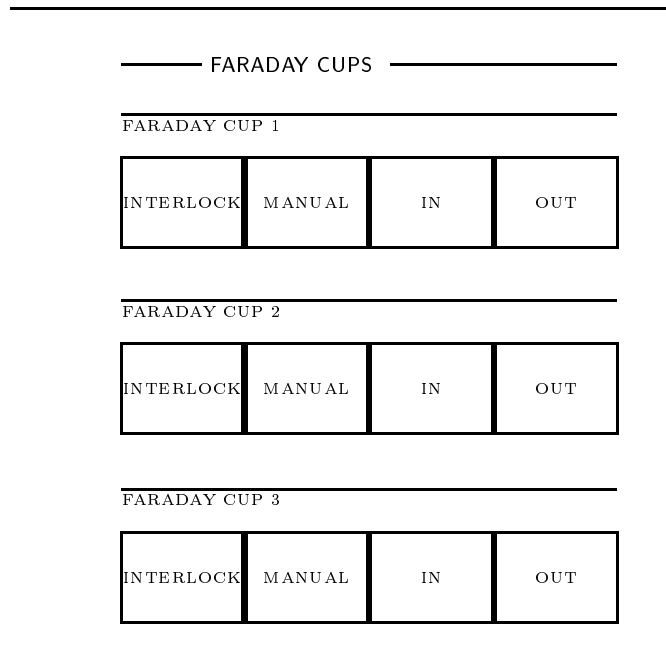


Figure 3.4: Faraday cup panel

Faraday Cup Manual

This lamp is on when the cyclotron operator has control over the cup. This lamp is on whenever line A or line B is selected for TEST. It is also on in TREAT mode, for cups 1 and 2 only, when the beam plug is closed and a run is not in progress. However, if the FARADAY CUP INTERLOCK lamp is also on, the cup cannot be moved.

Faraday Cup In

The cyclotron operator presses this momentary pushbutton to close the cup. If the MANUAL lamp is on, and there is no interlock, the cup will begin to close. If this button is pressed when the MANUAL lamp is off, there is no effect.

The lamp is on when the cup is closed. A flashing lamp indicates that the cup has been manually or automatically commanded to close but is not in the closed position.

Faraday Cup Out

The cyclotron operator presses this momentary pushbutton to open the cup. If the MANUAL lamp is on, and there is no interlock, the cup will begin to open. If this button is pressed when the MANUAL lamp is off, there is no effect.

The lamp is on when the cup is open. A flashing lamp indicates that the cup has been manually or automatically commanded to open but is not in the opened position.

3.3 Ion source

The panel that houses the controls for the ion source is shown in Fig. 3.5. This same panel also accommodates the beam probe controls.

The cyclotron operator usually controls the beam intensity by adjusting the ion source arc current using the multiturn potentiometer on this panel. The resulting current and voltage are displayed on the two meters.

During therapy operation the beam intensity is also controlled by a servo system in the Dose Monitor Controller (DMC) which keeps the dose rate near a prescribed value.

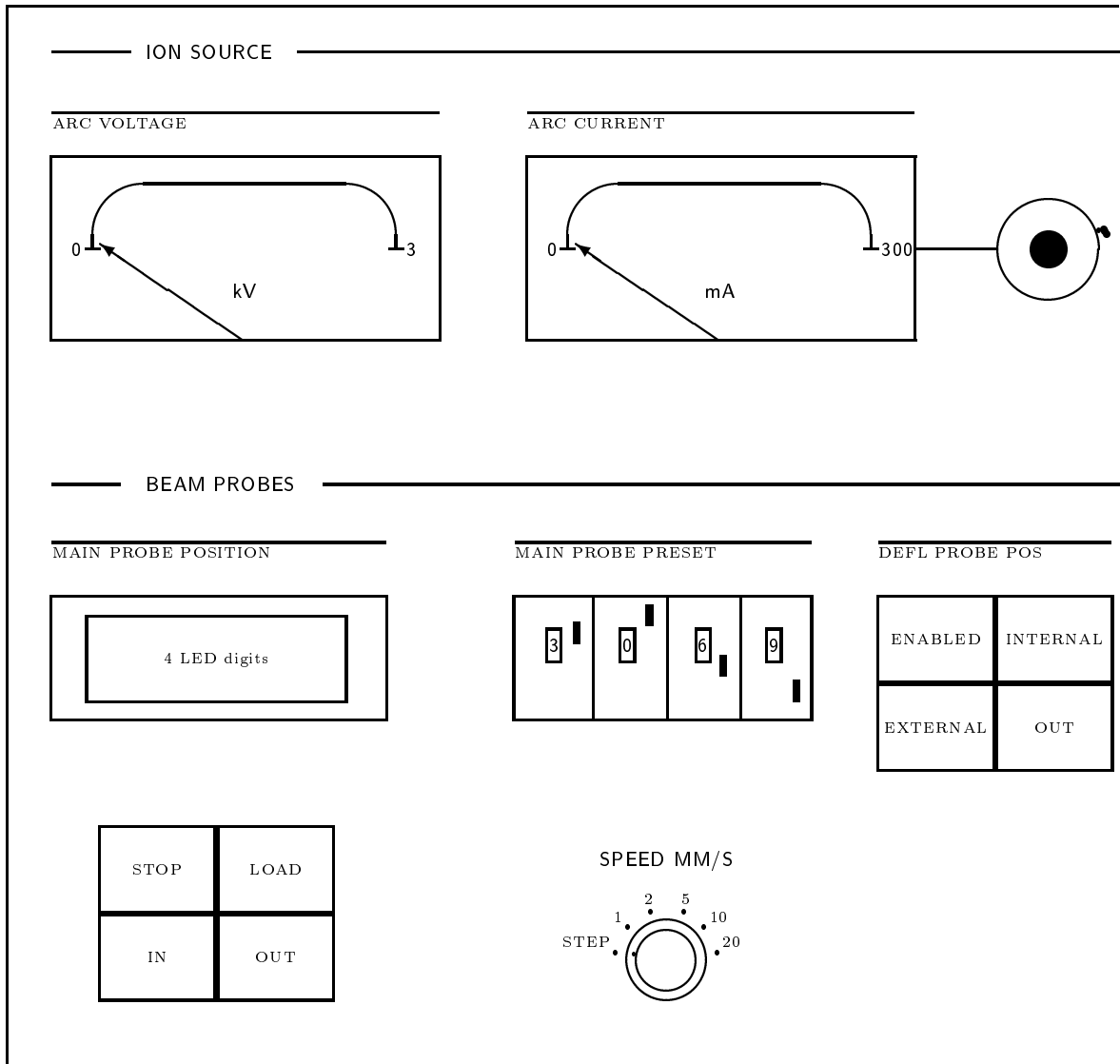


Figure 3.5: Ion source and beam probes panel

3.4 Beam probes

The controls for the beam probes are housed in the same panel as the controls for the ion source (Fig. 3.5).

3.4.1 Main probe positioning

The 4 digit LED display shows the current position of the main probe, measured from the center of the cyclotron in units of centimeters, with a resolution of 0.01 cm. These displays are lit whenever the main probe controller is on and are dark at other times.

There are two methods for moving the probe. The operator may press the IN or OUT button. The probe moves in the selected direction as long as the operator is pressing the button. Alternatively, the operator may set the intended probe position by adjusting the four thumbwheel switches on this panel. The switches select a probe position measured from the center of the cyclotron in units of centimeters, with a resolution of 0.01 cm. When the operator presses the LOAD button, the probe begins to move toward the preset position. The probe stops when the operator presses the STOP button, or when the probe reaches the preset position.

The operator sets the speed at which the probe moves with the six-position rotary switch.

3.4.2 Deflector Probe

The ENABLED lamp is on when the servo motor unit operating the deflector probe is on and the deflector probe is not controlled from a tuning module. Normally these controls are enabled during the transition to Standby 2 and remain enabled until the system returns to Standby 1. When the deflector probe is not enabled, all lamps are off and the pushbuttons do nothing.

The deflector probe has three main positions which can be selected by three pushbuttons: INTERNAL, EXTERNAL, and OUT. Each button has a lamp associated with it. If a button is pushed, that particular position is selected and the probe starts to move toward it. The lamp blinks when the probe is not in the selected position and stays on when the selected position is reached (within some small tolerance).

The three preset positions are prescribed in a file on the control system support host. In the INTERNAL position, the probe is positioned to stop the beam before it reaches the

extraction system. In the EXTERNAL position the beam is stopped after it passes through the electrostatic deflector, before entering the electromagnetic channel. Usually the probe is left in the OUT position, to allow the beam to leave the cyclotron.

When the transition to Standby 2 occurs, or a cyclotron setting is restored from the file of stored settings (section 4.6.4), the deflector probe automatically moves to its INTERNAL position. However, when the saved setting is recalled, the deflector probe remains in its current position. When the transition to Standby 1 occurs, the probe remains in its current position.

The deflector probe can also be operated using a tuning module (section 3.7), which enables intermediate positions to be reached. It is also possible to set the probe position at the cyclotron operations terminal, as described in chapter 4. While the probe is selected on a tuning module, or at the terminal, the ENABLED lamp and the lamps under the three pushbuttons are off and the pushbuttons have no effect.

3.5 Harmonic coils

The panel that houses the harmonic coil controls is on the right side of the same panel that houses the ion source and beam probe controls. It is pictured in Fig 3.6. There is a coaxial coarse/fine tuning knob that the operator uses to set the azimuth angle for each of the four sets of three coils. (The amplitudes are controlled from the tuning modules or the cyclotron operations terminal).

These controls are hardwired and are always enabled, whether or not an operator is logged in or the keyswitch is turned on. A cover (not shown in Fig. 3.6) can be lowered over these controls to prevent accidental operation.

3.6 Beam current

The Beam Current panel is pictured in Figs. 3.7 and 3.8. It houses four ammeters that display the readings from the beam current amplifiers. A series of LED lamps on each meter indicate the scale factor for the meter reading. The meters are autoranging: the scale factor is switched automatically to best display the current reading.

Below each meter is a set of buttons used to select the measurement point. The cyclotron operator presses a button to connect the meter to the sensor at the corresponding loca-

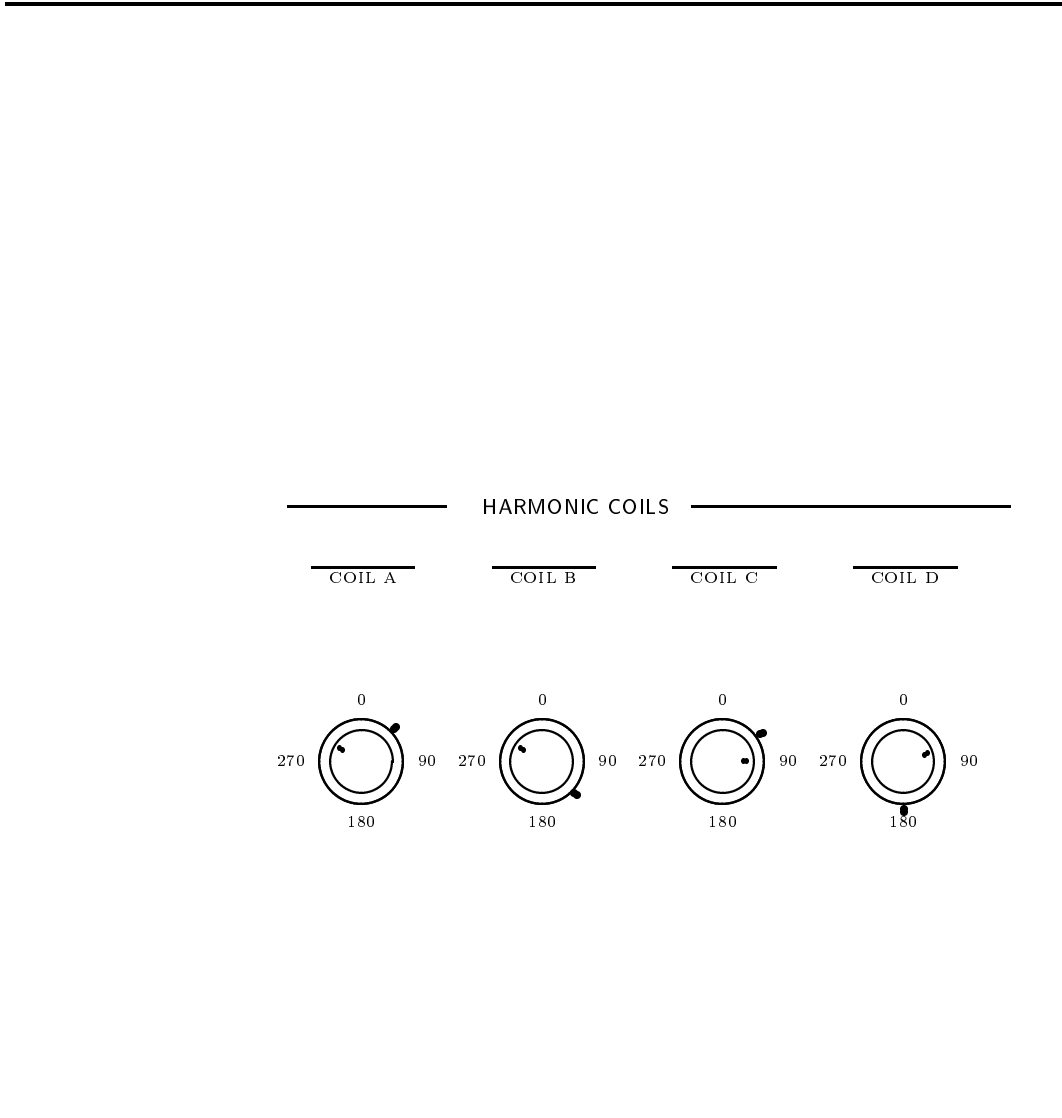


Figure 3.6: Harmonic coils panel

tion. These include the Faraday cups, stray beam detectors, diagnostic probes, and other locations. Each sensor is multiplexed to the currently selected beam line. More than one button can be pushed for each meter. In that case, the currents of all the selected sources are added and displayed.

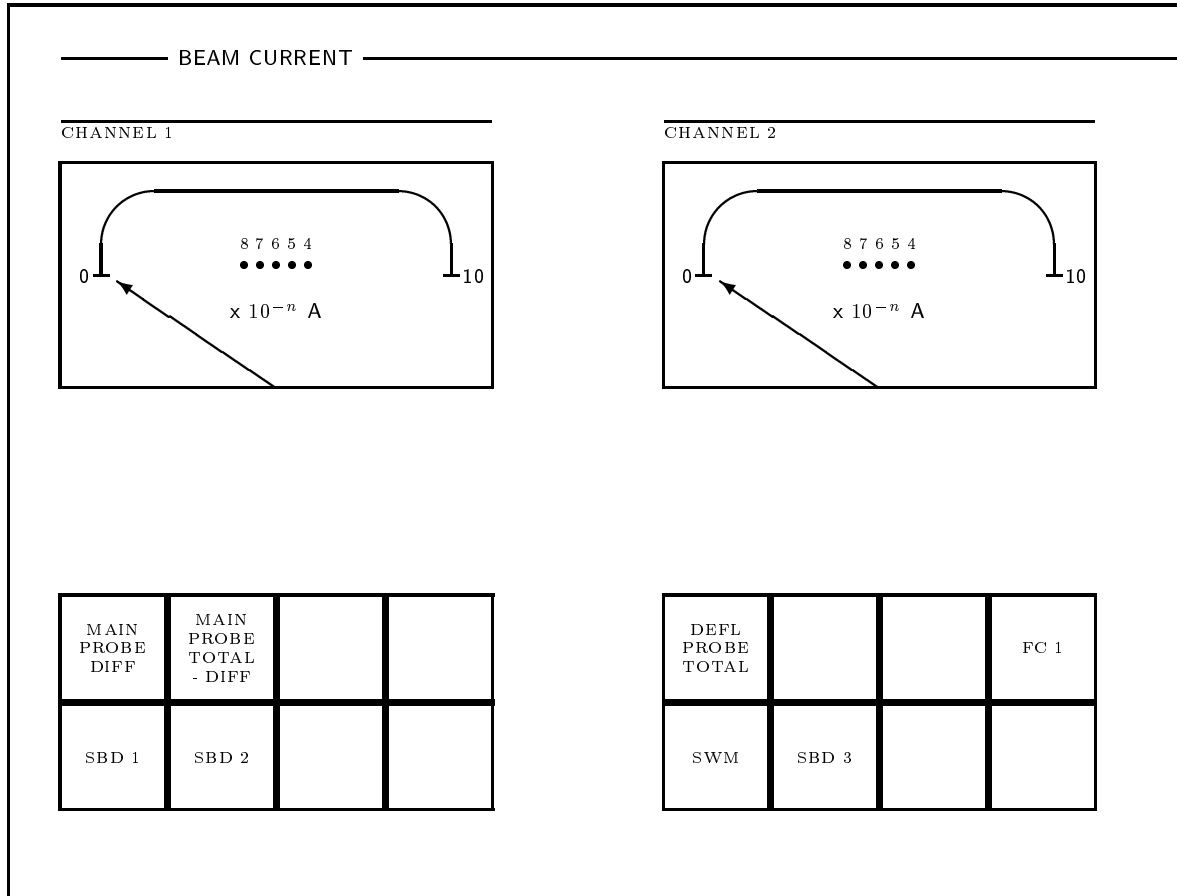


Figure 3.7: Beam current panel (left)

3.7 Tuning modules

The tuning module panel is pictured in Fig. 3.9.

This panel houses the Tuning Modules (TUM), a set of six dials and multicharacter LED

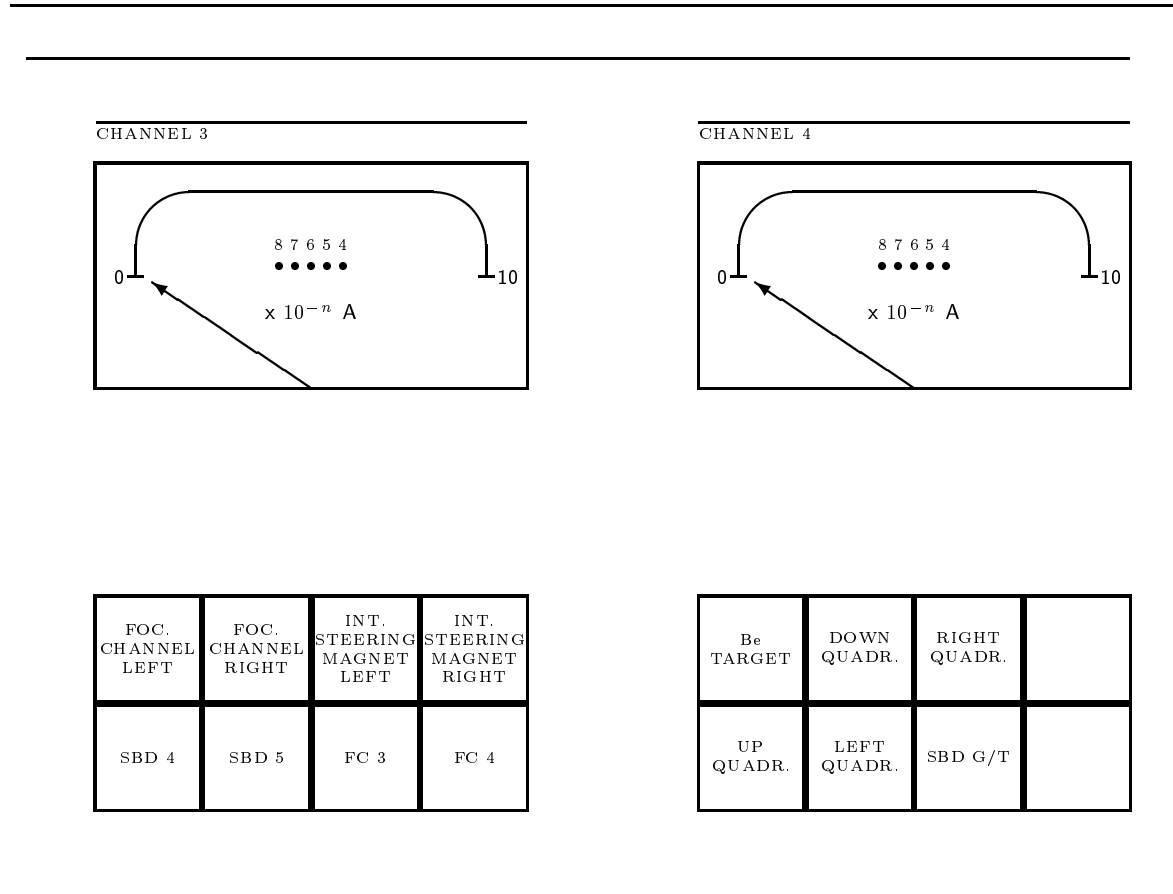


Figure 3.8: Beam current panel (right)

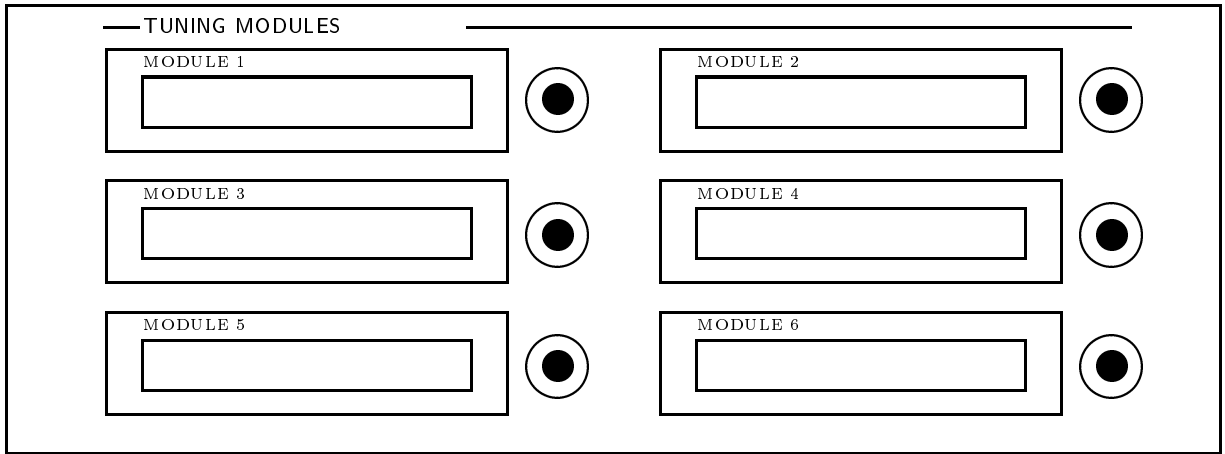


Figure 3.9: Tuning modules

displays. Operators use the tuning modules to adjust and observe analog control parameters. The operator turns a tuning module dial to change the value of a parameter. The LED display shows the name of the parameter assigned to the dial, the measured value of the parameter (called the PREAD value), and the units in which the value is expressed. The modules can be connected to various devices under software control. Therefore, it is not necessary to have a dedicated dial and display for each one of the approximately eighty adjustable analog parameters in the system.

Parameters are assigned to tuning modules by using the cyclotron operations terminal, as described in chapter 4. This can be done at any time, provided an operator is logged in and the keyswitch has been turned on. This is the only way to change the tuning module assignments; they do not automatically change as a side effect of other operations.

The value displayed on the tuning module is the actual value read from the device (called the PREAD value) which may be different from the value most recently requested by the operator (called the PSET value). In other words, the displayed value is not necessarily proportional to the dial position, but can be a complex function of the history of dial motion as well as other factors. The only exception is for the harmonic coil amplitudes, where the value most recently requested by the operator (PSET) is displayed, rather than the measured (PREAD) values (this decision was made because there are actually three different measured current values for each single harmonic coil amplitude setting).

The values of parameters that have been assigned to tuning modules can also be changed at the cyclotron operations terminal, as described in chapter 4. While that operation is in progress, the corresponding tuning module is disabled. When the operation completes, the tuning module is reenabled and its display is updated to show the new setting.

When the cyclotron operator logs out, or the console keyswitch is turned off, all tuning modules dials are disabled. The tuning module assignments are retained and are restored when the next operator logs in or the keyswitch is turned back on; it is not necessary to select the same assignment again.

3.8 NMR magnet control

There is an NMR magnetometer which can optionally be connected to regulate the magnetic field in either the switching magnet or the bending magnet (but not both).

3.9 Isotope targets

This panel houses several lamps that indicate the status of the isotope production station. In particular, the TARGET READY and LAB READY lamps are lit when these interlocks are clear. If these lamps are not lit, the cyclotron operator cannot open Faraday Cup 2C.

3.10 Interaction with cyclotron console terminals

The dedicated controls on the cyclotron console are largely independent of the the two cyclotron console terminals. The few interactions are summarized here.

3.10.1 Interaction with the cyclotron operations terminal

Logging in, logging out

LOGIN and LOGOUT operations at the operations terminal have a similar effect on the console controls as turning the console keyswitch on and off. When no operator is logged in at the operations terminal, some computer-controlled functions are disabled (see section 3.1.1). Table 3.1 summarizes the effects of the cyclotron console keyswitch and operator login/logout. Interactions between the keyswitch and the operations terminal are described in more detail in chapter 4.

Assigning parameters to tuning modules

Parameters are assigned to the six tuning modules (section 3.7) by performing an operation at the operations terminal, as described in more detail in chapter 4.

Setting parameter values

It is possible to set the values of most analog parameters at the cyclotron operations terminal, as described in chapter 4. Alternatively, most parameters can be assigned to tuning modules. In addition, the deflector probe position parameter is also attached to dedicated pushbutton controls on the cyclotron console.

Parameters may be set by any available method (terminal, tuning module, or dedicated console control). Each parameter is set to the value most recently requested, whatever the source. However, only one method may be active at a time; selecting one method disables the others. When the cyclotron operator selects a parameter to be set from the terminal, if that parameter has also been assigned to a tuning module, the tuning module is disabled while the terminal operation is in progress and is reenabled when the operation is complete. If the deflector probe position is assigned to a tuning module or set from the terminal, the dedicated panel controls for the deflector probe are disabled as long as the tuning module is selected or the terminal operation is in progress.

3.10.2 Interaction with the cyclotron status display terminal

Pressing any subsystem status button (section 3.1.3) causes the display for that subsystem to appear on the status display terminal. That display continues to update on that terminal until another is selected. The status display terminal is described in more detail in chapter 5.

3.11 Interaction with treatment operations

3.11.1 Selecting beam lines

The cyclotron operator and each therapy operator need to control the beam at different times. Safety and practical considerations determine the policies regarding who controls the beam:

- It is possible for each operator to select their own line in all of its available modes. So, the cyclotron operator can select the isotope production line in the cyclotron vault, and the two treatment operators can select the line into their own treatment room.
- The cyclotron operator may select the line to either treatment room in TREAT mode if the console keyswitch in the corresponding treatment console is on.
- Selection of a line in TEST mode is potentially hazardous, so this can only be done at the treatment console for the line, *not* from the cyclotron control console.
- It is only possible to select a line when no line is selected; it is *not* possible to switch lines without an intervening interval where no line is selected.
- It is not possible to directly change the mode of a selected line between TREAT and TEST; the only way to obtain a line in a particular mode is to select it in that mode from NO LINE SELECTED.
- A line can only be released by its own operator, or by the cyclotron operator. Therapy console operators can only release their own lines; the cyclotron operator may release any line.
- The line can only be released when Faraday Cup 1 is closed. This is to prevent the line from being released when the beam is on in that line. However, it is possible to release a line when the beam is on, but is not in the line.

These policies are implemented by the placement and function of the line select buttons, as described in section 3.2.1 in this chapter, and also in chapter 6: In brief, there are buttons to select and release the appropriate line at each console, and the buttons to release each line and to select the two treatment lines in TREAT mode are also duplicated on the cyclotron operator's console.

The line selection logic is hardwired and is not controlled by software. The computer only monitors the selection.

3.11.2 Controlling the Faraday cups and the beam path

In TEST mode, the cyclotron operator can open and close the Faraday cups and beam path by using buttons on the cyclotron console, interlocks permitting. In TREAT mode cup 3 is always open; the cyclotron operator cannot control cups 1 and 3 in TREAT mode. The cyclotron operator is permitted some control of cups 1 and 2 in TREAT mode, provided the beam plug is closed and a run is not in progress.

Interlocks that are active during both modes implement the following policies:

- The beam cannot turn on unless Faraday cup 1 is closed; the beam must always be stopped by Faraday cup 1 when it is first turned on. Faraday cup 1 may only be opened after the beam is on, if other safety conditions permit.
- Faraday cup 1 always closes automatically whenever the beam turns off (RF off) for any reason.
- The beam path always closes automatically whenever the beam turns off for any reason.
- In TREAT mode, the cyclotron operator may control cups 1 and 2 as long as the beam plug is closed and a run is not in progress. Cup 2 must be open when the beam plug is open.

These policies help ensure that the beam cannot reach either treatment room except during a proper test or treatment sequence, that the beam cannot strike the beam plugs or other path components, and that radiation exposure in the treatment room is minimized.

3.11.3 Turning on the beam

Treatments can be performed without the intervention of a cyclotron operator. Once the cyclotron operator has achieved a satisfactory tuning, therapy technologists can turn the beam on and off without the cyclotron operator's assistance.

The cyclotron operator retains control of beam characteristics by setting parameter windows, which are upper and lower limits for the values of analog parameters. If any analog parameters assume values outside their window limits, or any pertinent interlocks trip, the beam will go off and will not be able to be turned back on without the help of the cyclotron operator.

The cyclotron operator indicates to the therapy technologists that the cyclotron is ready to deliver a beam suitable for therapy to the treatment room by pressing the CYCLOTRON READY FOR TREATMENT button on the cyclotron console. If no interlocks prevent it, the lamp goes on and remains on until the cyclotron operator presses the BEAM ON, BEAM OFF, or FARADAY CUP 2 IN button on the cyclotron console, or an operator releases the line, or one of the pertinent interlocks trips.

The PROTON INTERLOCK lamp on the therapy console indicates that the cyclotron is *not* ready to produce a beam suitable for therapy. This lamp is off when the CYCLOTRON READY FOR TREATMENT lamp is on and all other interlocks associated with the cyclotron (but not the treatment room) are clear.

When the PROTON INTERLOCK lamp is off, the beam is available for therapy. When the treatment room equipment is ready to treat (check-and-confirm OK, etc.), the THERAPY INTERLOCK lamp on the therapy console turns off as well. Then the therapy technologist may begin the automatic sequence to turn on the beam in the treatment room by pressing the START button on the therapy console. The beam turns off automatically when the prescribed dose has been delivered.

3.12 Interaction with isotope production

The cyclotron operator assists in isotope production by selecting the C line, tuning and turning on the beam, and opening Faraday cup 2C. This allows the beam to reach the isotope production station in the cyclotron vault.

Many of the functions associated with isotope production are controlled externally by systems located in the Nuclear Medicine Radiochemistry Laboratory elsewhere in the building (not from the control room). These functions include transport of materials to be irradiated, control of beamline valve 2C, control of the isotope target assembly, and operation of the target beam current amplifier/integrator and timer for monitoring and terminating the run.

An isotope run ends when the target beam current amplifier/integrator opens a relay in the HSIS, which turns off the RF drive and closes the Faraday Cups.

It is not possible to select the C line, open Faraday cups, or turn on the beam from the Radiochemistry Laboratory. However, Faraday Cup 2C can be opened only when two interlocks, (TARGET READY and LAB READY) have been cleared by laboratory staff and valve C2 is open.

3.13 Some typical cyclotron operations

This section describes some typical scenarios for running the cyclotron from the operator's console. Many other operation sequences are possible.

3.13.1 Preparations for operating the system in any mode

Typically these preliminaries are done once in the morning each day. Beginning in Standby 1:

1. The cyclotron operator turns on the console enable key and logs in at the cyclotron operations terminal.
2. The cyclotron operator goes to the pump room and manually turns on the cooling water in the main loop, observing pump startup.
3. The cyclotron operator returns to the console, selects an appropriate setting at the operations terminal, and presses the STANDBY 2 button.

The transition to Standby 2 takes about 10 minutes while the main magnet ramps and the RF power tubes warm up. This provides an opportunity for the operator to enter the treatment room and set up the calibration phantom, or perform other chores.

4. If the transition to Standby 2 is unable to complete, the cyclotron operator attempts to find and fix the problem. When the difficulty is cleared, the transition usually continues; if not, the operator repeats step 3.

After performing those actions, the following prerequisites for running beam as far as FC1 should be true:

- SB2 lamp is on
- VAULT SAFETY lamp is on.

The beam cannot be turned on unless these conditions are met, and if these conditions are met, it should be possible to turn on the beam.

3.13.2 Producing beam with the cyclotron

In order for the cyclotron to produce an ion beam (protons, deuterons, ${}^3\text{He}^{++}$ ions or ${}^4\text{He}^{++}$), several conditions must be met:

- The magnet has to be set to produce the appropriate field strength and field shape.
- The ion source must produce the appropriate low energy ion beam. The source gas flow must properly adjusted and the arc current must be at the desired level.
- The RF must be applied to the dees at the correct frequency and voltage level.
- The extraction system parameters must be properly adjusted.

Most parameters are set before an attempt is made to produce beam. This means that magnet and extraction parameters are set to some values close to the optimal running parameters and the gas flow in the source is set to a reasonable level.

In order to run beam from this condition the RF system must be turned on and the arc current in the source must be set. Depending on the situation either of these two steps can be done first. The arc current is set by a multi-turn potentiometer at the control desk. The RF is turned on by pressing BEAM ON at the cyclotron console or START at a therapy console.

3.13.3 Running the beam in TEST mode

This is the mode used for beam tuning, in preparation for treatments or experimental runs. In this mode the Dose Monitor Controller (DMC) cannot turn off the beam, so the beam may remain on indefinitely. The treatment room equipment is not checked for conformance with a prescription.

In this example, the beam is run into the isocentric room.

To run beam in TEST mode:

1. The therapy technologist or the cyclotron operator presses the SELECT FOR TEST button *at the therapy console* (not the cyclotron console). This requires the therapy console enable keyswitch to be on, but does not require a therapy console operator to be logged in.

The SELECT FOR TEST lamp turns on at the therapy console. Back at the cyclotron console, the LINE A SELECTED FOR TEST lamp turns on.

If the power supplies for the A line are off (for example, because this is the first time that the A line has been selected that day), the power supplies turn on and begin approaching their final settings. The polarity of the switching magnet is set and the current begins changing automatically to the settings needed to direct the beam into the A line. It takes about a minute for the switching magnet to reach its final setting.

Faraday cups 2A and 3A open.

Beam line valve A1 opens, and valves B1 and C1 close if they are not already closed.

While the power supplies and other components are in transition, the relevant subsystem lamps (particularly BEAM LINE FC1 TO TARGET) on the cyclotron console turn off. They turn on again when the proper settings are achieved.

2. The cyclotron operator presses BEAM ON.

3. The cyclotron operator turns on the ion source arc current.
The proton beam appears on the first inserted barrier (one of the probes or FC1).
Alternatively, the operator may turn on the ion source arc before pressing BEAM ON. If the ion source is off, there will be no actual beam even though the BEAM ON lamp is lit and the BEAM ON warning flasher at the vault entrance is flashing.
4. Beam remains on. The cyclotron operator may tune the beam as far as FC1, using tuning modules, and possibly using extractor probe and main probe.
5. The cyclotron operator presses CLOSE FC2.
6. The cyclotron operator presses OPEN FC1.
The beam reaches FC2A.
7. The cyclotron operator may tune the beam on FC2 (e.g., adjust the switching magnet).
8. The cyclotron operator presses OPEN BEAM PATH.
This operation takes 7 – 8 seconds.
9. The cyclotron operator presses CLOSE FC3.
10. The cyclotron operator presses OPEN FC2.
The beam reaches FC3.
11. The cyclotron operator may tune the beam on FC3.
12. The cyclotron operator presses OPEN FC3.
The proton beam reaches the target and the neutron beam is produced in the treatment room.
13. The cyclotron operator may tune the beam on target. The cyclotron operator may turn up the beam current by increasing ARC CURRENT. The dose rate in the treatment room increases.
14. When tuning is complete, the cyclotron operator presses BEAM OFF.
The RF drive, the proton beam and the neutron beam turn off immediately.
The beam path and Faraday cup 1 close automatically. This takes about 7 – 8 seconds.
15. Alternatively to step 14, the cyclotron operator may press CLOSE BEAM PATH. FC1 and then the path will close automatically, and the neutron beam will go off in the treatment room. The proton beam will remain on up to FC1.
In still another alternative, the cyclotron operator may just CLOSE FC1 and leave the path open, leaving the beam running on FC1.

The cyclotron operator may repeat these steps as often as needed, or skip some, if the beam is known to have the proper quality.

If at any time excessive beam is detected on a stray beam detector (typically $5 \mu A$ for the beam line stray beam detectors) the beam turns off automatically.

To exit from TEST mode:

- The beam must not be running past FC1.
- The therapy technologist or the cyclotron operator presses RELEASE — NO LINE SELECTED at the therapy console or the cyclotron console.

The power supplies and beam line valves remain at their current settings. The Faraday cups remain in their current positions.

The proton beam may be left running on FC1 when the line is released.

3.13.4 Running the beam in TREAT mode

This is the mode used for morning calibration, some physics experiments, and routine patient treatments. In this example the beam is run into the isocentric room. The following sequence is preliminary to a series of runs in TREAT mode:

1. The cyclotron operator achieves a satisfactory tuning, for example by performing the sequence described in section 3.13.3.
2. The therapy technologist presses SELECT FOR TREATMENT at the therapy console *or* the cyclotron operator presses LINE A SEL FOR TREAT at the cyclotron console. This requires that the enable keyswitch be turned on at the therapy console, but does not require a therapy console operator to be logged in.

The SELECT FOR TREAT lamp turns on at the therapy console. Back at the cyclotron console, the LINE A SEL FOR TREAT lamp turns on.

If the power supplies for the A line are off (for example, because this is the first time that the A line has been selected that day), the power supplies turn on and begin approaching their final settings. The polarity of the switching magnet is set and the current begins changing automatically to the settings needed to direct the beam into the A line. It takes about a minute for the switching magnet to reach its final setting.

Faraday cups 2A and 3A open.

Beam line valve A1 opens, and valves B1 and C1 close if they are not already closed.

While the power supplies and other components are in transition, the relevant subsystem lamps (particularly BEAM LINE FC1 TO TARGET) on the cyclotron console turn off. They turn on again when the proper settings are achieved.

3. Optionally, the cyclotron operator presses BEAM ON at cyclotron console.

The RF drive turns on; the RF subsystem lamp turns off momentarily, then back on when the RF is running; the BEAM ON light turns on; the proton beam reaches FC1.

Alternatively, the beam may have been left running on FC1 all along.

In yet another alternative, the proton beam may be left off during these preliminaries. This is the standard state between therapy runs.

4. The cyclotron operator presses CYCLOTRON READY FOR TREATMENT at the cyclotron console.

The CYCLOTRON READY FOR TREATMENT lamp turns on at the cyclotron console. It remains on throughout and between normal treatments, unless some fault occurs.

The PROTON INTERLOCK lamp on the therapy console turns off.

And then, for each run:

1. The therapy technologist or clinical physicist prepares for the run at the therapy console and in the treatment room. Typically this includes selecting a stored field prescription and manually setting up the machine to match the prescription.

When the computer confirms that the therapy equipment setup conforms to the pre-stored field specifications, the dosimetry system is ready, and other treatment-related interlocks are clear (e.g. the therapy room door is closed), the THERAPY INTERLOCK lamp at therapy console goes out.

2. The operator presses START at the therapy console.

If the RF drive is not already on, it turns on and the proton beam reaches FC1. Alternatively, the beam may already be on up to FC1.

The beam path opens, then FC1 opens.

The proton beam reaches the target, and the neutron beam is produced in the treatment room.

3. The dosimetry system monitors the accumulating dose as the beam remains on.

4. The DMC detects that the prescribed dose has been delivered, and opens a relay in the HSIS.

The RF drive turns off.

The THERAPY INTERLOCK lamp comes back on.

FC1 closes. The beam path begin to close.

The PROTON INTERLOCK lamp turns on during the interval when the beam is off but the beam path has not completely closed. After the beam path closes the PROTON INTERLOCK lamp goes off. The CYCLOTRON READY FOR TREATMENT lamp remains on throughout.

The therapy console operator repeats these steps for each run.

3.13.5 Producing isotopes alternating with treatment runs

Isotope production runs can be alternated with normal treatment runs. Here is one possible sequence for performing an isotope production run.

This sequence begins at the point right after the last step in a treatment run in the isocentric treatment room, as described in the preceding section 3.13.4, has completed. At this point, the beam is off, Faraday Cup 1 is closed, Faraday cups 2A and 3 are open, and the beam line valves into the A line are open. The beam line valves for the C line are closed, and Faraday cup 2C is closed.

The Nuclear Medicine Radiochemistry Laboratory staff are responsible for preparing the target station and the other radiochemistry laboratory equipment for the isotope production run. They are also responsible for opening beam line valve C2. They indicate that preparations are complete by clearing the TARGET READY and LAB READY interlocks.

1. The cyclotron operator presses NO LINE SELECTED at the cyclotron console to take control of the beam from the therapy technologist. (Alternatively, the therapy technologist may press RELEASE – NO LINE SELECTED at the therapy console). At the cyclotron console, the LINE A SEL FOR TREAT lamp turns off and the NO LINE SELECTED lamp turns on. At the isocentric treatment console, the SELECT FOR TREAT lamp turns off and the RELEASE - NO LINE SELECTED lamp turns on at both therapy consoles, indicating that the beam is no longer available for treatments.

The CYCLOTRON READY FOR TREATMENT lamp turns off at the cyclotron console and the PROTON BEAM INTERLOCK lamp turns on both therapy consoles.

When line A is released, the equipment for the line does not change state: the beam line valves and Faraday cups remain in their current positions, and the power supplies remain on and their settings do not change.

2. The cyclotron operator presses 48° LINE SEL.

The 48° LINE SEL lamp turns on at the cyclotron console and the NO LINE SELECTED lamp turns off. The OTHER LINE SELECTED lamp turns on at both therapy consoles to indicate that the therapy technologists cannot select the line.

If the switching magnet is off, its polarity is set and its supply is turned on. If the bending magnet is off, it is turned on. Their currents begin approaching their settings.

If the switching magnet is already on, its polarity and current begin changing automatically to the settings needed to direct the beam into the C line. It takes about a minute for the switching magnet to reach its final setting.

Beam line elements between the cyclotron and FC1 are adjusted to settings appropriate for a C line run.

Beam line valve C1 opens, and valve A1 closes. Valve B1 closes if it is not already closed.

While the power supplies and other components are in transition, the relevant subsystem lamps (particularly BEAM LINE FC1 TO TARGET) on the cyclotron console turn off. They turn on again when the proper settings are achieved.

3. The cyclotron operator presses BEAM ON.

The RF drive turns on.

The beam reaches Faraday cup 1.

4. The cyclotron operator presses FARADAY CUP 1 OUT.

Faraday Cup 1 opens.

The beam reaches Faraday Cup 2C.

The cyclotron operator tunes the beam.

If the radiochemistry laboratory staff have completed preparing for the run then the TARGET READY and LAB READY interlocks are clear, beam line valve C2 is open, and the FARADAY CUP 2 INTL lamp is off.

5. The cyclotron operator presses FARADAY CUP 2 OUT.

The beam reaches the isotope production target system. The selected radionuclides are produced.

6. The beam remains on and isotope production continues while interlocks remain clear.

7. One of the interlocks under control of the radiochemistry laboratory is set (e.g., a run timer), opening a relay in the HSIS.

The RF drive turns off, so the beam turns off and isotope production ceases.

Faraday cup 1 closes.

Faraday cup 2C closes.

8. The cyclotron operator releases the C line by pressing NO LINE SELECTED. The 48° LINE SEL lamp turns off at the cyclotron console. The NO LINE SELECTED lamp turns on at all consoles.

Releasing the line does not affect the C line power supplies, Faraday cups or beam line valves.

9. The cyclotron operator presses LINE A SEL FOR TREAT, or the therapy technologist for the isocentric room presses SELECT FOR TREAT. The LINE SEL FOR TREAT lamps turn on.

The polarity and current in the switching magnet and the bending magnet begin changing automatically to the settings needed to direct the beam into the A line. It takes about a minute for the switching magnet to reach its final setting.

Beam line elements between the cyclotron and FC1 are readjusted to settings for an A line run.

Beam line valve A1 opens, as well as any other valves in beam line A which are not already open. Beam line valve C1 closes.

Faraday cups 2A and 3A open if they are not already open.

While the power supplies and other components are in transition, the relevant sub-system lamps on the cyclotron console turn off. They turn on again when the proper settings are achieved.

10. The cyclotron operator presses BEAM ON.
The RF drive turns on.
The beam reaches Faraday cup 1.
11. The cyclotron operator presses FARADAY CUP 2 CLOSE.
Faraday cup 2A closes.
12. The cyclotron operator presses FARADAY CUP 1 OPEN.
Faraday Cup 1 opens.
The beam enters the A line and reaches Faraday Cup 2A.

13. The cyclotron operator checks the setting of the switching magnet by observing the beam profile monitors and losses on the stray beam detectors, particularly BPM3 and SBD3. The cyclotron operator adjusts the switching magnet current if necessary.

14. The cyclotron operator presses BEAM OFF.
15. The RF drive turns off.
Faraday Cup 1 closes automatically.
16. The cyclotron operator may press FARADAY CUP 2 OPEN.
Faraday cup 2A opens.
17. The cyclotron operator presses CYCLOTRON READY FOR TREATMENT.
Faraday Cup 2A opens automatically, if it is not already open.
The CYCLOTRON READY FOR TREATMENT lamp turns on at the cyclotron console.
The PROTON INTERLOCK lamp on the therapy console turns off.

At this point, the system is ready for another therapy run, as described in the preceding section 3.13.4.

Chapter 4

Cyclotron operations terminal

This chapter describes all of the operations that are performed at the cyclotron operations terminal installed in the cyclotron console. (In this document the word “cyclotron” often refers to the the whole beamline system as well as the cyclotron itself. The cyclotron operations terminal also controls all the beamline components.)

4.1 Parameters and settings

The operating characteristics of the cyclotron and the beam lines are largely controlled by the values of about 120 analog quantities called *cyclotron control parameters* or just *parameters*. (In this document we usually use the term *parameter* in this sense, not the programming languages sense.) These quantities are such things as the currents in various magnets, the gas flow in the ion source, the voltage on the deflector etc. The parameters are referred to by abbreviated names such as PSMC, GASFLOW, DFLVOLT etc.

Many cyclotron operations involve reading or setting these quantities. The process of adjusting these quantities to obtain satisfactory performance is called *tuning* the cyclotron; one can also speak of tuning (adjusting) some particular parameter.

Several quantities are associated with each parameter. *PREAD* is the most recently measured actual value for the parameter. Usually PREAD is read from a channel on an analog-to-digital converter (ADC) card. *PHIGH* and *PLow* define the upper and lower limits, respectively, for a range of acceptable PREAD values which is called a parameter *window*. It is sometimes considered a fault for the PREAD value to lie outside its window. *PSET*

is the value at which the control system is currently trying to set the parameter. Usually PSET is the value most recently written to a channel on a digital-to-analog converter (DAC) card. For a variety of reasons, PREAD is not always exactly equal to PSET. *PSETPOINT* is the output value most recently requested by the operator.

PSET can be much different from PSETPOINT. For example, the operator may request an output value for some power supply current, but loading and equipment protection considerations limit the rate at which the power supply current may be changed. The control system will vary PSET from its current value to the requested PSETPOINT value in several steps extending over some seconds. Performing this graduated transition is called *ramping* the power supply. For some parameters, ramping is accomplished in software; the control system successively loads different PSET values in the DAC. For other parameters, ramping is accomplished by special hardware in the power supply, so PSET can be set equal to PSETPOINT immediately.

About 80 parameters are associated with values for PREAD, PSET, PSETPOINT, PHIGH and PLOW. About 40 parameters are “read only”; they have no associated PSET or PSETPOINT. A few parameters are “write only”; they have no associated PREAD, PHIGH or PLOW.

The values of PSETPOINT, PHIGH and PLOW for the approximately 80 parameters that can be set by the control system are together called a *system setting* or just a *setting*. (The setting also includes the tuning sensitivity for each parameter, as described in section 4.8.1). Some cyclotron operations involve recording or applying settings. The setting which is actually in effect at some particular moment is called the *current setting* or *active setting*. The *saved setting* is a temporary *copy* of an active setting, kept resident in the computer’s working memory, so that an operator may restore a previous state quickly and easily after having done some tuning that he/she has decided not to utilize. There is a collection of useful *stored settings* kept in a file on the control system support host. In addition, a checkpoint file is written periodically to provide for some recovery after system problems. This checkpoint file includes a copy of the active setting and the (memory-resident) saved setting.

4.2 Cyclotron operations display

The display screen on the treatment operations terminal always shows two regions: the status region and the operations region, as described in section 2.2. In addition, the screen may show other regions, such as a message region, a log region, a confirmation region, or a query region, as described in section 2.2. These regions are not required to always be visible; they may appear only when needed.

The status region on this terminal always includes the ID (username) of the operator on duty (or “none” if no operator is logged in), the particle energy, particle type and a brief description of the loaded setting, including the date and time the setting was established. These items are automatically updated on the screen when they are changed. See Figure 4.1.

4.3 Keyswitch

When the cyclotron console enable keyswitch is turned off, the operations region of the display clears and this message appears:

```
THIS CONSOLE HAS BEEN DISABLED  
TURN KEYSWITCH TO ENABLE CONTROLS
```

If the keyswitch is turned off while an operator is logged in, the operator is not logged out.

Turning on the keyswitch again simply erases the above message and restores the terminal to its state before the keyswitch was turned off.

When the keyswitch is turned on and no operator is logged in, the login sequence proceeds as described in Section 2.5.3.

The effect of the keyswitch, and of logging in and out on the dedicated cyclotron console controls is given in chapter 3.

4.4 Cyclotron operations summary

There are four groups of cyclotron operations:

- Common operations
- System setting operations
- Equipment control operations
- Parameter control operations

Users might invoke operations by pressing functions keys on the terminal keyboard, by selecting items from an on-screen menu using a graphic cursor and a “mouse,” or even by pressing dedicated buttons built into a control panel.

Common operations work as described in section 2.5: WRITE LOG MESSAGE, LOGOUT, and the login procedure. Any details specific to the cyclotron operations terminal are described in subsequent sections.

The values of PSETPOINT, PHIGH and PLOW for the approximately 80 parameters that can be set by the control system are together called a *system setting* or just a *setting*. Operations that involve the system setting are: SAVE ACTIVE SETTING, RESTORE SAVED SETTING, WRITE SETTING TO FILE, and SELECT SETTING FROM FILE.

The third group of operations select groups of equipment for display in the operations region and for possible subsequent selection and switching (“togglng”) of one piece of equipment between states such as on and off, open and closed etc: TOGGLE CYCLOTRON POWER SUPPLIES, TOGGLE BEAM LINE POWER SUPPLIES, TOGGLE BEAM LINE VALVES, and TOGGLE PUMP GROUPS.

The fourth group of operations select analog parameters for display in the operations region and for possible subsequent adjustment from the terminal or from a tuning module: SET VALUES, SET DEFAULT WINDOWS, ASSIGN SINGLE TUNING MODULE, and ASSIGN ALL TUNING MODULES.

A few operations are disabled when the beam is on, or could be turned on from the therapy console; they are RESTORE SAVED SETTING, SELECT SETTING FROM FILE, and SET DEFAULT WINDOWS. These operations can result in simultaneous large changes in most adjustable parameters. These operations are disabled whenever the BEAM ON lamp or the CYCLOTRON READY FOR TREATMENT lamp on the cyclotron operator’s console is on.

A complementary requirement is that the beam cannot be turned on, and CYCLOTRON READY FOR TREATMENT cannot be turned on, when these operations are in progress. This is similar to the effect of many interlocks.

4.5 Common operations

WRITE LOG MESSAGE, LOGOUT and the login procedure work as described in section 2.5. Details specific to the cyclotron operations terminal are described in this section.

4.5.1 LOGOUT

LOGOUT works as described in section 2.5.3. LOGOUT does not affect the current setting or the saved setting. LOGOUT is not disabled when the beam is on.

4.5.2 Login procedure

When the keyswitch is turned on and no operator is logged in, or after the LOGOUT operation is performed, the login sequence proceeds as described in section 2.5.3.

When an operator successfully logs in, the current setting and the saved setting remain as they were when the previous operator logged out. The first time an operator logs in after the system is started up, the active setting read from the checkpoint file is the current setting and the saved setting from the checkpoint file is the (memory resident) saved setting.

4.6 System setting operations

The second group of operations involve the system setting:

4.6.1 SAVE ACTIVE SETTING

This operation requests a confirmation by the operator before saving the current setting. If the operator confirms the request, the system queries for a brief description of setting. Then the saved setting parameter values are replaced by active setting values and a message appears in the message region:

```
ACTIVE setting <description> saved at <date, time>
```

There is no operations display associated with this operation. All interaction can occur in a confirmation region, query region, and a message region. Whatever was displayed in the operations region remains there while this operation is in progress.

4.6.2 RESTORE SAVED SETTING

If the beam is on or the CYCLOTRON READY FOR TREATMENT lamp is on, a message such as

```
RESTORE SAVED SETTING disabled - Beam on.
```

appears and nothing further happens. Otherwise, the message:

```
Setting <date, time> <description> to be made ACTIVE.
```

is displayed. The system then requests confirmation of the command to change the setting. If the operator chooses to proceed, the message:

```
Do you want the main magnet ramped through the top?
```

is then displayed, and a confirmation is requested. If the operator confirms, the main magnet will be taken up to its maximum current and then brought down to the value specified in the new setting. Ramping the main magnet cancels out hysteresis, which might otherwise cause the magnetic field to differ from the intended value. The operator must confirm this because it takes several minutes and might not be necessary if the new setting is only slightly different from the current setting. The switching magnet, gantry dipole and bending magnet are always ramped if their new settings differ (without asking the operator) because they can be ramped rapidly.

```
<date, time> Restored saved setting <date, time> <description>
```

is displayed and is also appended to the log file.

There is no operations display associated with this operation. Whatever was displayed in the operations region remains there when this operation is in progress, and any affected items update when the settings change. The tuning module assignments are not changed and the tuning module displays update to show the new values of the parameters assigned to them.

4.6.3 WRITE SETTING TO FILE

The operator is requested to confirm the operation. If so, the operator is requested to provide a description for the setting to be saved, and the active setting is stored in a file. The operator is then requested to indicate whether this setting is to be made the new *standard setting* for its particle type. The standard setting for protons is the setting usually used to start the system in the morning to get ready for routine therapy operations. If the operator assents, this setting will appear first in the list of stored settings when SELECT SETTING FROM FILE is invoked. Otherwise it will appear right after the (previously chosen) standard setting when SELECT SETTING FROM FILE is invoked.

The collection of stored settings for each particle type is numbered consecutively. The standard setting for each particle type is number 1. When a new setting is stored, and is not made the standard setting, it is given the next highest number for its particle type; otherwise, the previous standard setting is given this new highest number.

When a setting is stored, this message appears on the screen and is also written to a log file:

```
<operator-ID> <date, time> <particle, energy> <description>  
saved as setting number <nn>.
```

The settings file is on the control system support host. It is possible to delete or change the order of stored setting records or to change the standard setting using a program that runs on that host. It is not possible to delete setting records or change their order from any control system console.

There is no operations display associated with this operation.

4.6.4 SELECT SETTING FROM FILE

When this operation is invoked, the operator is requested to select the particle type:

```
Enter particle type (Proton, Deuteron, 3He, 4He)
```

A list of available stored settings for the selected particle type appears in the operations region (Fig. 4.1). This is a list selection display, as described in section 2.3.1.

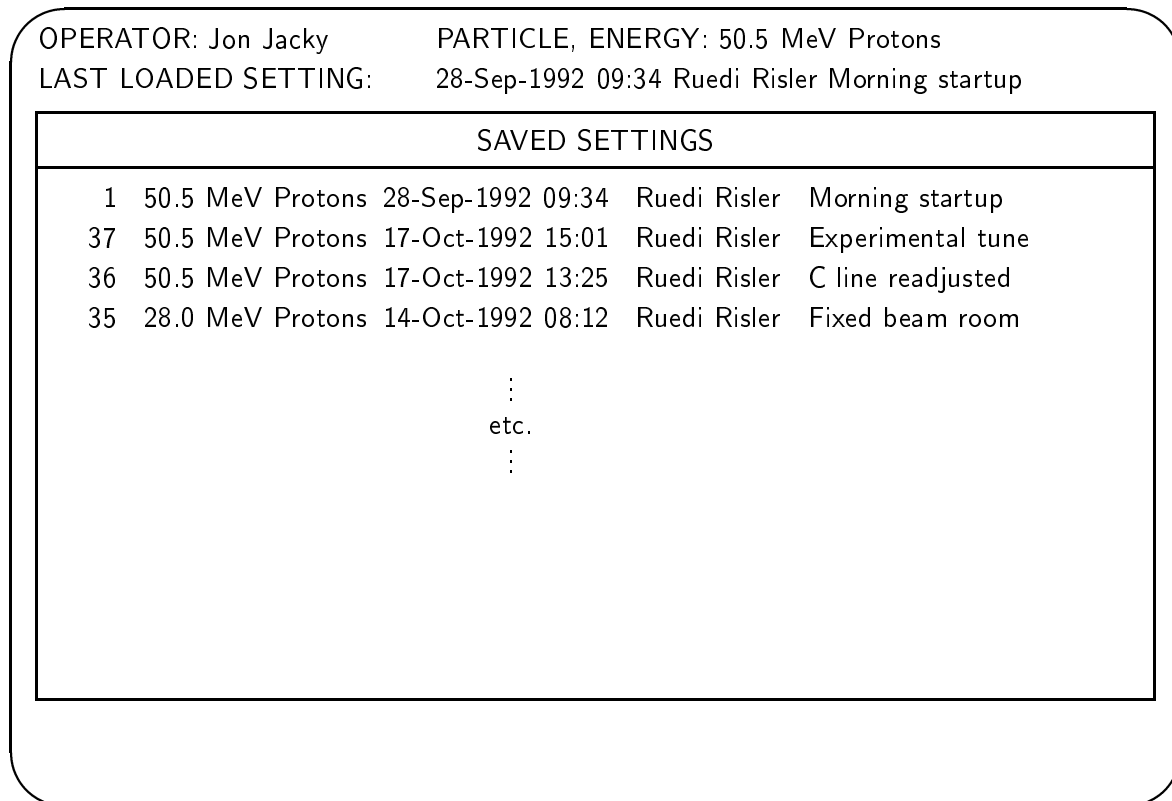


Figure 4.1: Terminal screen during SELECT SETTING FROM FILE operation.

On each line there is an entry for a different setting. The line begins with a setting number, and also contains the particle energy and type, the date and time the setting was established, the name of the operator on duty when the setting was stored, and a brief description.

The first numbered setting in the list is the standard setting for the particle type, number 1. After the standard setting, the settings are listed in descending order, with the most recently saved (highest numbered) settings at the top of the list.

If the operator selects a setting while the beam is on or the CYCLOTRON READY FOR TREATMENT lamp is on, a message such as

```
SELECT SETTING FROM FILE disabled - beam on.
```

appears the current setting is not changed. Otherwise, another message appears

```
Saved setting number <nn>
<operator-ID> <date, time> <particle, energy> <description>
to be selected.
```

and the operator must confirm that the settings should be changed. If operator chooses to proceed, the message:

```
Do you want the main magnet ramped through the top?
```

appears and the operator is asked to confirm. If the operator does confirm, the main magnet is taken up to its maximum current and then brought down to the value specified in the new setting. The switching magnet, gantry dipole and bending magnet are always ramped if their new settings differ without asking the operator. The message

```
<date, time> Restored saved setting number <nn>
<operator-ID> <date, time> <particle, energy> <description>
```

is displayed and is also appended to the log file.

The tuning module assignments are not changed and the tuning module displays update to show the new values of the parameters assigned to them. The gas valves in the ion source manifold are set for the selected particle type. The deflector probe automatically moves to its INTERNAL position.

CAPTION	STATE
OPEN	Valve open
CLOSED	Valve closed
INTLK	Valve closed and interlocked (cannot be opened)
OP → CL	Valve in transition, open to closed
CL → OP	Valve in transition, closed to open
CLOSED?	Open requested, valve remains closed (stuck or disconnected)
OPEN?	Closed requested, valve remains open (stuck or disconnected)
***	Valve sensors inconsistent

Table 4.1: Beam line valve states

4.7 Equipment control operations

The third group of operations selects groups of equipment for display in the operations region and for possible subsequent selection and switching (“toggling”) of equipment between states such as on and off, open and closed etc. Invoking each of these operations causes its control panel display (section 2.3.2) to appear in the operations region.

4.7.1 TOGGLE BEAM LINE VALVES

When this operation is selected, the names of all the beam line valves and the actual (sensed) states of their controls appears in the operations region, showing a graphic representation of the beam lines and the location of each valve (Fig. 4.2). The valves are BEV, A1, A2, B1, B2, C1 and C2. The status of the vacuum between valves is also displayed. Table 4.1 lists the possible valve states, and an example of how they could be indicated on the display. When the state of a valve changes, the corresponding information on the screen updates.

Operators may select and toggle valves. Toggling a valve usually causes it to attempt to change to the opposite state (from OPEN to CLOSED or CLOSED to OPEN). A normal transition may take as long as thirty seconds; the display indicates transitions in progress.

Immediately after the operator toggles a valve, it is possible to select and toggle another valve, even though the first valve may remain in transition. The user may also toggle the

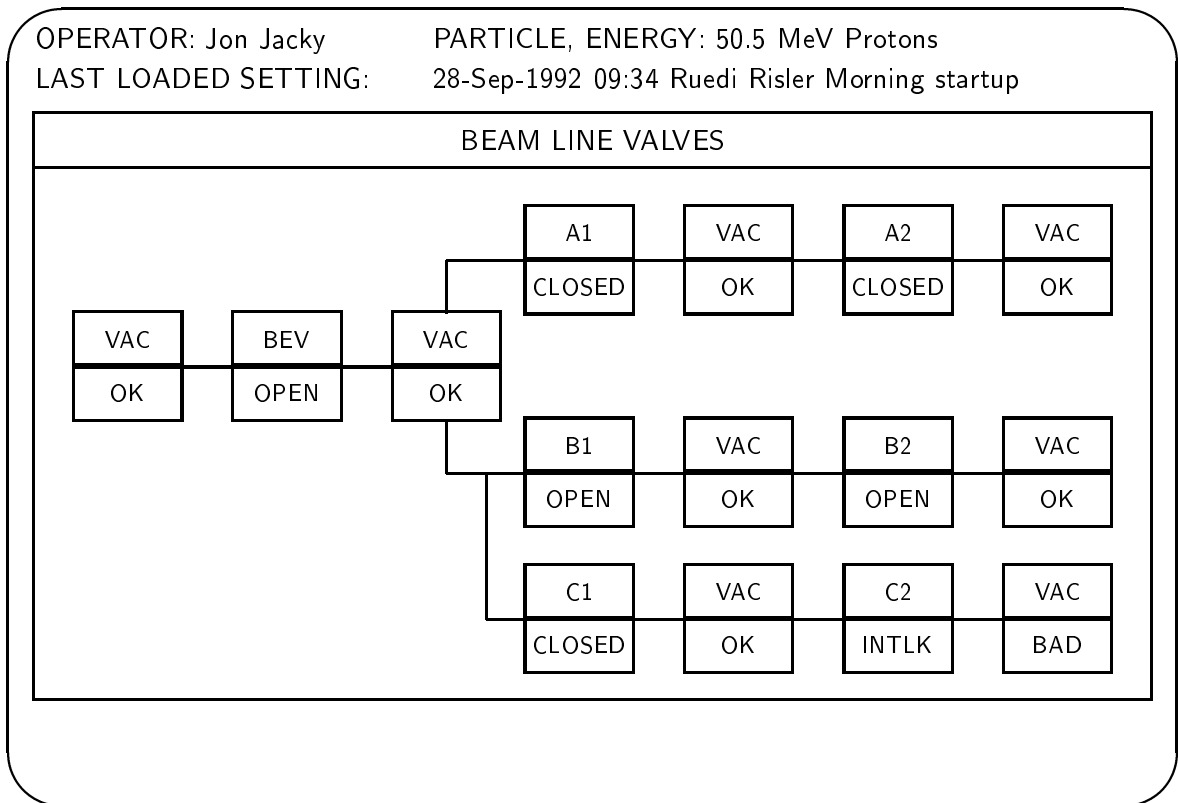


Figure 4.2: Terminal display screen during TOGGLE BEAM LINE VALVES operation.

same valve again before that valve's previous transition has fully completed.

Interlocked valves are closed and cannot be opened. The valves are interlocked in the closed position if the vacuum on either side of the valve is bad. In addition, valves A1 and B1 cannot be opened if valve C1 is open. If an attempt is made to open an interlocked valve, a list of interlock conditions in effect for that valve appears in a message region (for example, *Vacuum bad in ...*). Open valves are never interlocked; an open valve can always be closed; if the beam is on when a valve is commanded to close, the beam will turn off as soon as the valve begins to move from its open position.

4.7.2 TOGGLE PUMP GROUPS

When this operation is selected, the names of all the vacuum system pump groups and their actual states (OFF, STANDBY and PUMP) appear in the operations region, showing a graphic representation of the beam lines and the location of each pump group, similar to fig. 4.2. Each group's most recently requested state (OFF REQUESTED, STANDBY REQUESTED and PUMP REQUESTED) also appears, if it differs from the current state of that group. When the state of a pump group changes, the corresponding information on the screen updates. The display shows a graphic representation of the cyclotron and beamlines and the location of each pump group. The pump groups are PG1, PG2, PGSWM, PGA1, PGA2, PGB1, PGB2, and PGC.

It is sometimes necessary to show both the current state and the most recently requested state of each group because the state transitions can be slow; in particular, in STANDBY and PUMP the diffusion pump is hot (ready) and in OFF it is cold. Transitions in and out of the OFF state can take up to 45 minutes to complete.

A pump group can be toggled between the three states PUMP, STANDBY, and OFF. The requested state appears in the TOGGLE PUMP GROUP display as soon as the operator enters it. The actual state does not change until the group actually achieves the requested state. When the actual state conforms to the most recently requested state, the requested state indication does not appear; only the actual state is shown.

Immediately after the operator toggles a pump group, it is possible to select and toggle another group, even though the first group may remain in transition. Therefore, it is possible that more than one group may be in transition at the same time. The user may also toggle the same group again before that group's previous transition has fully completed.

4.7.3 TOGGLE CYCLOTRON POWER SUPPLIES

When this operation is invoked, the names of all cyclotron power supply groups and the states of their controls appear in the operations region in a tabular or related format, as in Figure 4.3. When the state of a power supply group changes, the corresponding information on the screen updates.

OPERATOR: Jon Jacky		PARTICLE, ENERGY: 50.5 MeV Protons							
LAST LOADED SETTING:		28-Sep-1992 09:34 Ruedi Risler Morning startup							
CYCLOTRON POWER SUPPLIES									
MAGNET		ION SOURCE		RF	EXTRACTION	PROBES			
PSMC	ON	PSARC	INTL	RFDC	OFF	PSHV	OFF	MPPC	OFF
PSCC	ON					PSEMC	ON	DFLPRBE	ON
PSHC	ON					PSISM	ON		

Figure 4.3: Terminal display screen during TOGGLE CYCLOTRON POWER SUPPLIES operation.

The power supply groups in this display are PSMC, PSCC, PSHC, PSARC, RFDC, RFDC, PSHV, PSEMC, PSISM, MPPC and DFLPRBE. The list of power supplies in each group, the interlocks that prevent each group from being turned on, and other details are listed in another volume.

The groups may be in the states OFF, START, STANDBY, FAULT, ON, RDOWN or INTLK. OFF means that the contactor which connects line power to all the supplies in the

group is open. START means the contactor has been closed, but some or all of the power supplies in the group have not achieved their assigned settings. This can occur for a number of reasons, depending on the supply; for example, there are filament delays in the RF system and the main magnet takes several minutes to ramp. FAULT means the contactor is closed but the supply group is indicating some fault. ON means the contactor is closed and the supply is operating. RDOWN means that the contactor is closed and the supply is ramping down in preparation for turning off. STANDBY is used for the high voltage supplies of the RF system and the ion source. It is a state in which the high voltage is ready to be turned on but requires an additional "ON" command to start the transition to ON. INTLK means that the contactor cannot be closed because of an interlock or fault. The exact definition of each state for each power supply group, and the interlocks associated with each group, appear in another volume.

Operators may select and toggle supply groups. Toggling a group which is OFF or RDOWN causes it to switch to one of the states START, FAULT, ON or INTLK, depending on the condition of the supply group. Toggling a group which in the INTLK state causes a list of the interlocks in effect for that group to appear in a message region.

Toggling a group which is the START, FAULT, or ON states is supposed to switch it to RDOWN or OFF; if the group fails to switch OFF, a message appears. In particular, if the user attempts to toggle a group to OFF when the beam is on or the CYCLOTRON READY FOR TREATMENT condition is true, a message like this appears: example:

```
BEAM ON - PSHC group must not be turned off.
```

and no further action is taken. The exceptions are the two probe supply groups; they can be turned off at any time.

Immediately after the operator toggles a supply group, it is possible to toggle another supply group, even though the first group may remain in transition. Therefore, it is possible that more than one group may be in transition at the same time.

TOGGLE POWER SUPPLIES does not include changing the polarity of a power supply. Changing polarity is included in the SET VALUES operation.

Servo amplifiers for RF tuning, extractor position and deflector probe position must be turned on before they can be set and some must be turned off again after the setting has been achieved. It is not necessary to use the TOGGLE POWER SUPPLIES operation to do this. These actions are performed implicitly when the parameters are attached to tuning modules, or the parameters are selected during SET VALUES.

4.7.4 TOGGLE BEAM LINE POWER SUPPLIES

This operation works like TOGGLE CYCLOTRON POWER SUPPLIES, except the operations regions shows a graphic representation of the beam lines and the location of the magnets controlled by each power supply group (Fig. 4.4). The list of power supplies in each group, the interlocks that prevent each group from being turned on, and other details are listed in another volume.

It is not possible to toggle supplies in the selected line when the beam is on or CYCLOTRON READY FOR TREATMENT is in effect. The display indicates this condition.

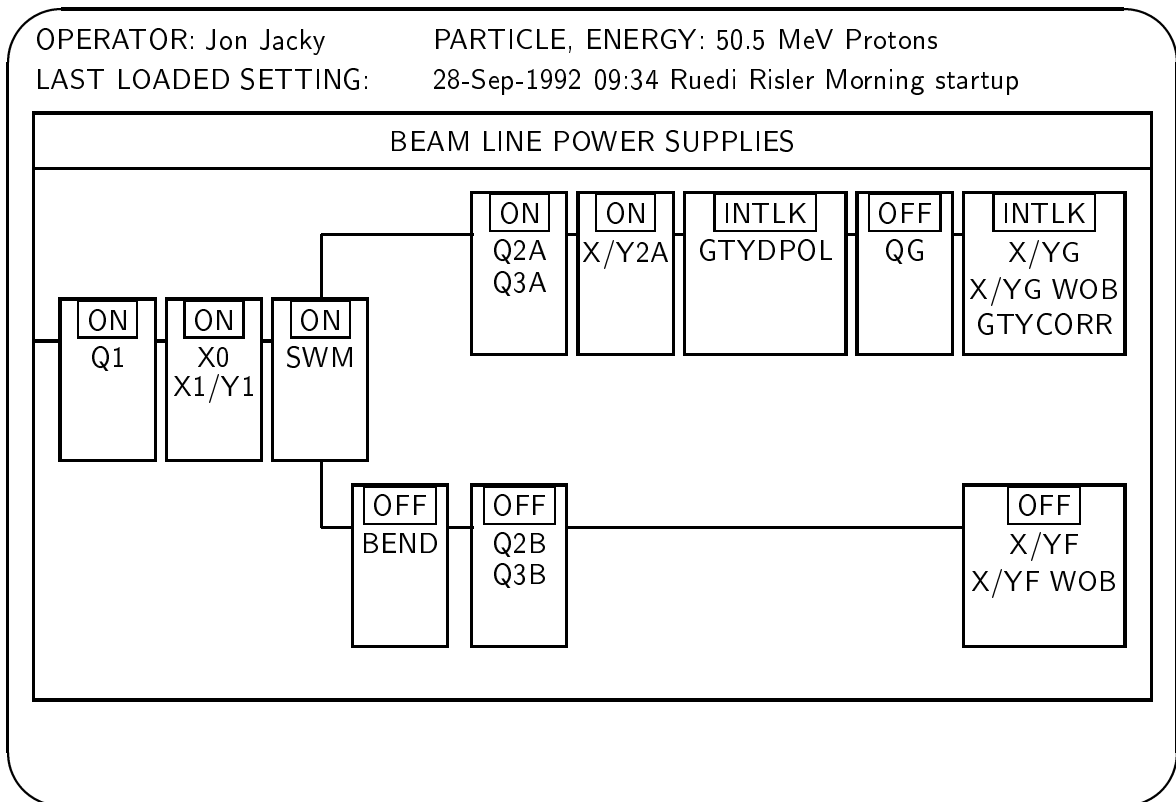


Figure 4.4: Display Screen during TOGGLE BEAM LINE POWER SUPPLIES operation.

4.8 Parameter control operations

This group of operations selects analog parameters for display in the operations region and for possible subsequent adjustment from the terminal or from a tuning module.

4.8.1 SET VALUES

This operation allows the user to examine and set the PSETPOINT, PHIGH, PLOW, values and tuning module sensitivity for each of the many cyclotron control parameters. When it is invoked, the operations region displays the names of the parameters (Fig. 4.5). The parameter setpoint PSETPOINT and the tuning module sensitivity can be set for parameters that have outputs; there are about 70 of those. The PHIGH and PLOW window limits can be set for all of the almost 120 parameters that have inputs, including about 50 “read-only” inputs that have no corresponding outputs.

The operations region shows an example of a tabular display (section 2.3.3). When the operator selects a parameter, a display region appears (“pops up”) that displays information about the selected parameter (Fig. 4.5). This box always shows the number and name of the selected parameter; for parameters that have outputs, the current PSET and PSETPOINT are shown. For parameters that have inputs, the PREAD, PHIGH and PLOW values appear. The values are shown in engineering units, and for PSET, PSETPOINT and PREAD the values are also shown in hexadecimal and binary; this is useful for certain calibration and maintenance procedures. Other information about the parameter may be shown. For parameters that can be attached to tuning modules, tuning sensitivity appears; for parameters that are power supply currents, whether the supply is on or off, its polarity, and any interlocks in effect may be shown. The information in the region updates as the values change, much like a status display.

```

33 DFLVOLT  PSETPOINT = 45.5 kV   #0000 1100 0001 1110  H 0C1E
   ON       PSET      = 30.0 kV   #0000 1000 0000 0010  H 0802
           PREAD     = 29.8 kV   #0000 0111 1111 0110  H 07F3
           PLOW      = 42.0 kV
           PHIGH     = 46.0 kV   Tuning sensitivity: 4

```

(This example shows the somewhat unusual case where PSETPOINT and PSET are not the same, in this case because the high voltage supply is in the process of being ramped by the software.)

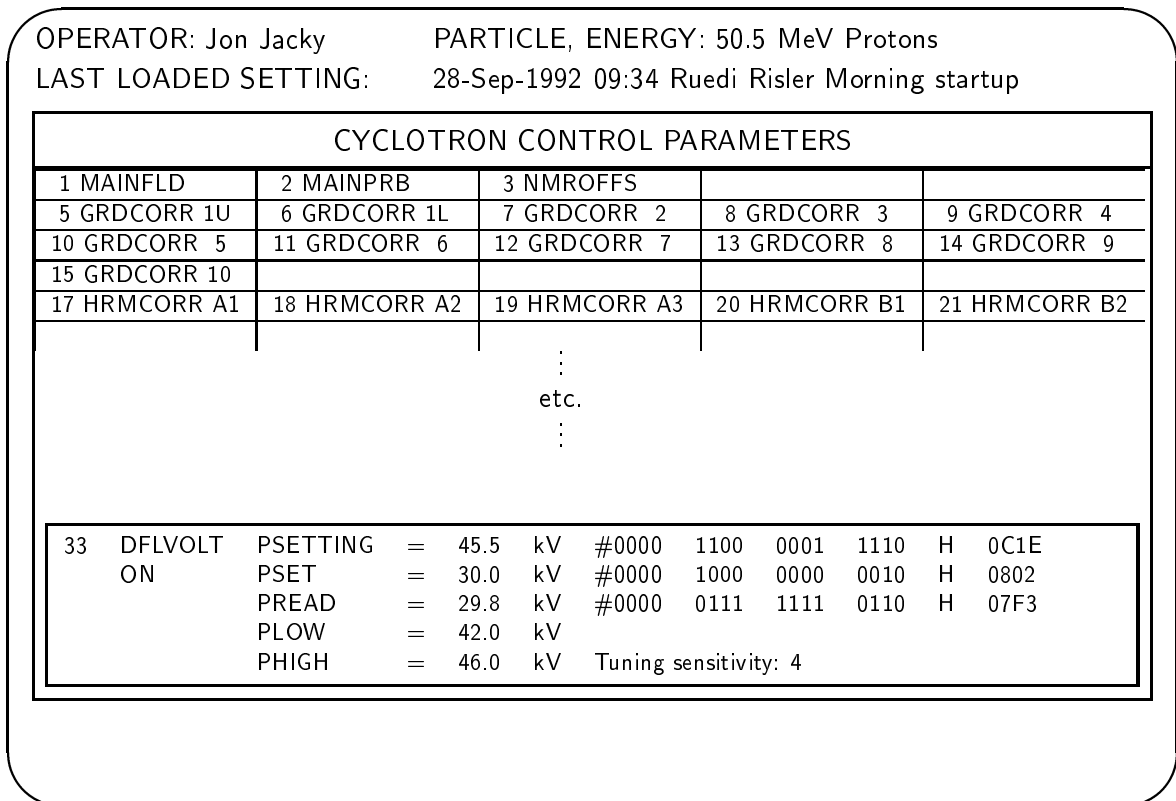


Figure 4.5: Terminal display screen during SET VALUES operation.

The operator may change the PSETPOINT, PLOW, PHIGH, and SENSITIVITY values for the selected parameter. The numbers can be entered in engineering units, binary, or hexadecimal. The values are checked for proper range and an error message appears if the operator tries to enter invalid (non-numeric) data or a value that cannot be physically achieved (for example, because it is outside the power supply capability). There are eight available tuning sensitivities, numbered 1 (least sensitive) through 8 (most sensitive). The sensitivities are associated with parameters, not modules; the tuning sensitivity will be set to the proper value for the parameter whenever it is attached to any tuning module.

If the operator selects a parameter when the beam is on, that would influence the running beam (e.g. a quadrupole through which it is running), the operator must confirm the selection. The parameter display region is distinctively labelled or highlighted when a parameter that affects the running beam has been selected.

If the operator attempts to set a PSETPOINT, PHIGH or PLOW value that would place the PSETPOINT value outside the window determined by PHIGH and PLOW, the operator must confirm the new setting. If confirmed, the newly entered PSETTNG value is applied; if the beam is on, and is affected by the parameter, it turns off.

It is not necessary for a power supply to be turned on to change its PSETPOINT value. What is being changed is the setting which the power supply will attempt to achieve when it is turned on.

Changing polarity

Operators can use SET VALUES to change power supply polarities, by including a sign when typing the new PSETPOINT value. Positive polarity is indicated by a leading '+' sign or no sign; negative polarity is indicated by a leading '-' sign. Operators can refer to the contents of the parameter display region (or status displays) to see whether +/- refers to right/left, vertical/horizontal, etc.

Some supplies are inherently bipolar, others are monopolar but are made bipolar as a result of adding polarity-reversing contactors. Switching polarity of this latter type can be time-consuming, so unnecessary changes should be avoided. If the user types a new value that implies changing the polarity of a parameter of this type, the operator must confirm the operation in order to proceed. This guards against the operator forgetting to include a minus sign for a parameter which already has negative polarity.

Binary and hexadecimal input

New parameter values can be entered in scaled application units as decimal numbers (with an optional negative sign, an optional decimal point and with as many digits to the right and left of the decimal point as needed). Alternatively, they may be entered as binary numbers, which are merely the bit patterns to be loaded into the PSET output register. This permits digital-to-analog converters (DAC's) to be calibrated according to the vendor's instructions. An additional alternative is to enter the hexadecimal equivalent of the binary pattern.

Servoamplifiers

Some parameters are settings for servoamplifiers for RF tuning, ion source gas flow, and extractor probe position. Most servoamplifiers are usually kept off. These amplifiers are turned on when the user enters a new value and they remain on until the new value has been achieved or they time out. The timeout period is determined by the software and is stored in a file on the control system support host. It is long enough to permit the servo to attain the requested position. This can take several minutes.

Interaction with tuning modules

It is possible to select a parameter which is also assigned to a tuning module. The operator can observe its values updating in the parameter display region as the tuning module is adjusted. When an interaction to set such a parameter's PSETPOINT is in progress, the tuning module to which that parameter has been assigned is disabled, and its display becomes dark. When the interaction to set the PSETPOINT value from the terminal is complete, the tuning module is reenabled and its display updates to indicate the new setting.

Interaction with deflector probe panel controls

The deflector probe position, which is one of the parameters that can be set from the terminal, can also be controlled from dedicated units on the cyclotron console. When the user selects this parameter's PSETPOINT value to be set from the terminal, the dedicated console control is disabled and its ENABLE lamp goes dark. The user then then enter the probe position, and the probe begins moving. As soon as the probe stops, because it has reached the requested position or for any other reason, the panel controls are reenabled and

the ENABLE lamp lights. The probe will remain where it is and the dedicated position lamps will stay dark until one of them is pushed.

Concurrent operation

Power supplies, servoamplifiers and parameters in the RF system may not immediately assume the requested parameter value. PSET may not be set equal to PSETPOINT immediately; transitions may take many seconds, or even minutes, while power supplies ramp, servos move, or internally-controlled sequencing takes place. In fact, power supplies need not even be turned on when their settings are changed.

Immediately after the operator enters a new setting, it is possible to set another parameter, even though the first parameter may remain in transition. Therefore, it is possible that more than one parameter may be in transition at the same time. The user can enter a new setting before a parameter's previous transition has completed.

4.8.2 SET DEFAULT WINDOWS

When this operation is invoked, the operator is requested to confirm this action. If the operator responds yes, the PLOW and PHIGH window values for *every* parameter are replaced by a new set from a table of defaults.

There are three types of defaults:

- Absolute values which are independent of the current parameter setting. For example, the steering magnet current windows should always default to a lower current limit (for example, 0.0 A) and an upper current limit (for example 2.0 A).
- Some interval above and below the current parameter setting, where the interval is independent of the setting. For example, the gantry dipole windows should default to 1 amp below and 1 amp above whatever the current setting is.
- Plus or minus some percentage of the current parameter setting. For example the quadrupole currents and extractor motions should default in this way.

The default window type and values for each parameter are in a file on the control system support host and cannot be changed from the cyclotron console.

This operation is disabled when the beam is on or CYCLOTRON READY FOR THERAPY is in effect.

4.8.3 ASSIGN SINGLE TUNING MODULE

When this operation is invoked, the operations region shows the names and numbers of the parameters available for assignment to tuning modules in a tabular format. The operator can select a parameter and then enter a tuning module number.

When a tuning module number is entered, the current parameter is attached to the indicated tuning module. The selected tuning module's LED display then shows the name and current setting of the selected parameter as long as the parameter is attached to the tuning module.

In addition to the table of parameters, the operations display also includes a option named DISABLE that can be selected as if it were a parameter. If the user selects DISABLE when a parameter is requested, and then selects a tuning module as above, the specified tuning module is disabled and its LED display becomes blank.

Some servoamplifiers (used for RF tuning and probe positioning) can be assigned to tuning modules. Servos must be turned on before they can be moved. Some servos are left off most of the time and turned on only when needed. These servos are turned on when they are assigned to a tuning module and turned off when they are deassigned.

One of the parameters that can be assigned to a tuning module is the deflector probe position. The deflector probe can also be moved to preset positions by pressing dedicated control buttons on the cyclotron console (chapter 3). The dedicated panel controls for the deflector probe are disabled (and its lamps are dark) as long as the deflector probe position is assigned to a tuning module.

4.8.4 ASSIGN ALL TUNING MODULES

Invoking this operation causes a list of preassigned tuning module assignments to appear in the operations region. Each entry lists a group of six parameters and the number of the tuning module assigned to each parameter. The definitions of these groups are in a file on the control system support host and may be changed by using software on that computer. They cannot be changed from any control system console.

This operation can be implemented as a list selection display, as described in section 2.3.1.

Chapter 5

Cyclotron status display terminal

This chapter describes operations that are performed at the cyclotron status display terminal installed in the cyclotron console.

5.1 Status display screen

The Status Display terminal screen always shows a display of information concerning some subsystem. The display updates continuously as the information changes. It is essentially a computer-based replacement for a bank of analog meters and indicator lamps. It is multiplexed between different subsystems; the cyclotron operator can select which subsystem display is shown.

Unlike most other terminals, the status display does not include a status region. The operations region usually occupies the entire screen (Fig. 5.1).

5.2 Keyswitch

The status display terminal remains enabled whether or not the cyclotron console keyswitch is off. It continues to update with information about the currently selected subsystem, and it is possible to change which subsystem display is shown. It is also not necessary for an operator to be logged in.

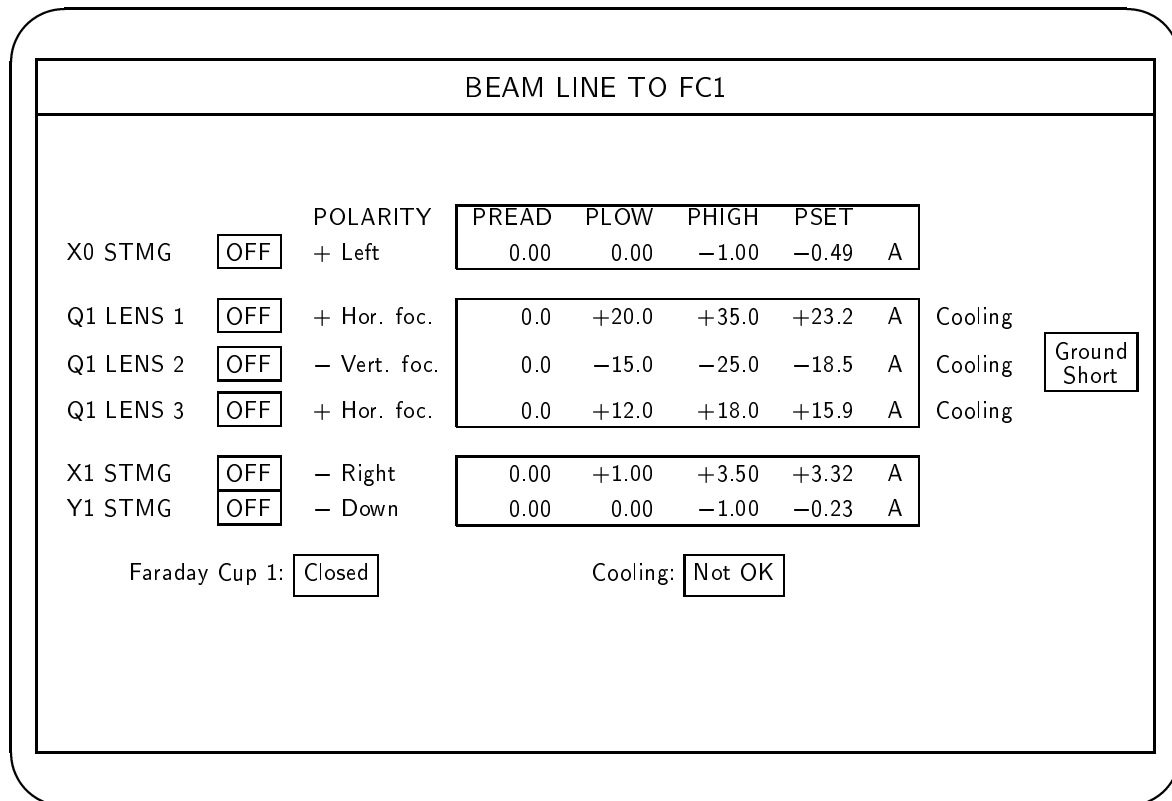


Figure 5.1: Status display screen

5.3 Status display operations summary

This terminal is used solely as a display device. It is not possible to change the state of the controlled equipment from this terminal. The only operations that are provided for this terminal have the effect of changing what is displayed on the terminal itself.

The operator can select which subsystem display is shown by pressing one of the dedicated subsystem buttons on the On/Off Control and System Status panel on the cyclotron control console (chapter 3). Buttons are available for these subsystems:

- Magnet system
- RF system (DC)
- RF system
- Ion source system
- Extraction system
- Beam diagnostic system
- Vacuum system
- Beam line to FC1
- Beam line FC1 to target
- Cooling system
- Vault safety
- Beam line safety
- Therapy room status

Pressing the button for BEAM LINE FC1 TO TARGET, VAULT SAFETY, BEAM LINE SAFETY, and TREATMENT ROOM STATUS calls up the display for the currently selected beam line (or the corresponding treatment room), or if no line is selected, the line which was most recently released (except there is a display VAULT SAFETY, NO LINE SELECTED). Before any line is selected (after the control system programs are started up) these call up the display for the A line (isocentric treatment room).

The subsystem selection buttons are always enabled, whether or not the cyclotron console keyswitch is turned on or an operator is logged in.

Alternatively, the operator may select subsystems at the terminal. The `SELECT STATUS DISPLAY` operation provides selection at the terminal of any of the displays enumerated above, as well as other displays for which there are no dedicated buttons, such as displays for each individual vacuum pump groups. `SELECT STATUS DISPLAY` can also be used to bring up displays for beam lines and treatment rooms that are not presently selected.

As soon as a display is requested by either method, the screen updates with the requested subsystem display. The display continues to update as the information changes, until another subsystem is requested.

When the control system software first starts up, this terminal shows the `SAFETY TO FC1` display.

5.4 Status display design conventions

The next section (Section 5.5) describes most of the status displays in detail. They should be considered examples or recommendations; it is not required that the actual displays must appear exactly as described here. What is required is that the items described in section 5.5 be depicted in some informative way, and that some consistent set of conventions be observed.

The present section describes the conventions used to portray different kinds of data items on status displays, and explains the notation used in this document for describing displays. These conventions describe designs that can be accommodated on character displays. Different conventions might be better suited for graphic workstations.

5.4.1 Title

At the top of every status display there is a title bar that shows the subsystem name.

5.4.2 Display background

Section 5.5 illustrates several sample displays. Most status displays are divided into several regions that collect functionally related items into groups. In section 5.5, suggested designs for some regions are pictured in (unlabelled) boxes. In other cases, no design is pictured, but the elements that must appear are enumerated in itemized lists. Unless otherwise indicated,

the contents of each box appear literally on the display screen, and form part of the fixed display background that does not change when the display updates.

A single picture is not a sufficient specification for a status display, because the display contents change. We use several notational conventions to describe the changing display elements.

5.4.3 Modes

Some display elements indicate alternatives or *modes* where exactly one alternative is displayed at any time (because exactly one mode is in effect at a time). In the boxes that appear in section 5.5, words or groups of words separated by slashes (e.g. Left/Right means either Left or Right will be displayed, but not both). indicate collections of modes (the slash characters do not appear on the running status display).

It is possible that faults or other problems will result in equipment being in an erroneous or inconsistent state, instead of a predefined mode. In such cases a special error indicator is displayed. The indicators — (dash) and also ?, (question mark, where this is necessary to avoid confusion with minus signs) are used for erroneous states where the equipment appears disconnected or powered off, and the indicator *** is used for other erroneous states. To save space and reduce clutter, these indicators are not shown in the boxes that appear in section 5.5.

5.4.4 Interlocks and other conditions

Some display elements indicate conditions (usually interlocks) where any number of the conditions may be true at the same time; each condition that is true (each interlock that is set) is displayed, while conditions that are false (interlocks that are clear) are not displayed. In the boxes that appear in section 5.5, words or groups of words separated by commas (e.g. Ground short, Overtemp, Main fuse) indicate these conditions (the commas do not appear on the running status display).

5.4.5 Parameters

Many status displays include one or more regions that show the values of several digital indicators and analog quantities associated with a set of related cyclotron control parameters. Usually this information is shown in tabular form, one row per parameter, with the

parameter name in the left column (Fig. 5.7). This column forms part of the fixed display background.

Next, there may be one or more columns indicating modes associated with the parameter, for example whether the associated power supply is ON or OFF, etc.

Some parameters (for example, currents in the steering magnets and quadrupole magnets) are bipolar (they may have positive or negative signs). These parameters have modes corresponding to the polarity, e.g. LEFT and RIGHT. When these parameters are displayed, there is a column showing the sign of the the actual (measured) polarity and the mode corresponding to that sign.

Next, the numeric values of some or all of the analog quantities PREAD, PLOW, PHIGH, and PSET appear in consecutive columns. In the boxes in section 5.5, the format for displaying values is indicated. For example, -nnn.n indicates that there is one digit to the right of the decimal point, up to three digits to the left, and the sign is shown. For bipolar parameters, the sign is always shown, including the + sign when the polarity is positive; no sign appears with unipolar parameters.

Next, there is usually a column giving the physical units in which the values of these quantities are reported, for example A (for Ampere). This column forms part of the fixed background.

Then may follow one or more columns showing any interlocks associated with each parameter.

5.4.6 Color and highlighting

Color is particularly useful in status displays. On monochrome displays, similar effects can be achieved by using highlighting attributes such as boldface and reverse video.

Color is useful for mode indicators. Some mode names occur in more than one display element; these should be colored the same way wherever they appear. Sometimes all the modes in group have the same color (for example, in Left/Right). In other cases, particular modes within a group may be colored differently, for example to enable the operator to easily see which power supplies are turned on. In section 5.5, these modes are indicated by enclosing them in boxes: ON/OFF. The indicators —, ? and *** that indicate erroneous or inconsistent modes are always colored differently than the other modes in a group. On monochrome displays, the modes which are not enclosed in boxes could be shown in normal mode, the modes enclosed in boxes could be shown in bold, and the erroneous modes could

be shown in bold reverse video.

There are two kinds of interlocks. The first kind of interlocks can be set during normal operation. For example, cooling interlocks are set when the main cooling pumps are off overnight. Others are transient and are automatically reset by their particular subunit (for example, some faults that occur during RF sparks). The second kind are only set if something unusual happens (for example, ground shorts). The two kinds of interlocks are indicated by different colors. On monochrome displays, the first kind could be shown in bold, and the second kind in bold reverse video. In this chapter, the two kinds of interlocks are indicated by the absence or presence, respectively, of an enclosing box: Cooling,

Ground short

¹.

The columns containing the analog data (parameter values and physical units), including the column headings, are set off from the rest of the display by using a different color scheme (Fig. 5.1). On monochrome displays, this could be achieved by using reverse video. Parameter values which are outside their windows are indicated in a different color than the other text in these columns, but *only when the power supply for that parameter is turned on*. On monochrome displays these values could be shown in bold reverse video.

A possible color scheme is described in Tables 5.1 and 5.2. Items and colors which stand out from the background are shown enclosed in boxes. If status displays are shown on monochrome terminals, these are the items that should be highlighted in bold or bold reverse video.

¹In a future version we might (for example) indicate the cooling interlock in red also, if it becomes set when it should not (e.g., when the cooling pump is running).

ELEMENT	COLOR
Title bars	Various
Background	Black
Captions, fixed text	Cyan
Safety trace (safety displays)	Cyan
Safety trace captions	White
Modes	(see below)
Interlocks	(see below)
Parameters	(following table)

MODES	COLORS
OK/NOT OK	Cyan/Yellow
ON/OFF/OFF (fault) (Power supplies, servoes, pumps)	Cyan/Yellow/Red
ON/OFF/ON-OFF (PSHC only)	Cyan/Yellow/White
Local/Remote (Power supplies)	White/Cyan
Left/Right (Quadrupole power supplies)	Green
Hor.Foc./Vert.Foc. (Quadrupole power supplies)	Green
Up/Down (Steerer power supplies)	Green
Line A/Line B (A line displays)	Green/Magenta
Line A/Line B (B line displays)	Magenta/Green
Deuterium/Hydrogen/3-He/4-He (Ion source)	Blue, cyan background
All HV PS on/Not all HV PS on/ ... (RF DC system)	Green
OK/tuning/pulse start/ ... (RF system status)	Cyan
PUSH PULL/PUSH PUSH (RF system)	Cyan
Preset/Regulate/Wait (RF SAM status)	Cyan
FAULT/ON/OFF (RF tuning)	Red/Cyan/Yellow
Running/Not running (Cooling system)	Cyan/Yellow
OPEN/CLOSED (Valves, Faraday cups)	Cyan/Yellow
Penning/Pirani (Vacuum system)	Cyan
OFF/STANDBY/PUMP (Vac. pump group)	Yellow/Cyan/Cyan
OFF/ON/READY (Vac. diffusion pump)	Yellow/Cyan/Cyan
Clear/Set (Intlks. on safety displays)	Cyan/Yellow
- (Error, disconnected)	White
*** (Error, other)	Red

INTERLOCKS	COLOR
Normal	Yellow
Urgent	Red

Table 5.1: A status display color scheme: modes and interlocks

ELEMENT	COLOR
Background (except RF DC)	Blue
Column, row captions	White
Parameter values (inside windows)	White
Parameter values (outside windows, PS off)	White
Parameter values (outside windows, PS on)	Red
Background, RF DC: I-CA, U-G1, I-G2, I-AN	Black
RF System 1/System 2 captions	Green
Column, row captions, " "	Cyan
Parameter values, " "	Green
Background, RF DC: Grid, Coupl., Coarse, Fine	White
Column, row captions, " "	Black
Parameter values, " "	Black
Right/Left (INTSTMG power supply polarity)	White
-/+ (GRDCORR power supply polarity)	White
? (PS polarity error, disconnected)	Red
* (PS polarity error, other)	Red

Table 5.2: A status display color scheme: parameters

5.5 Status displays and contents

5.5.1 Magnet system

The first region displays modes and interlocks for the main coil (PSMC), the circular coils (PSCC), and harmonic coils (PSHC):

PSMC	<input type="checkbox"/> OFF / ON	Intl:	<input type="checkbox"/> Reg.Overload , <input type="checkbox"/> Water , <input type="checkbox"/> Line Voltage ,
	Remote / <input type="checkbox"/> Local		<input type="checkbox"/> PS Overtemp , <input type="checkbox"/> Ground short , <input type="checkbox"/> Start pos. ,
			<input type="checkbox"/> Trstor fail. , <input type="checkbox"/> Overcurrent , <input type="checkbox"/> Output short ,
			Magnet water , <input type="checkbox"/> Magnet temp , Yoke pos. ,
			EMC water , <input type="checkbox"/> EMC overtemp , EMC pos. .
PSCC	<input type="checkbox"/> OFF / ON	Intl:	<input type="checkbox"/> Liner Cooling , <input type="checkbox"/> Ground Short
PSHC	<input type="checkbox"/> OFF / ON / <input type="checkbox"/> ON-OFF	Intl:	<input type="checkbox"/> Ground short , <input type="checkbox"/> Overtemp , <input type="checkbox"/> Main fuse

The ON-OFF indicator appears if some harmonic coils are on and others are off.

The second region displays the main magnet current parameter, MAINFLD:

	PREAD	PLOW	PHIGH	PSET	
MAINFLD	nnn.n	nnn.n	nnn.n	nnn.n	A

The third region displays 11 parameters for the circular coils (GRDCORR 1U, GRDCORR 1L, GRDCORR 2, ... GRDCORR 10):

GRDCORR	PREAD	PLOW	PHIGH	PSET	
1U	-nn.n	-nn.n	-nn.n	-nn.n	A
1L	-nn.n	-nn.n	-nn.n	-nn.n	A
2	-nn.n	-nn.n	-nn.n	-nn.n	A
etc. ...					
10	-nn.n	-nn.n	-nn.n	-nn.n	A

The set and actual polarities of each circular coil are indicated by the signs of the displayed values.

The harmonic coils power supply group is unusual because there are three different PREAD values for each single harmonic coil PSET. The PSET's are displayed in a box by themselves:

HRMCORR	PSET	
A(magn)	n.nn	A
B(magn)	n.nn	A
C(magn)	n.nn	A
D(magn)	n.nn	A

For each PSET, the corresponding group of three PREAD's is displayed, and the sum of each group of PREAD's also computed (not measured) and displayed:

HRM CORR	PREAD
A1	-n.nn A
A2	-n.nn A
A3	-n.nn A
SUM	-n.nn A

The complete display is shown in Fig. 5.2.

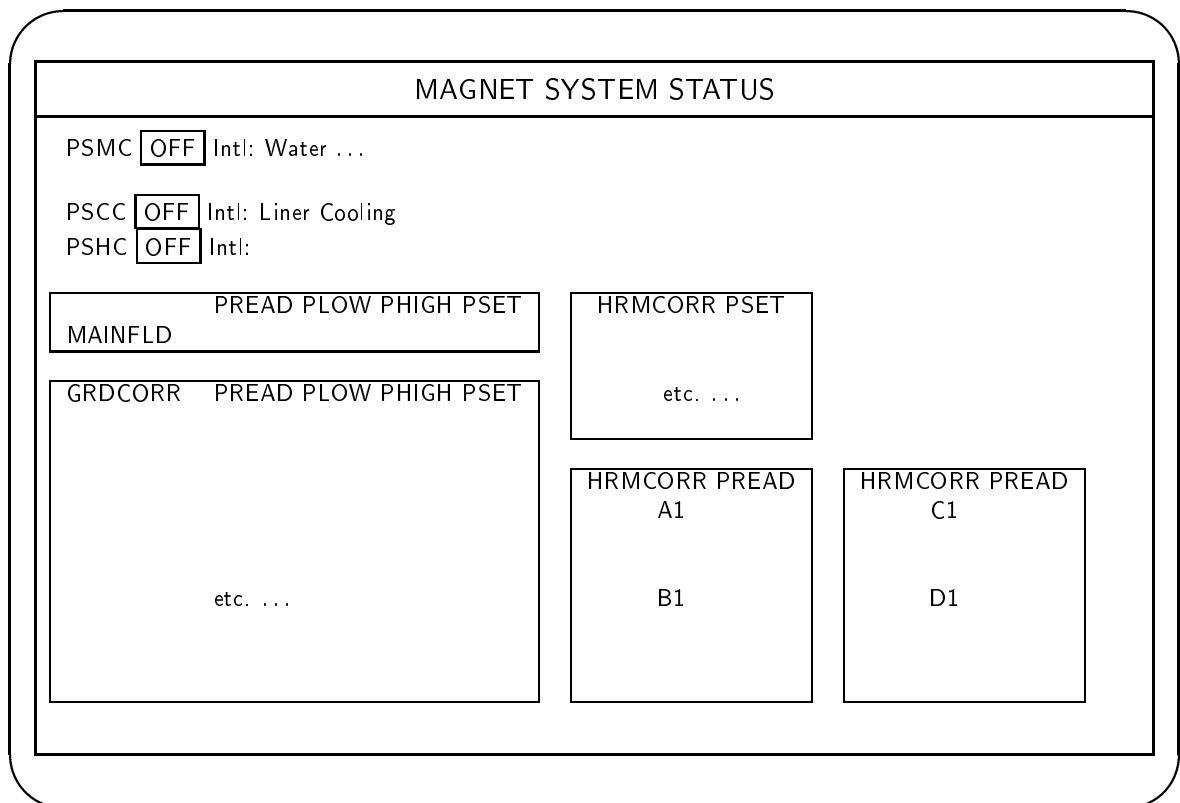


Figure 5.2: Magnet system status display

5.5.2 RF system (DC)

This display, with title bar RF DC SYSTEM STATUS, shows the status of the DC components of the two RF power amplifiers (PAMP). The top of the display summarizes the system status and interlocks for both systems:

PS SYSTEM STATUS:	All HV PS on/Not all HV PS on/All SB PS on/Not all SB PS on /Not all PS off/All PS off
Intl. RF System:	<input type="checkbox"/> Emergency, <input type="checkbox"/> AN-PS fault, <input type="checkbox"/> Overcurrent
Intl. System 1:	Pamp intl., RDRA fault, PS fault, PRSC contr, Pamp fault
Intl. System 2:	Pamp intl., RDRA fault, PS fault, PRSC contr, Pamp fault

The next section shows analog parameters for RF system 1:

- I-CA 1 (AC filament current in the power tube)
- U-G1 1 (DC control grid voltage on the power tube)
- I-G2 1 (DC output current from the screen grid power supply, PSG2)
- I-AN 1 (DC anode current)

Only the PREAD values are shown. There are no PSET's or windows for these parameters.

SYSTEM 1		
PREAD		
I-CA	nnn.	A
U-G1	nnn.	V
I-G2	nn.	mA
I-AN	n.nn	A

An identical section shows the corresponding parameters for RF system 2:

- I-CA 2
- U-G1 2
- I-G2 2
- I-AN 2

Another section shows remotely tunable RF parameters for Power Amplifier 1, with associated modes and interlocks:

- GRIDTUN 1
- COUPCAP 1
- CRSETUN 1
- FINETUN 1

These parameters are controlled by mechanical drives using servomotors. The parameter values are in units of percent (%) of the full range of the servo drives. The format is:

	PREAD	PLOW	PHIGH	PSET		SERVO
Grid	nnn.n	nnn.n	nnn.n	nnn.n	%	<input type="checkbox"/> OFF / <input type="checkbox"/> ON
Coupl.	nnn.n	nnn.n	nnn.n	nnn.n	%	<input type="checkbox"/> OFF / <input type="checkbox"/> ON
Coarse	nnn.n	nnn.n	nnn.n	nnn.n	%	<input type="checkbox"/> OFF / <input type="checkbox"/> ON
Fine	nnn.n	nnn.n	nnn.n	nnn.n	%	<input type="checkbox"/> OFF / <input type="checkbox"/> ON

Fine Tuning Status:	<input type="checkbox"/> FAULT / <input type="checkbox"/> ON / <input type="checkbox"/> OFF
SAM Status:	Preset / Regulate / Wait

An identical section shows the corresponding parameters (etc.) for system 2:

- GRIDTUN 2
- COUPCAP 2

- CRSETUN 2
- FINETUN 2

The complete display is shown in Fig. 5.3.

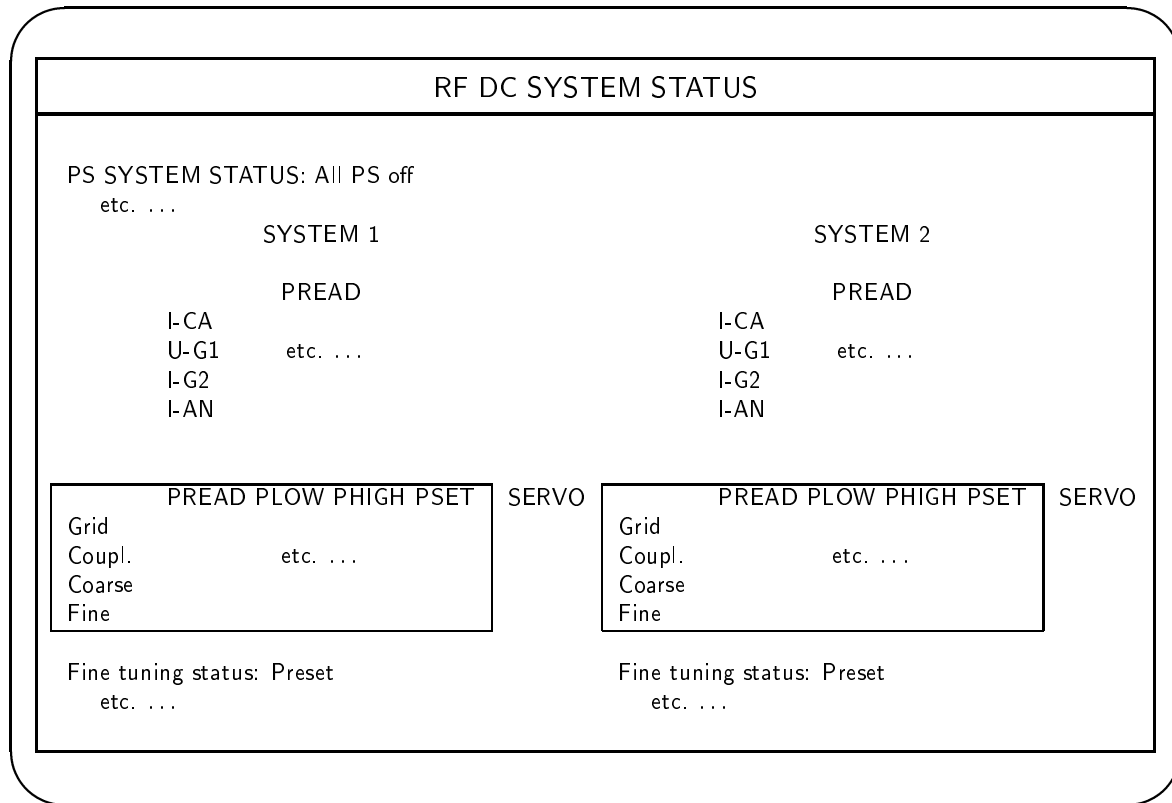


Figure 5.3: RF system (DC) status display

5.5.3 RF system

This display, with title bar RF SYSTEM STATUS, shows the status of the running parameters of the two RF amplifiers (running parameters are not meaningful when the RF drive is off). The top of the display shows the parameters for RF system 1. Only the PREAD for the following parameters are shown; there are no PSET's or windows for these parameters:

- A-GPHAS 1 (Anode to Control Grid phase)
- P-FORW 1 (Forward drive power)
- P-REFL 1 (Reflected drive power)
- UR-AN 1 (RF voltage on the power tube anode)
- FINETUN 1 (Fine tuning position)

PREAD, PLOW, PHIGH and PSET are shown only for this parameter:

- DEEVOLT 1 (Dee voltage)

The parameters are displayed along with related modes and interlocks:

GENERAL STATUS:		Normal drive OK/tuning/pulse start/on, error pause/on permitted/not permitted			
Dynamic errors:		Deevolt low, Phase high, Overcurrent			
Intl:		Strt fail, Run fail, Grid cool, RDRC ctrl, Cav.cool, D-ref loc			
		PREAD			
A-G PHAS	nnn.n	deg			
P-FORW	nnn.n	W			
P-REFL	n.n	W			
		PREAD	PLOW	PHIGH	PSET
DEEVOLT	nnn.n	nnn.n	nnn.n	nnn.n	%
UR-AN	n.n	KV			
FINETUN	nn.n	%			

(In this display, Normal drive is part of the caption on the first line; the first mode is OK.)

An identical section displays the corresponding parameters for RF system 2, along with their modes and interlocks:

- A-GPHAS 2
- P-FORW 2
- P-REFL 2
- UR-AN 2
- FINETUN 2
- DEEVOLT 2

A third section displays parameters which are common to both RF systems:

- DEEPHASE
- RFFREQ

There is only a PSET for RFFREQ. Related interlocks and modes are also shown:

RF Intl: Not all HV PS on, External intl., RMC control						
		PREAD	PLOW	PHIGH	PSET	
MODE: PUSH PULL/PUSH PUSH	DEEPHASE	nnn.n	nnn.n	nnn.n	nnn.n	deg
	RFFREQ				nn.nn	MHz

The complete display is shown in Fig. 5.4.

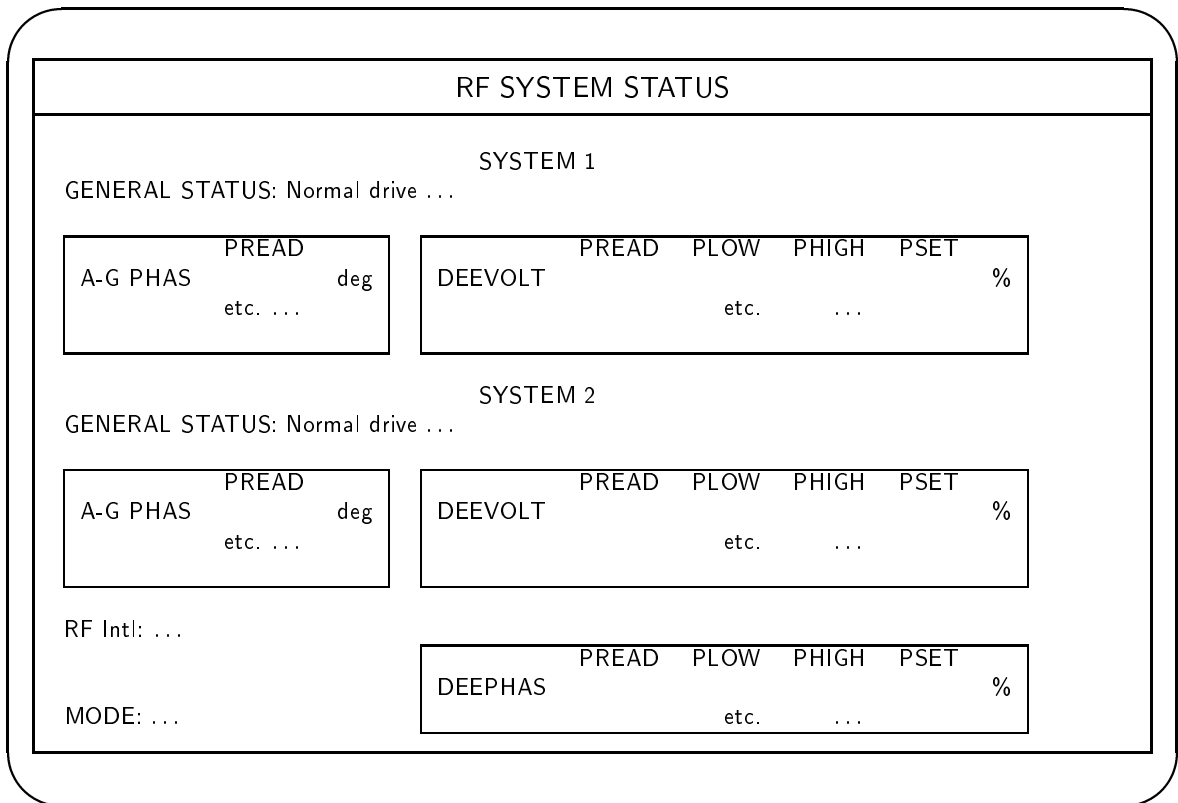


Figure 5.4: RF system status display

5.5.4 Ion source system

This display (title bar ION SOURCE SYSTEM STATUS) shows these parameters, along with related power supplies and interlocks:

- GASFLOW
- ARCCURR
- ARCVOLT

For GASFLOW, the PREAD, PLOW and PHIGH are in units of cc (cubic centimeters per minute), but the PSET is in units of % (percent of maximum needle valve range). Only the PREAD values for ARCCUR and ARCVOLT are shown; there are no windows nor PSET for these parameters. The arc current of the source is controlled via a dedicated, hardwired potentiometer at the control desk and these controls do not use the computer. Also shown is the status (OFF/ON) for the servo amplifier module (SAM) which contains the servo (SERVO, also shown) which controls the gas flow valve.

		Gas: Deuterium/Hydrogen							
SAM	<input type="checkbox"/> OFF / <input type="checkbox"/> ON	PREAD		PLow	PHIGH	PSET			
SERVO	<input type="checkbox"/> OFF / <input type="checkbox"/> ON	GASFLOW	n.nn	n.nn	n.nn cc	nn.nn	%	Limit 1, Limit 2, <input type="checkbox"/> Overtemp	
PSARC	<input type="checkbox"/> OFF / <input type="checkbox"/> ON	<input type="checkbox"/> Local / <input type="checkbox"/> Remote		Intl: Cooling, Filam. Cold, <input type="checkbox"/> Overload, Safety cover, Cathode pos., Magn. field, <input type="checkbox"/> Emerg.loop					
		PREAD							
		ARCCUR	nn.	mA					
		ARCVOLT	nnn.	V					

5.5.5 Extraction system

This display, with title bar EXTRACTION SYSTEM STATUS, shows the status the following parameters:

- DFLVOLT

- SEPTEMP

- DFLCURR

- DFLENTN

- DFLEXIT

- EMCEXIT

- INTSTMG

- EMCCORR

Related modes and interlocks are also shown, in this format:

PSHV	<input type="checkbox"/> Local / Remote <input type="checkbox"/> OFF / ON	Intl: Defl.cool., Safety cov, Vacuum, Magn.field, Sept.temp					
			PREAD	PLOW	PHIGH	PSET	
			DFLVOLT	nn.n	nn.n	nn.n	nn.n kV
			SEPTEMP	nnn.n	%		
			DFLCURR	n.nn	mA		
SAM	<input type="checkbox"/> OFF / ON		PREAD	PLOW	PHIGH	PSET	
SERVO	<input type="checkbox"/> OFF / ON		DFLENT	nnn.n	nnn.n	nnn.n	nnn.n %
	<input type="checkbox"/> OFF / ON		DFLEXIT	nnn.n	nnn.n	nnn.n	nnn.n %
	<input type="checkbox"/> OFF / ON		EMCEXIT	nnn.n	nnn.n	nnn.n	nnn.n %
							<input type="checkbox"/> Overtemp, (etc.)
							<input type="checkbox"/> Overtemp, (etc.)
							<input type="checkbox"/> Overtemp, (etc.)
PSISM	<input type="checkbox"/> OFF / ON	Intl: ISM Cooling, <input type="checkbox"/> Ground short					
	-/+ Right/Left		PREAD	PLOW	PHIGH	PSET	
			INTSTM	n.n	n.n	n.n	n.n A
PSEMC	<input type="checkbox"/> Local / Remote	Intl: <input type="checkbox"/> Power fail, Cooling, Water, <input type="checkbox"/> Overtemp, Position, <input type="checkbox"/> Overload, <input type="checkbox"/> Trstr.fail					
M.P.	ON / <input type="checkbox"/> OFF		PREAD	PLOW	PHIGH	PSET	
C.P.	ON / <input type="checkbox"/> OFF		EMCCORR	nnn.n	nnn.n	nnn.n	nnn.n A

In this display, the complete list of interlocks for the DFLENTER, DFLEXIT and EMCEXIT parameters is Overtemp, Limit 1, Limit 2.

5.5.6 Beam diagnostic system

This display (title bar BEAM DIAGNOSTIC SYSTEM STATUS) shows these parameters, along with related power supplies and interlocks:

- MAINPROBE
- DFLPROBE

The status of the three beam current amplifiers is also shown. The TRIP indicators, when visible, show that a stray beam detector, target quadrant or the target itself has sensed a current exceeding safe operating limits and has turned of the beam by setting a hardwired interlock.

MAIN PROBE			
MPPC:	<input type="checkbox"/> OFF / <input type="checkbox"/> ON		
Interlock:	Inner limit, Outer limit, TankValve closed		
Cooling:	OK / <input type="checkbox"/> Not OK		
Position:	nn.nn cm		
DEFLECTOR PROBE			
MPPC:	<input type="checkbox"/> OFF / <input type="checkbox"/> ON		
Interlock:	Inner limit, Outer limit, Overtemp, SAM OFF		
Cooling:	OK / <input type="checkbox"/> Not OK		
Position:	nn.nn cm		
BEAM CURRENT AMPLIFIER			
BCA-C:	<input type="checkbox"/> OFF / <input type="checkbox"/> ON	TRIP:	<input type="checkbox"/> SBD-1, <input type="checkbox"/> SBD-2, <input type="checkbox"/> SWM, <input type="checkbox"/> SBD-3, <input type="checkbox"/> SBD-4, <input type="checkbox"/> SBD-5
BCA-G:	<input type="checkbox"/> OFF / <input type="checkbox"/> ON	TRIP:	<input type="checkbox"/> Target, <input type="checkbox"/> Up, <input type="checkbox"/> Down, <input type="checkbox"/> Left, <input type="checkbox"/> Right, <input type="checkbox"/> SBD-G/T
BCA-F:	<input type="checkbox"/> OFF / <input type="checkbox"/> ON	TRIP:	<input type="checkbox"/> Target, <input type="checkbox"/> Up, <input type="checkbox"/> Down, <input type="checkbox"/> Left, <input type="checkbox"/> Right, <input type="checkbox"/> SBD-T

5.5.7 Vacuum system

This display (title bar VACUUM SYSTEM STATUS) shows the status of pump groups 1, 2, SM, A1, A2, B1, B2 and C1. The display is simply a table with one row per pump group, and a column for each data item, as shown below. The table column headings (with abbreviations) are the Pump Group (PG), Pressure in mbar ([mbar]), Pump Mode, Mechanical Pump (MECH. PUMP or MP), Diffusion pump (DIFF. PUMP or DP), Cooling (COOL.), Roughing Valve (RV), Backing valve (BV), High vacuum valve (HIGH VAC. VALVE or HVV), Beam line valve (BEAML. VALVE or BLV), and Fast Valve (FV). Pressure is shown in n.nE-n format, e.g. 3.9E-7. Pump modes are OFF / STANDBY / PUMP, Diffusion pump modes are OFF / ON / READY, Mechanical pump modes and Diffusion pump cooling modes are ON / OFF, and all valve modes are CLOSED / OPEN. Not all data items are meaningful for all groups: there are no roughing valve and backing valve for group 2, there are no beam line valves for groups 1 and 2, and there is no fast valve for any group except 1. In those cases the table entry is simply left blank.

PG	mbar	MODE	MP	DP	COOL	RV	BV	HVV	BLV	FV
1	n.nE-n	<input type="checkbox"/> OFF / STANDBY/ PUMP	ON / <input type="checkbox"/> OFF	<input type="checkbox"/> OFF / ON / READY	ON / <input type="checkbox"/> OFF	<input type="checkbox"/> CLOSED / OPEN	etc. ...			
etc.	...									

The status display is shown in Fig. 5.5.

VACUUM SYSTEM STATUS										
PG	mbar	MODE	MP	DP	COOL	RV	BV	HVV	BLV	FV
1	3.9E-7	PUMP	ON	READY	ON	<input type="checkbox"/> CLOSED	OPEN	OPEN		OPEN
2	3.9E-7	PUMP	ON	READY	ON			OPEN		
SM	2.0E-6	PUMP	ON	READY	ON	<input type="checkbox"/> CLOSED	OPEN	OPEN	OPEN	
A1	etc.	...								
A2	...									
etc.										
...										

Figure 5.5: Vacuum system status display

5.5.8 Vacuum Pump Groups

There is a status display for each vacuum pump group: PG1, PG2, PGSWM, PGA1, PGA2, PGB1, PGB2, and PGC. The displays should resemble the pump group diagram shown in Fig. 5.6. In each display, the status of these components of are shown (not all components are present in all groups):

- Tank pressure (n.nE-n mbar)
- Vacuum gauge in use (Penning/Pirani)
- Beam line valves (BLV) that seal the tank; there may be one, two or three of these. For each valve: (CLOSED)/OPEN)
- High vacuum valve (HVV) (CLOSED)/OPEN)
- Roughing valve (RV) (CLOSED)/OPEN)
- Diffusion pump (DP) (ON/OFF)
- Diffusion pump heating status (Ready/Not Ready)
- Diffusion pump cooling water temperature (OK/NOT OK)
- Diffusion pump cooling water flow (OK/NOT OK)
- Backing pressure (Pirani gauge between DP and BV) (n.nE-n mbar)
- Backing valve (BV) (CLOSED)/OPEN)
- Mechanical pump (MP) (ON/OFF)

In addition, the state of the whole group is shown:

- Pump group state (OFF)/STANDBY/PUMP)
- Pump group errors (Timeout,Error)

If the pump group state is PUMP, then both DP and MP are ON. STANDBY is like PUMP, except the HVV is CLOSED instead of OPEN.

If TIMEOUT is the only pump group error, then the pump group state is STANDBY. If there are other errors, the state is OFF.

(Insert diagram of vacuum pump group)

Figure 5.6: Schematic diagram of a vacuum pump group.

5.5.9 Beam line to FC1

This display is largely devoted to the parameters for the X0 steerer, the Q1 quadrupoles, and the X/Y1 steerers:

- X0 STEERING MAGNET (X0 STMG)
- QUADRUPOLE 1, LENS 1 (Q1 LENS1)
- QUADRUPOLE 2, LENS 2 (Q2 LENS2)
- QUADRUPOLE 1, LENS 3 (Q1 LENS3)
- X1 STEERING MAGNET (X1 STMG)
- Y1 STEERING MAGNET (Y1 STMG)

A possible layout for these items is:

X0 STMG	ON/ <input type="checkbox"/> OFF	POLARITY -/+ Right/Left	PREAD -n.nn	PLOW -n.nn	PHIGH -n.nn	PSET -n.nn	A	Cooling, <input type="checkbox"/> Ground Short
Q1 LENS 1 etc. ...	"	-/+ Hor.Foc./ Vert.Foc.	-nn.n	-nn.n	-nn.n	-nn.n	"	"
... Y1 STMG	"	-/+ Up/Down	-n.nn	-n.nn	-n.nn	-n.nn	"	"

The steerer currents are displayed in -n.nn format but the quadrupole currents are in -nn.n format. For the X steerers, -/+ polarities correspond to Right/Left, for the Y steerers Up/Down, and for the quadrupole lenses Horizontal Focussing/Vertical Focussing. In the POLARITY column, the signs and meanings of the actual values (Up/Down etc.) are shown.

The status of Faraday Cup 1 is also shown:

Faraday Cup 1: OPEN/CLOSED Cooling: OK/NOT OK

Combining these elements, the complete display is shown in Fig. 5.7. This figure shows the display as it usually appears when the system is shut down overnight (apart from Ground Short, which indicates a fault).

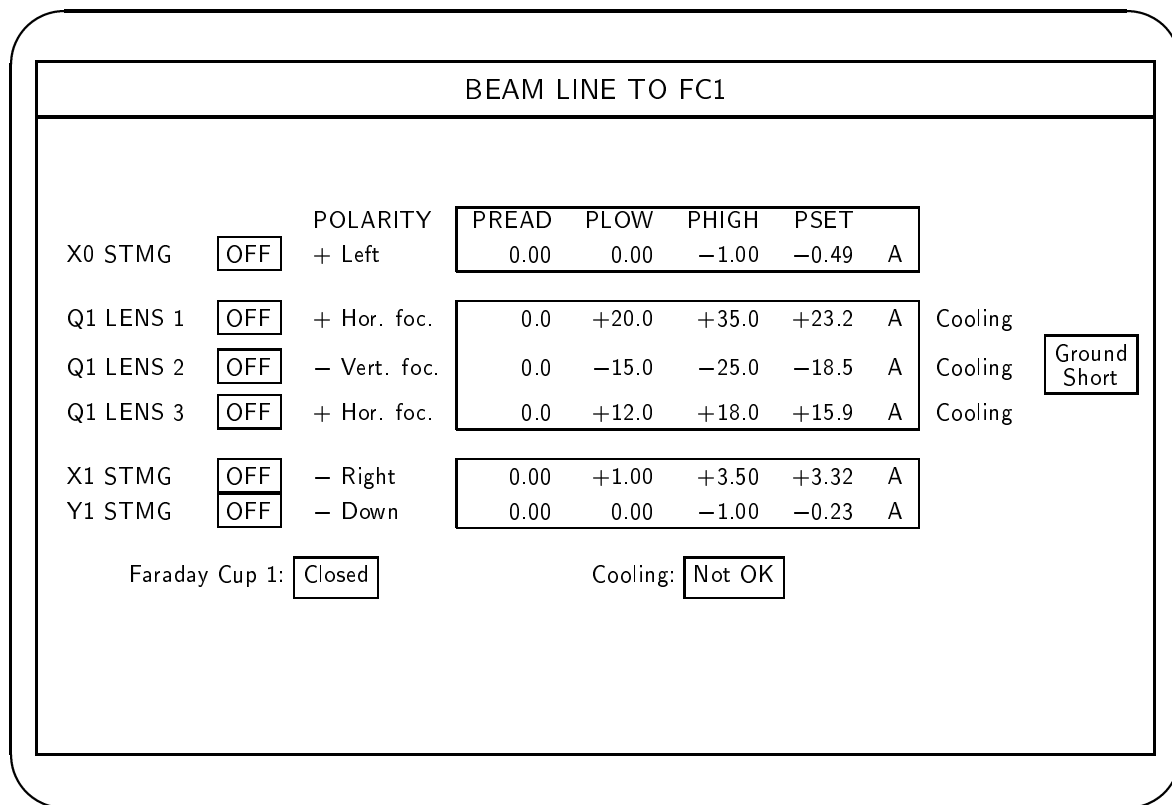


Figure 5.7: Beam line to FC1 status display

5.5.10 Beam line FC1 to target (line A)

The title bar contents are BEAM LINE A (Downstream FC1). This display resembles the Beam line to FC1 display (Section 5.5.9, Fig. 5.7); see Fig. 5.8. The columns are the same, but there are more parameters. Listed in order from top to bottom, they are:

- SWITCHING MAGNET (SWM)
- NMRFIELD
- QUADRUPOLE 2A, LENS 13 (Q2A LENS13)
- QUADRUPOLE 2A, LENS 2 (Q2A LENS2)
- X2A STEERING MAGNET (X2A STMG)
- Y2A STEERING MAGNET (Y2A STMG)
- QUADRUPOLE 3A, LENS 13 (Q3A LENS13)
- QUADRUPOLE 3A, LENS 2 (Q3A LENS2)
- X3A STEERING MAGNET (X3A STMG)
- Y3A STEERING MAGNET (Y3A STMG)
- GANTRY DIPOLE (GTYPDOL)
- GANTRY CORRECTION (GTYCORR)
- GANTRY QUADRUPOLE, LENS 1 (QG LENS1)
- GANTRY QUADRUPOLE, LENS 2 (QG LENS2)
- GANTRY QUADRUPOLE, LENS 3 (QG LENS3)
- GANTRY X STEERING MAGNET (XG STMG)
- GANTRY Y STEERING MAGNET (YG STMG)
- GANTRY X WOBLER (XG WOB)
- GANTRY Y WOBLER (YG WOB)

Every parameter has modes ON/OFF. The contents of the other columns differ, as follows:

As in the Beam Line to FC1 display, the beam line steerer currents X2A STMG, Y2A STMG, X3A STMG and Y3A STMG are displayed in -n.nn format; and the quadrupole currents are in -nn.n format. For the X steerers, the -/+ polarities correspond to Right/Left, for the Y steerers Up/Down, and for the quadrupole lenses Hor.Foc./Vert.Foc.. The interlocks for the quadrupoles are Cooling, Ground short, and for the X/Y2 and X/Y3 steerers, Magnet temperature, Ground short.

The gantry steerers XG STMG and YG STMG, and the gantry wobblers XG WOB and YG WOB form another group. Their currents are displayed in -nn.n format. The interlocks are Magn.Temp, PS cool., Ground short.

The switching magnet SWM and the gantry dipole GTYDPOL form a third group. Their currents are shown in nn.n format, except for the SWM PREAD only, which is in -nn.nn format. SWM only has polarity. There are modes Remote/Local. The interlocks are Pwr.fail., PS.cool, Magn.cool, Overload, Trst.fail. Each of these parameters is followed by a line captioned C.P., which indicates that the 24 volt control power is on (Fig. 5.8). In both cases, this line includes the modes ON/OFF; the line after SWM also includes the modes Left/Right.

The gantry correction coils GTYCORR form the last group. Its current values are shown in -nn.n format, the polarities are Up/Down, and the interlocks are Cooling, Ground short.

This display also may show the parameter NMRFIELD, in the analog columns of the row following the SWM entry (Fig. 5.8). Only the PSET for this parameter is shown, in nn.nnn format, in units of kG (kilogauss). If the NMR is not being used to regulate the SWM field, no PSET value appears.

Also shown are the status of Faraday Cups 2A and 3A, and beam plug A.

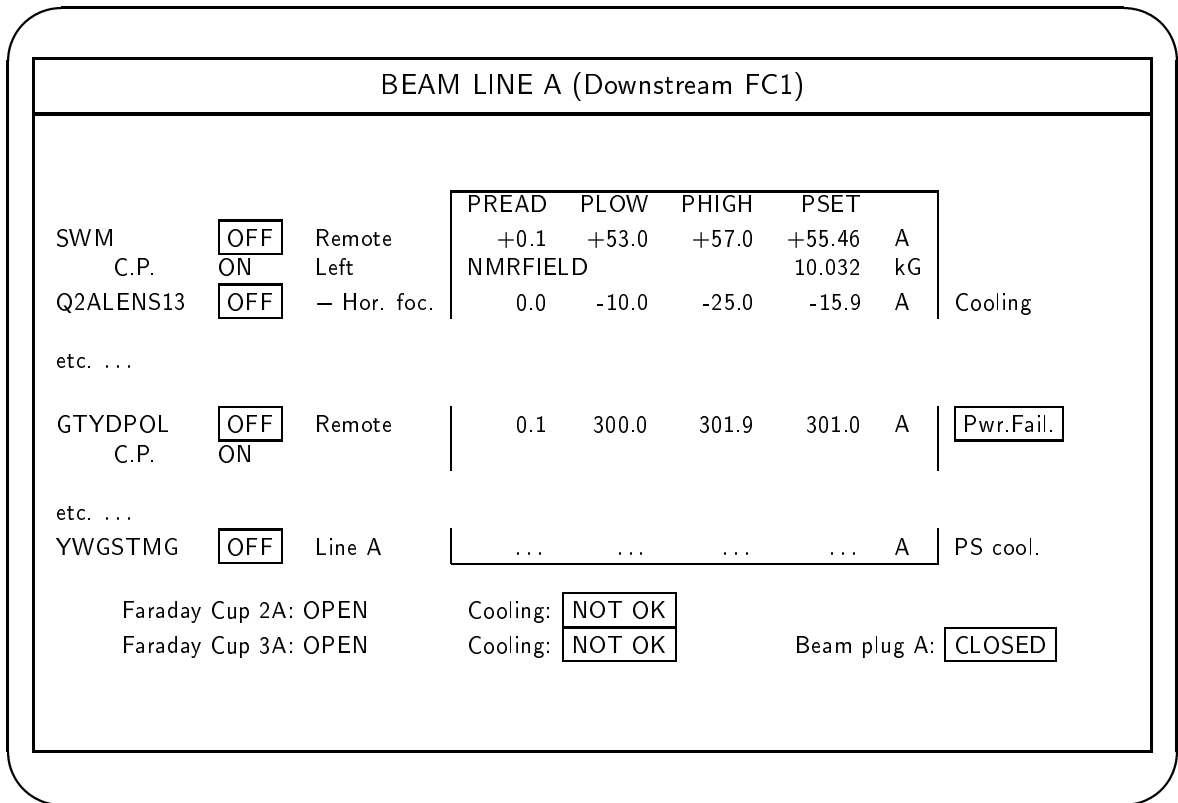


Figure 5.8: Beam line FC1 to target (line A) status display

5.5.11 Beam line FC1 to target (line B)

This display is very similar to the display for line A described in the preceding section. The title bar contents are BEAM LINE B (Downstream FC1). These parameters are shown:

- SWITCHING MAGNET (SWM)
- NMRFIELD
- QUADRUPOLE 2B, LENS 13 (Q2B LENS13)
- QUADRUPOLE 2B, LENS 2 (Q2B LENS2)
- QUADRUPOLE 3B, LENS 13 (Q3B LENS13)
- QUADRUPOLE 3B, LENS 2 (Q3B LENS2)
- FIXED BEAM X STEERING MAGNET (XF STMG)
- FIXED BEAM Y STEERING MAGNET (YF STMG)
- FIXED BEAM X WOBBLER (XF WOB)
- FIXED BEAM Y WOBBLER (YF WOB)
- BENDING MAGNET (BEND)

The line for BEND has the same columns as the row for SWM. Both the SWM and BEND rows are followed by the C.P. (Control Power) line. In both cases, this line includes the modes ON/OFF; the line after SWM also includes the modes Left/Right.

In this display, there is provision for displaying the NMRFIELD PSET for SWM. If the NMR is being used to regulate the SWM field, the NMRFIELD PSET value appears by that parameter.

The status of Faraday Cup 2B and Beam Plug B are also shown.

5.5.12 Beam line FC1 to target (line C)

This display is very similar to the displays for the other two beam lines. The title bar is BEAM LINE C (Downstream FC1). The only parameters shown are:

- SWM
- BEND
- NMRFIELD

These parameters are displayed just as they are on the line B display.

The status of Faraday Cup 2C and the Target Interlock (OK/Not OK) are also shown.

5.5.13 Cooling system

This display should resemble the cooling system diagram shown in Fig. 5.9. The display shows these items:

- Cooling tower fan (On/Off)
- Cooling tower spray pump (On/Off)
- Flow in secondary loop (OK/Not OK)
- Flow in primary loop (OK/Not OK)
- Flow in 24 hour loop (OK/Not OK)
- Flow in chiller loop (OK/Not OK)
- Chiller operation (OK/Not OK)
- Primary loop supply temperature (nn.n deg C)
- Secondary loop supply temperature (nn.n deg C)
- 24-hour loop supply temperature (nn.n deg C)

5.5.14 Safety sytem, vault, line A

This display shows the safety status of the equipment inside the cyclotron vault that is needed to deliver beam to line A. Some features of this display are common to all safety displays.

(Insert diagram of cooling system)

Figure 5.9: Cooling system

On the display, the safety logic is represented by a series of connected line segments that begin at a single source at the top of the display and converge on a single node at the bottom. Each line segment contains several labelled indicators that show the state of particular interlocks. Interlocks that are *clear* are displayed differently from interlocks that are *set*.

An interlock is *clear* if the associated equipment is in the proper, safe condition to allow the beam to run in the equipment indicated by the display banner (in this case, the cyclotron and portions of beam line A inside the cyclotron vault). An interlock is *set* if the equipment is not in the proper condition to run the beam. If an interlock is clear, its indicator on the status display is shown as a thick continuous portion in the line segment, and its text label indicates the clear condition. If an interlock is set, the status display usually shows a break in the line segment, and the accompanying text describes the condition that causes the interlock to be set. The graphics and text are both displayed with different attributes when the interlock is set.

For example, in the segment from the safety display shown in Figure 5.10, beam plug A is closed (the interlock is clear), but plug B is open (the interlock is set). In order to turn on the beam, plug B must be closed as well.

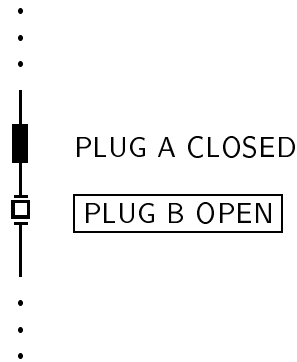


Figure 5.10: Detail from safety system status display

If there is a continuous trace from the source at the top of the status display to node at the bottom, it means that all the interlocks pertinent to an operating mode are clear. This typically means that the beam can be turned on, and if it is on it will remain on. If interlocks are set, the status display will show breaks in the trace between the source and the node. If all traces between the source and node are broken by set interlocks, then the beam cannot

htbp

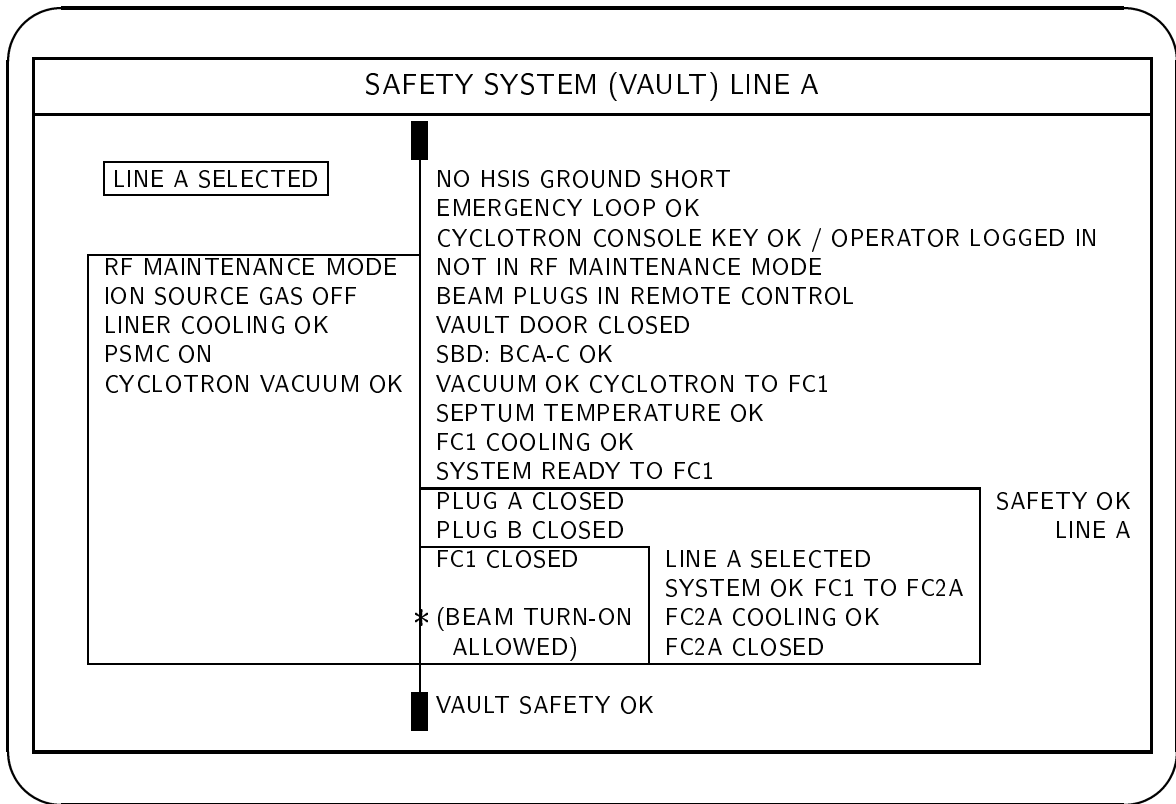
	Interlock clear.
–	Interlock set.
?	Interlock set, sensors inconsistent
#	Interlock set. Beam turn-on not allowed, but beam remains on if already on when set.
*	Interlock clear. Beam turn-on allowed.
■	Site (vault, line A, or line B)

Table 5.3: Safety display symbols

be on in the region indicated on the display. If the beam was on when an interlock in a relevant portion of the trace becomes set, it will turn off.

In addition to the set and clear indicators shown in Figure 5.10, some interlocks have states that are indicated by a few special symbols, shown in table 5.3. In particular, for safety reasons the conditions for turning on the beam are more restrictive than the conditions for the beam remaining on: the beam can only be turned on when both beam plugs are closed and Faraday cup 1 is also closed. Also an operator must be logged in and the main enable key must be turned on. This condition is indicated by * (BEAM TURN-ON ALLOWED). Once the beam is on, the plugs may be opened and the cup pulled out. If the operator logs out or the console key is turned off when the beam is on, the beam remains on, but if it turns off for any reason it cannot be turned on. This kind of condition is indicated by # (for example, # OPERATOR NOT LOGGED IN).

Figure 5.11 shows the safety display for the line A equipment in the vault. This figure shows the text for each interlock as it appears when that interlock is clear. (It is never possible to have all interlocks clear at the same time because some are mutually exclusive, e.g. RF MAINTENANCE MODE and NOT IN RF MAINTENANCE MODE.) When an interlock is set, the accompanying text is different. Some items on the display actually indicate the sum of several interlocks. There can be different labelling texts, depending on which of the interlocks is set. Tables 5.4 through 5.7 show the texts for all interlock states.



- The text changes as the status changes. This figure shows the text for each interlock as it appears when the interlock is clear (it is not possible for all interlocks to be clear at the same time). For other texts, see the tables in this section.
- This figure shows the display as it appears when the A line is selected. When a safety display is selected (via the keypad) which does not correspond to the current line selection, the line selection indicator in the upper left corner is depicted using different display attributes.
- For safety reasons the beam (RF) can only be turned on when both beam plugs are closed and Faraday cup 1 is also closed. This condition is indicated by * (BEAM TURN-ON ALLOWED). Once the beam is on, the plugs may be opened and the cup pulled out.
- When the line selection is changed (via the hardwired push-buttons), this safety display automatically changes to the safety display for the newly selected line.

Figure 5.11: Safety system (vault) line A

Figure 5.11 shows the display as it appears when the A line is selected. When a safety display is selected (at the terminal) which does not correspond to the current line selection, the line selection indicator in the upper left corner is depicted using different display attributes.

When the line selection is changed (via the hardwired push-buttons), this safety display automatically changes to the safety display for the newly selected line.

INTERLOCK CLEAR	INTERLOCK SET
NO HSIS GROUND SHORT	– HSIS GROUND SHORT
EMERGENCY LOOP OK	– EMERGENCY-OFF PUSHED IN THERAPY LOOP
CYCLOTRON CONSOLE KEY OK / OPERATOR LOGGED IN	– CYCLOTRON CONSOLE KEY NOT OK / OPERATOR NOT LOGGED IN # CYCLOTRON CONSOLE KEY OK / OPERATOR NOT LOGGED IN # CYCLOTRON CONSOLE KEY NOT OK OPERATOR LOGGED IN
RF MAINTENANCE MODE	– NOT IN RF MAINTENANCE MODE ? INCONSISTENT RF MODE
ION SOURCE GAS OFF	– N=1 GAS VALVE OPEN – N=2 GAS VALVE OPEN – BOTH GAS VALVES OPEN
LINER COOLING OK	– LINER COOLING NOT OK
PSMC ON	– PSMC NOT ON
CYCLOTRON VACUUM OK	– CYCLOTRON VACUUM NOT OK
NOT IN RF MAINTENANCE MODE	– RF MAINTENANCE MODE ? INCONSISTENT RF MODE
BEAM PLUGS IN REMOTE CONTROL	– BEAM PLUGS NOT IN REMOTE – BEAM PLUG A NOT IN REMOTE – BEAM PLUG B NOT IN REMOTE
VAULT DOOR CLOSED	– VAULT DOOR OPEN
SBD: BCA-C OK	– BCA-C TRIPPED ON SBD-1 (or SBD-2, SBD-3, ...)
VACUUM OK CYCLOTRON TO FC1	– VACUUM NOT OK CYCLOTRON TO FC1 – VACUUM NOT OK: COOLING WATER OVERTEMP – CYCLOTRON VACUUM NOT OK – SWM VACUUM NOT OK – BEAM EXIT VALVE CLOSED – BEAM EXIT VALVE IN TRANSITION – FAST VALVE CLOSED – FAST VALVE IN TRANSITION – BEV AND FAST VALVE CLOSED ? VACUUM INCONSISTENCY

Table 5.4: Safety display text: basic cyclotron safety (1)

INTERLOCK CLEAR	INTERLOCK SET
SEPTUM TEMPERATURE OK	– SEPTUM TEMPERATURE LIMIT EXCEEDED
FC1 COOLING OK	– FC1 WATER FLOW INSUFFICIENT
SYSTEM READY TO FC1	<ul style="list-style-type: none"> – SYSTEM NOT READY TO FC1 – MAIN PROBE WATER FLOW INSUFFICIENT – DEFLECTOR PROBE FLOW INSUFFICIENT – DEFLECTOR WATER FLOW INSUFFICIENT – DEFLECTOR SAFETY COVER REMOVED – HSIS INCONSISTENCY – MAGNET SYSTEM NOT READY – RF SYSTEM NOT READY – ION SOURCE SYSTEM NOT READY – EXTRACTION SYSTEM NOT READY – BEAMLINE MAGNETS TO FC1 NOT OK – POWER SUPPLY FAULT (if more than one) – PSHV LOW – (etc. . . . various power supply faults)

Table 5.5: Safety display text: basic cyclotron safety (2)

INTERLOCK CLEAR	INTERLOCK SET
PLUG A CLOSED	<ul style="list-style-type: none"> – PLUG A OPEN – PLUG A IN TRANSITION ? PLUG A INCONSISTENCY
PLUG B CLOSED	<ul style="list-style-type: none"> – PLUG B OPEN – PLUG B IN TRANSITION ? PLUG B INCONSISTENCY
FC1 CLOSED	<ul style="list-style-type: none"> – FC1 OPEN – FC1 IN TRANSITION ? FC1 INCONSISTENCY
* BEAM TURN-ON ALLOWED	BEAM TURN-ON NOT ALLOWED
SYSTEM OK FC1 TO FC2A	<ul style="list-style-type: none"> – SYSTEM NOT READY FC1 TO FC2A – A1 VACUUM NOT OK – BLV A1 CLOSED – BLV A1 IN TRANSITION ? VACUUM INCONSISTENCY FC1 TO FC2A – SWITCHING MAGNET OFF – SWM PREAD OUTSIDE WINDOW – SWITCHING MAGNET WRONG POLARITY – SWM VACUUM NOT OK
FC2A COOLING OK	– FC2A WATER FLOW INSUFFICIENT
FC2A CLOSED	<ul style="list-style-type: none"> – FC2A OPEN – FC2A IN TRANSITION ? FC2A INCONSISTENCY
SAFETY OK LINE A	– SAFETY LINE A NOT OK
█ VAULT SAFETY OK	█ VAULT SAFETY NOT OK
SYSTEM OK FC1 TO FC2B	<ul style="list-style-type: none"> – SWM VACUUM NOT OK – B1 VACUUM NOT OK – BLV B1 CLOSED ? VACUUM INCONSISTENCY FC1 TO FC2B – SWITCHING MAGNET OFF – SWM PREAD OUTSIDE WINDOW – SWITCHING MAGNET WRONG POLARITY – BENDING MAGNET OFF – BENDMAG PREAD OUTSIDE WINDOW – SYSTEM NOT READY FC1 TO FC2B

Table 5.6: Safety display text: vault (1)

INTERLOCK CLEAR	INTERLOCK SET
FC2B COOLING OK	– FC2B WATER FLOW INSUFFICIENT
FC2B CLOSED	– FC2B OPEN – FC2B IN TRANSITION ? FC2B INCONSISTENCY
SAFETY OK LINE B	– SAFETY LINE B NOT OK
SYSTEM READY FC1 TO FC2C	– SYSTEM NOT READY FC1 TO FC2C – SWM VACUUM NOT OK – C1 VACUUM NOT OK – BLV C1 CLOSED – BLV A1 NOT CLOSED – BLV B1 NOT CLOSED ? VACUUM INCONSISTENCY FC1 TO FC2C – SWITCHING MAGNET OFF – SWM PREAD OUTSIDE WINDOW – SWITCHING MAGNET WRONG POLARITY – BENDMAG OFF – BENDMAG PREAD OUTSIDE WINDOW
FC2C COOLING OK	– FC2C WATER FLOW INSUFFICIENT
FC2C CLOSED	– FC2C OPEN – FC2C IN TRANSITION ? FC2C INCONSISTENCY
TARGET C AND HOT LAB READY	– TARGET C AND/OR HOT LAB NOT READY
SWITCHING MAGNET READY	– SWITCHING MAGNET NOT READY
VACUUM READY 0 DEG. LINE	– 0 DEG. LINE VACUUM NOT READY
0 DEG. TARGET READY	– 0 DEG. TARGET NOT READY

Table 5.7: Safety display text: vault (2)

5.5.15 Safety system, vault, line B

Fig. 5.12 shows the safety status of the equipment inside the cyclotron vault that is needed to deliver beam to line B. Complete texts for this display appear in tables 5.4 through 5.7.

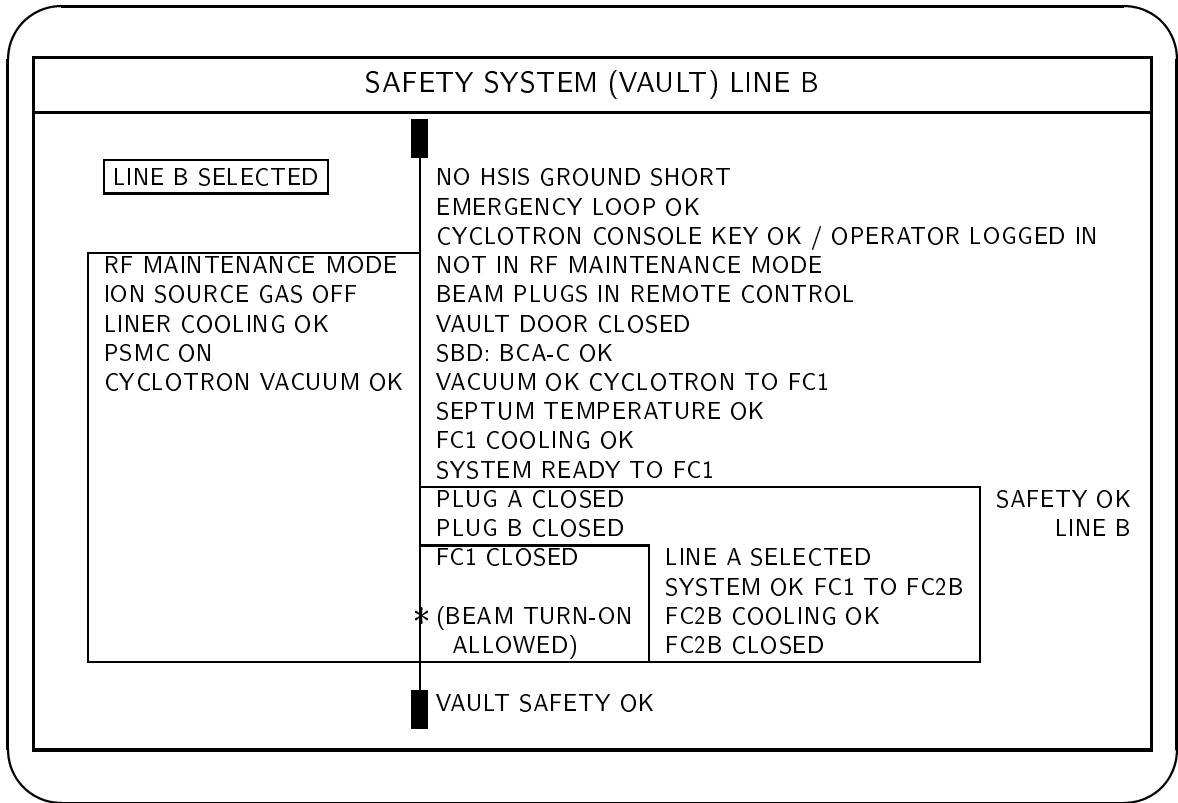


Figure 5.12: Safety system (vault), line B

5.5.16 Safety system, vault, line C

Fig. 5.13 shows the safety status of the equipment inside the cyclotron vault that is needed to deliver beam to line C. Complete texts for this display appear in tables 5.4 through 5.7.

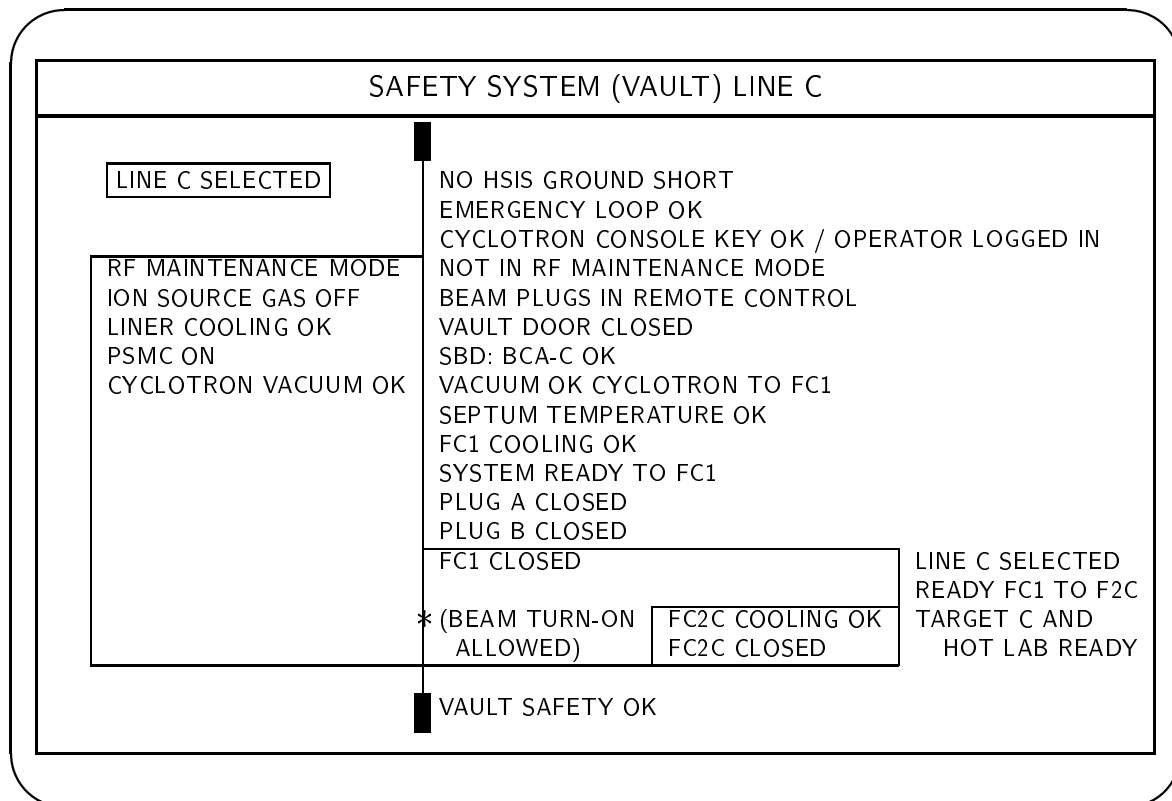


Figure 5.13: Safety system (vault), line C

5.5.17 Safety system, vault, no line selected

Fig. 5.14 shows the safety status of the equipment inside the cyclotron vault that is needed to run beam when no line is selected (e.g., for tuning on FC1). Complete texts for this display appear in tables 5.4 through 5.7.

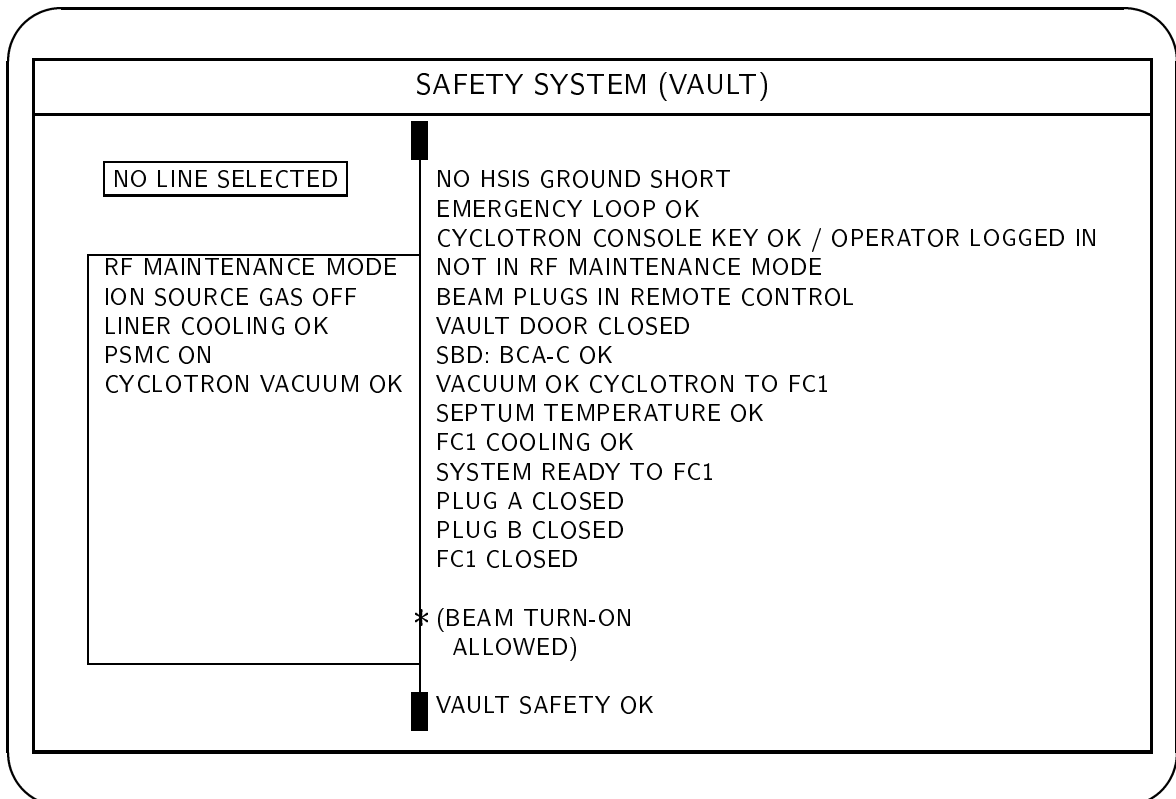


Figure 5.14: Safety system (vault), no line selected

5.5.18 Safety system, vault, zero degree line

Fig. 5.15 shows the safety status of the equipment inside the cyclotron vault that is needed to deliver beam to the zero degree line. (this line is currently not installed). Complete texts for this display appear in tables 5.4 through 5.7.

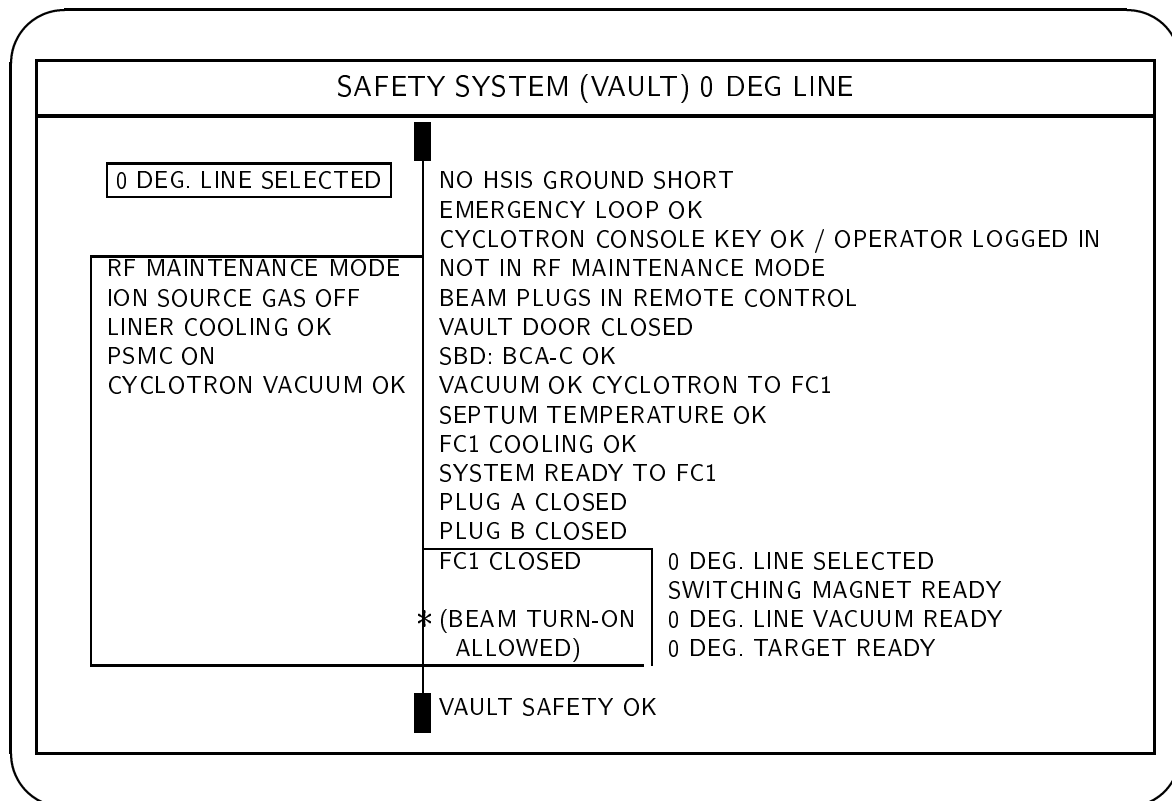
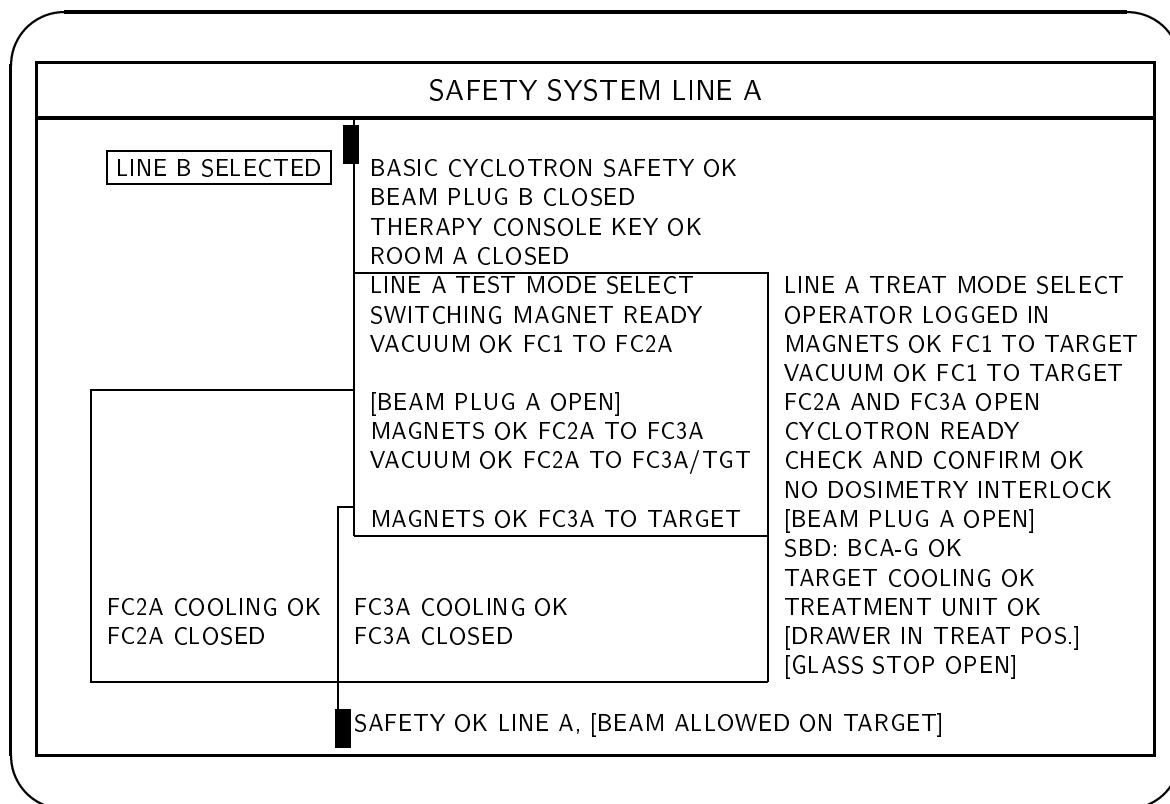


Figure 5.15: Safety system (vault), zero degree line

5.5.19 Safety system, line A

Fig. 5.16 shows the safety status of the equipment needed to deliver beam to the A line. Complete texts for this display appear in tables 5.8 through 5.10.

In the figure, interlocks enclosed in brackets (e.g., [BEAM PLUG A OPEN]) are not included in the SAFETY OK hardwired trace, they only affect BEAM (NOT) ALLOWED ON TARGET (OR FC3A). In other words, the beam may be turned on when the bracketed interlocks are set, but the the Faraday cups may only be opened to allow the beam to reach the target when the bracketed interlocks are clear.



Safety status display for the equipment needed to deliver beam to the A line.

- The text changes as the status changes. This figure shows the text for each interlock as it appears when the interlock is clear (it is not possible for all interlocks to be clear at the same time). For other texts, see the tables in this section.
- When line A is selected, no text appears in the upper left corner (the banner already indicates line A). Besides LINE B SELECTED, this display might also show NO LINE SELECTED, LINE C SELECTED, or 0 DEG. LINE SELECTED.
- Interlocks enclosed in brackets (e.g., [BEAM PLUG A OPEN]) are not included in the SAFETY OK hardwired trace, they only affect BEAM (NOT) ALLOWED ON TARGET (OR FC3A). In other words, the beam may be turned on when the bracketed interlocks are set, but the the Faraday cups may only be opened to allow the beam to reach the target when the bracketed interlocks are clear.

Figure 5.16: Safety system, line A

INTERLOCK CLEAR	INTERLOCK SET
BASIC CYCLOTRON SAFETY OK	– BASIC CYCLOTRON SAFETY NOT OK
BEAM PLUG B CLOSED	– BEAM PLUG B OPEN – BEAM PLUG B IN TRANSITION ? BEAM PLUG B INCONSISTENCY
THERAPY CONSOLE KEY OK	– THERAPY CONSOLE KEY NOT OK
ROOM A CLOSED	– ROOM A NOT CLOSED
LINE A TEST MODE SELECTED	– LINE A TREAT MODE SELECTED – LINE B TEST MODE SELECTED – LINE B TREAT MODE SELECTED – NO LINE SELECTED – C LINE SELECTED – 0 DEG. LINE SELECTED
SWITCHING MAGNET READY	– SWITCHING MAGNET OFF – SWM MAGNET PREAD OUTSIDE WINDOW – SWITCHING MAGNET WRONG POLARITY
VACUUM OK FC1 TO FC2A	– SWM VACUUM NOT OK – A1 VACUUM NOT OK – BLV A1 CLOSED – BLV A1 IN TRANSITION ? VACUUM INCONSISTENCY FC1 TO FC2A
FC2A COOLING OK	– FC2A WATER FLOW INSUFFICIENT
FC2A CLOSED	– FC2A OPEN – FC2A IN TRANSITION ? FC2A INCONSISTENCY
[BEAM PLUG A OPEN]	– [BEAM PLUG A CLOSED] – [BEAM PLUG A IN TRANSITION] ? [BEAM PLUG A INCONSISTENCY]
MAGNETS OK FC2A TO FC3A	– MAGNETS NOT READY FC2A TO FC3A
VACUUM OK FC2A TO FC3A/TGT	– A1 VACUUM NOT OK – A2 VACUUM NOT OK – BLV A2 CLOSED – BLV A2 IN TRANSITION ? VACUUM INCONSISTENCY FC2A TO FC3A

Table 5.8: Safety display text: line A (1)

INTERLOCK CLEAR	INTERLOCK SET
MAGNETS OK FC3A TO TARGET	– MAGNETS NOT READY FC3A TO TARGET
FC3A COOLING OK	– FC3A WATER FLOW INSUFFICIENT
FC3A CLOSED	– FC3A OPEN – FC3A IN TRANSITION ? FC3A INCONSISTENCY
LINE A TREAT MODE SELECTED	– LINE A TEST MODE SELECTED – LINE B TEST MODE SELECTED – LINE B TREAT MODE SELECTED – NO LINE SELECTED – C LINE SELECTED – 0 DEG. LINE SELECTED
OPERATOR LOGGED IN	– OPERATOR NOT LOGGED IN
MAGNETS OK FC1 TO TARGET	– MAGNETS NOT READY FC1 TO TARGET
VACUUM OK FC1 TO TARGET	– SWM VACUUM NOT OK – A1 VACUUM NOT OK – A2 VACUUM NOT OK – BLV A1 CLOSED – BLV A1 IN TRANSITION – BLV A2 CLOSED – BLV A2 IN TRANSITION ? VACUUM INCONSISTENCY FC1 TO TARGET – VACUUM NOT READY FC1 TO TARGET
FC2A AND FC3A OPEN	– FC2A AND FC3A CLOSED – FC2A CLOSED – FC2A IN TRANSITION ? FC2A INCONSISTENCY – FC3A CLOSED – FC3A IN TRANSITION ? FC3A INCONSISTENCY ? FC2A + FC3A INCONSISTENCY
CYCLOTRON READY	– CYCLOTRON NOT READY

Table 5.9: Safety display text: line A (2)

5.5.20 Safety system, line B

Fig. 5.17 shows the safety status of the equipment needed to deliver beam to the B line. Complete texts for this display are almost the same as appear in tables 5.8 through 5.10, except all the A's should be replaced by B's, and vice-versa.

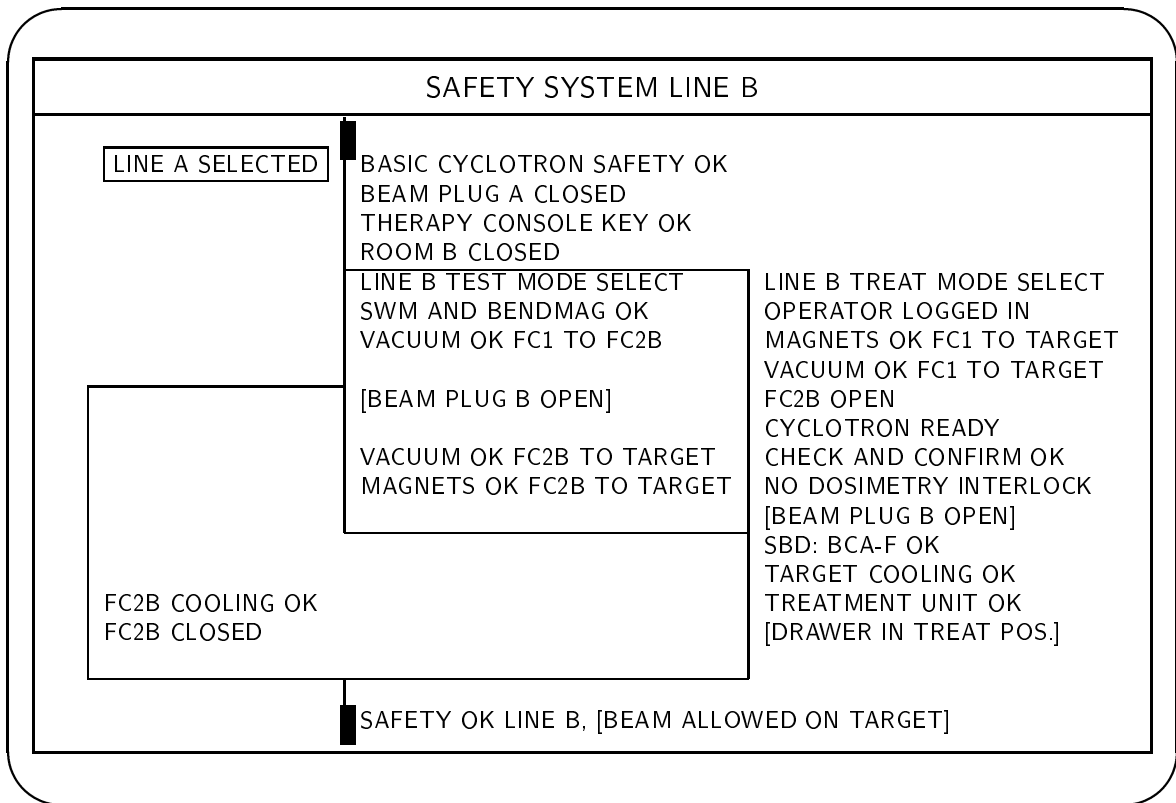


Figure 5.17: Safety system, line B

INTERLOCK CLEAR	INTERLOCK SET
CHECK AND CONFIRM OK	– CHECK AND CONFIRM NOT OK
NO DOSIMETRY INTERLOCK	– DOSIMETRY CHANNEL 1 INTERLOCK – DOSIMETRY CHANNEL 2 INTERLOCK – DOSIMETRY INTERLOCK
[BEAM PLUG A OPEN]	– [BEAM PLUG A CLOSED] – [BEAM PLUG A IN TRANSITION] ? [BEAM PLUG A INCONSISTENCY]
SBD: BCA-G OK	– BCA-G TRIPPED ON TARGET, UP, DOWN, LEFT,...
TARGET COOLING OK	– INSUFFICIENT TARGET FLOW – INSUFFICIENT QUADRANT FLOW – INSUFFICIENT TARGET AND QUADRANT FLOW
TREATMENT UNIT OK	– MOBILE PEDESTAL ENABLED – GANTRY MOTION ENABLED – COLLIMATOR ROTATION ENABLED – COUCH HEIGHT ENABLED – COUCH LATERAL ENABLED – FLATTENING FILTER SELECTION ENABLED – WEDGE ORIENTATION ENABLED – LEFT FLOOR ENABLED – LEFT BEAM ENABLED – NOT ALL MOTIONS DISABLED
[DRAWER IN TREAT POSITION]	– DRAWER IN SAFE – DRAWER IN X-RAY – DRAWER IN TRANSITION ? DRAWER INCONSISTENCY
[GLASS STOP OPEN]	– GLASS STOP CLOSED – GLASS STOP IN TRANSITION ? GLASS STOP INCONSISTENCY
■ SAFETY OK LINE A	■ SAFETY LINE A NOT OK
[BEAM ALLOWED ON TARGET]	[BEAM ALLOWED ON FC2A] [BEAM ALLOWED ON FC3A] [BEAM NOT ALLOWED ON TARGET]

Table 5.10: Safety display text: line A (3)

5.5.21 Therapy room status (Isocentric and Fixed)

There is a display for each treatment room that shows these dosimetry items, in the formats shown:

- Preset dose (nnn.n MU)
- Dose A (nnn.n MU)
- Dose B (nnn.n MU)
- Preset time (nn.nn minutes)
- Time elapsed (nn.nn minutes)
- Target current (uA)
- Target charge (uA × min.)
- Dose rate (nnn.n MU per min.)
- Dose rate of the day (nnn.n MU per min.)

It also shows these mechanical setups:

- Gantry angle (isocentric room only) (nnn.n deg)
- Collimator angle (nnn.n deg)
- Wedge type (None/30 deg/45 deg/60 deg/In Transition)
- Wedge rotation angle (0 deg/90 deg/180 deg/270 deg/In Transition)
- Flattening filter (None/Large Field/Small field/In Transition)

Chapter 6

Therapy control console

This chapter describes the therapy control consoles, also called the *therapy control desks* (TCD). There are two identical consoles, one for each treatment room. Each console (Fig. 6.1) houses several panels, each holding a functionally related set of controls and indicators. Each console also houses a terminal, the Treatment Operations Terminal. The operations performed at this terminal are described in chapter 8.

The following sections describe each of the controls and indicators on the following panels, which are shown in Fig. 6.1.

- Treatment control
- Dose monitoring

Other panels shown in Fig. 6.1 are not described; their functions are not considered part of the control system.

Subsequent sections describe how the controls on these panels are used together to perform treatments.

6.1 Treatment control

The treatment control panel is shown in Fig. 6.2 (the right side of this panel does not house any control system elements, so it is not pictured).

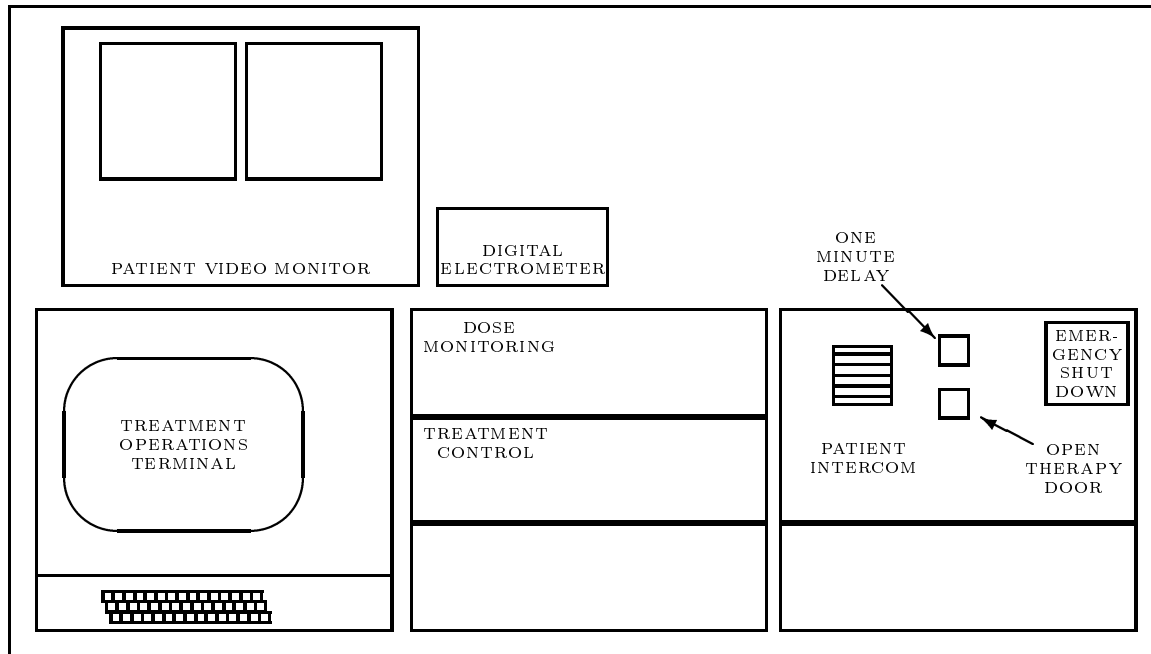


Figure 6.1: Therapy control console

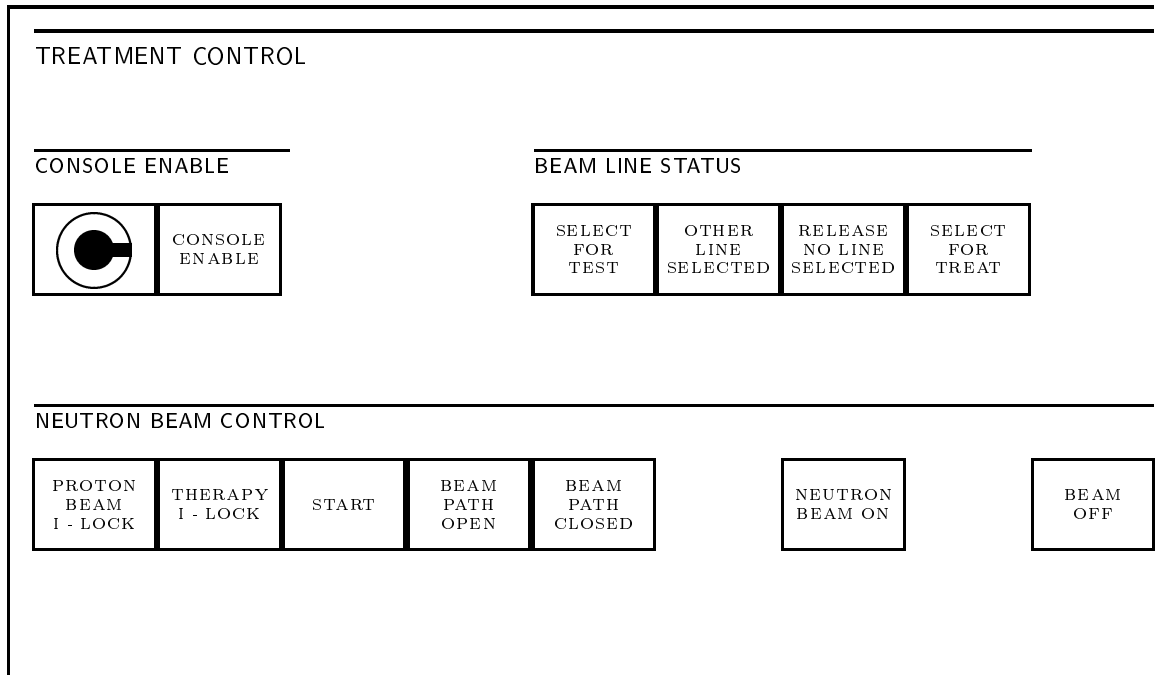


Figure 6.2: Treatment control

6.1.1 Keyswitch

When the keyswitch is turned off, most functions on the treatment control panel are disabled. This provides some security: operators can prevent some tampering with the controls by taking the key along if they have to leave the control room.

If the line is selected when the keyswitch is turned off, the line is released. It does not automatically become selected again when the keyswitch is turned back on; it is necessary to select it again (possibly after waiting for it to be released by another operator).

If the beam is on target when the keyswitch is turned off, the beam turns off. It does not automatically come back on when the keyswitch is turned back on; it is necessary to go through the usual sequence to turn the beam on again.

The console enable lamp is on when the keyswitch is turned on.

Controls disabled by the keyswitch

These are the console controls which are *disabled* when the keyswitch is off:

- SELECT FOR TEST
- SELECT FOR TREAT
- START

In addition, turning off the keyswitch disables the button on the cyclotron control console that selects the line associated with that console for treatment.

The beam is turned off and the line is released when the keyswitch is turned off, so pressing the BEAM OFF or RELEASE LINE buttons when the keyswitch is off has no further effect.

Interactions with treatment operations terminal

Turning off the keyswitch disables almost all operations provided at the treatment operations terminal, including LOGIN and LOGOUT.

KEYSWITCH	OPERATOR	FUNCTIONALITY
No key	No operator logged in	Beam on target not possible; turns off if previously on Most treatment console controls disabled Operations terminal mostly disabled Line selection not possible
No key	Operator logged in	Beam on target not possible; turns off if previously on Most treatment console controls disabled Operations terminal mostly disabled LOGOUT at operations terminal disabled Line selection not possible
Key	No operator logged in	Beam on target possible in TEST mode only Line selection enabled START at treatment console disabled Operations terminal mostly disabled; LOGIN enabled Between operator change Tuning to target in therapy head from cyclotron console
Key	Operator logged in	Full functionality

Table 6.1: Effect of keyswitch and operator login on treatment console

The LOGIN and LOGOUT operations at the operations terminal have a similar effect on the START button as turning the console keyswitch on and off. However, line selection and release remain enabled even when the therapy console operator is logged out. Table 6.1 summarizes the effects of the treatment console keyswitch and operator login/logout.

Note that No Key/Operator logged in is *not* the same as Key/No Operator logged in. In the Key/No Operator condition, the line may be selected for TREAT or TEST mode. In TEST mode, the beam may be turned on at the cyclotron console and run to the target in the treatment room even if no treatment console operator is present, as long as the treatment console key is available.

LOGOUT is disabled when the keyswitch is off, so the keyswitch must remain on to enable operators to change. Operator changes can occur during regular therapy operations: the

first operator logs out and then the second operator logs in.

When no operator is logged in, the THERAPY I-LOCK lamp on the console is on. The START button is disabled.

Interactions between the keyswitch and the therapy operations terminal are described in more detail in chapter 8.

6.1.2 Beam line status

The beam line controlled from each treatment console has two modes, test mode and treat mode. In *TEST mode*, the beam can only be turned on in the treatment room from the cyclotron console, and in this mode the beam may remain on target indefinitely. This is the mode usually used by the cyclotron operator for tuning the beam and is also used for some experimental runs. The beam cannot be turned on in the treatment room from the treatment console in TEST mode.

TREAT mode is used for treating patients. In treat mode, the beam can only be turned on in the treatment room from the therapy console. In this mode additional safety conditions must be satisfied before the beam can reach the target. In particular, a *check and confirm* facility checks that the treatment room equipment is set up to conform to a treatment prescription, and a *dosimetry system* automatically turns off the beam when the prescribed dose is delivered. Treat mode is also used during certain operational checks such as the daily performance check of the dosimetry systems or for experimental runs which involve the dosimetry system. In TREAT mode, the beam cannot be turned on in the treatment room from the cyclotron console.

The Beam Line Status section on the Treatment Control panel houses three momentary pushbuttons and four lamps. They are used to select (and indicate) the beam line and mode:

- SELECT FOR TEST
- OTHER LINE SELECTED
- RELEASE — NO LINE SELECTED
- SELECT FOR TREAT

OTHER LINE SELECTED is an indicator only. The other three units are both momentary pushbuttons and indicators.

The buttons are enabled when the console enable keyswitch is turned on, even if no operator is logged in at the therapy console. This makes it possible for the cyclotron operator to select the line into a treatment room in test mode if no therapy operator is present. The cyclotron operator must come to the therapy console to do this; there are no TEST MODE SELECT buttons on the cyclotron operator's console. Test mode must never be selected when there is a patient in the treatment room.

Line select buttons

Pressing SELECT FOR TEST or SELECT FOR TREAT selects the line into the treatment room in test or treat mode, respectively. If the line selection can be performed, the lamp under the button turns on immediately. After that, no other operator can select the line until the RELEASE button is pressed at this console or at the cyclotron control console.

After one of the line selection buttons is pressed, there may be a delay of twenty seconds or more before the line is ready to accept the beam. (During this interval, power supplies may be turning on and ramping up, beamline valves may be opening or closing, etc.). During this interval, the PROTON BEAM I-LOCK lamp is on.

The two line select buttons only work when the NO LINE SELECTED lamp is on. It is only possible to select the line when no other line is selected. Moreover, it is not possible to change between treat and test modes without first releasing the line. The only way to obtain the line in a particular mode is to select it in that mode from NO LINE SELECTED.

Release button

The operator de-selects or *releases* the line by pressing the RELEASE button. This releases the line, allowing it to be reselected in a different mode, or allowing another operator to select a different beam line. When RELEASE is pressed, the NO LINE SELECTED lamp turns on and remains on until some operator selects a line.

Pressing the RELEASE button when the beam is on and FC1 is open has no effect. The line cannot be released when the beam is on in the treatment room.

Lamps

Exactly one of the lamps is on at any time, to indicate which line and mode are selected (or that none are selected).

The NO LINE SELECTED LAMP is on when none of the beam lines in the facility are selected (including the isotope production line and the line into the other treatment room). It is only possible to select the line when this lamp is on.

The OTHER LINE SELECTED lamp is on when another operator has selected their line (either the isotope production line or the line into the other treatment room). It is not possible to select the line when this lamp is on.

The TEST MODE SELECT lamp is on when the line has been selected in test mode from the therapy console.

The SELECT FOR TREATMENT lamp is on when the line has been selected in treat mode, either from the treatment console or from the cyclotron operator's console. It is possible for the cyclotron operator to select a line in treat mode, as described in chapter 3. The effect of this is exactly the same as if the treatment operator had selected it. The line may subsequently be released by either operator.

6.1.3 Neutron beam control

This section houses several buttons and lamps concerned with turning on the neutron beam in the treatment room.

Beam path

The “Beam path” refers to three barriers that normally occlude the beam line into each treatment room. It consists of the beam plug, the X-ray drawer, and the glass stop. (There is no glass stop in the fixed beam room.) The beam plugs prevent stray radiation from the cyclotron vault from reaching the treatment rooms, and the X-ray drawer and glass stop help limit radiation from the target, treatment head, and collimator. Before the beam can be turned on in a treatment room, these barriers must be moved; the beam plug and glass stop are opened, and the X-ray drawer is moved to its TREAT position. These operations together are called “opening the beam path.”

In TREAT mode the path is only opened and closed under automatic control; the therapy console operator cannot control the path components directly. In TEST mode, the cyclotron operator can open and close the path by using buttons on the cyclotron console.

The path always closes automatically whenever the beam turns off for any reason. This prevents radiation from the cyclotron vault from reaching the treatment room and reduces radiation from the treatment head.

Each treatment console houses two lamps which indicate the condition of the beam path for the line into the treatment room. The BEAM PATH OPEN lamp is on when the beam plug and glass stop are open and the X-ray drawer is in the TREAT position. A flashing lamp indicates that the path has been manually or automatically commanded to open but not all three devices are in the open position. The BEAM PATH CLOSED lamp is on when the the beam plug and glass stop are closed and the X-ray drawer is in the SAFE position. A flashing lamp indicates that the path has been manually or automatically commanded to close but not all three devices are closed (SAFE).

The BEAM PATH CLOSED lamp also flashes when the X-ray drawer is in the X-ray position. The glass stop is open and the shield blocking radiation from the target is withdrawn in this condition.

Proton beam interlock (I-lock)

The PROTON BEAM I-LOCK lamp is on when the cyclotron is *not* ready to deliver a beam suitable for therapy to the treatment room, for some reason concerning the cyclotron or other subsystems which are controlled from the cyclotron console. Nothing can be done with the controls at the therapy console to clear the condition indicated by this lamp.

When the PROTON BEAM I-LOCK lamp is off, cyclotron and other subsystems controlled from the cyclotron control console are in the proper condition for turning on the neutron beam in the treatment room.

Therapy interlock (I-lock)

This lamp is on when the treatment room equipment is *not* in the proper condition to allow the beam to turn on in the treatment room, for some reason concerning the treatment room or other subsystems which are controlled by the therapy operator. For example, this lamp is on when the line has not been selected in TREAT mode, or the therapy room door is open, or the treatment room equipment is not set up to conform to the appropriate treatment

specification, or the therapy console key has been turned off, or no therapy operator is logged in. The dosimetry system must go through its initial self-test, resetting of dose counters and loading of prescribed values before the interlock is cleared. There are other conditions as well.

The complete list of conditions that is required for the THERAPY I-LOCK lamp to go off is described in another volume.

Start

Pressing the START button in treat mode begins the automatic sequence to turn on the beam in the treatment room, if interlocks permit. This sequence always includes opening the beam path and Faraday Cup 1; it may also include turning on the RF drive, if the cyclotron operator has not already done so. This sequence takes a few seconds before the neutron beam actually comes on.

The beam turns off automatically when the prescribed dose is delivered, and then Faraday cup 1 and the beam path close automatically.

Pressing the START button has no effect when the PROTON BEAM I-LOCK or THERAPY I-LOCK lamp is on. In TREAT mode, the neutron beam can come on in the treatment room only when both of these lamps are off.

Pressing START has no effect if the line has not been selected in TREAT mode. (the THERAPY I-LOCK lamp is on at all times that the line is not selected in TREAT mode). In particular, it is not possible to turn on the beam from the treatment console in TEST mode.

If START is not pressed within 15 minutes of the last reset of the dosimetry system, the THERAPY I-LOCK lamp turns back on and START is disabled. Past this interval, drift in the dose monitors (due to counting residual radiation from components in the treatment head) becomes excessive.

Neutron beam on

This lamp is on when the RF system is on, the beam plug is open and Faraday Cup 1 is open to let the proton beam through to the target, resulting in neutron production. Normally, it turns on a few seconds after the therapy console operator presses the START button, after the RF system has started and the path and FC1 have been opened. It is also on when the

beam has been turned on in the treatment room by the cyclotron operator, during TEST mode.

This lamp is on exactly when the BEAM ON warning flasher at the treatment room entrance is on.

Beam off

Pressing the BEAM OFF button immediately and unconditionally turns off the neutron beam in the treatment room. It accomplishes this by turning off the RF drive, thereby turning off the proton beam. Then, Faraday cup 1 and the beam path close (as they always do whenever the beam turns off for any reason).

Pressing BEAM OFF does not cause the THERAPY I-LOCK lamp to turn on. The PROTON BEAM I-LOCK lamp turns on briefly while the path is closing. After that, both interlock lamps are off and it is possible to resume the run by pressing START again (unless some fault has occurred).

One minute delay

This lamp remains on for one minute after the beam has turned off. It reminds therapy technologists that residual radiation is present in the room and allows for the decay of very short lived nucleides after the therapy run.

This lamp is mounted on the panel adjacent to the Treatment Control panel, close to one of the buttons that opens the treatment room door (Fig. 6.1).

It is possible to open the treatment room door when this lamp is on. Therapy technologists always have immediate access to the patient to deal with emergencies.

6.2 Dose monitoring

The dose monitoring panel is pictured in Fig. 6.3. It houses eight four-digit LED displays that show various quantities related to dosimetry. Some of these quantities are treatment prescription data and others are derived from measurements using the ion chambers and target in the treatment head.

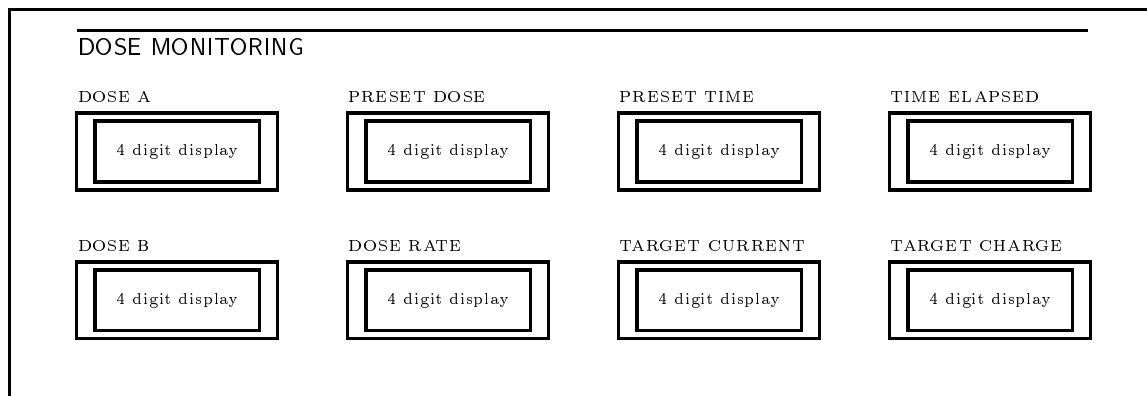


Figure 6.3: Dose monitoring panel

All eight displays are driven by a subsystem called the *Dose Monitor Controller* (DMC), whose function and operating modes are described in another volume. Initially the displays are dark with only the decimal points lit to show the panel is powered and operational. Before each therapy run the DMC undergoes a self test where artificial signals are fed into the system and results are displayed. Subsequently the prescribed treatment parameters are loaded and displayed and the system is then ready to monitor the dose delivered to the patient. As the therapy run progresses the displays are continuously updated.

6.2.1 Preset dose

This display shows the prescribed dose read from the treatment prescription, measured in monitor units (MU). One MU corresponds to one centigray (cGy) measured specified conditions (10×10 field, phantom positioned so that reference depth D_{max} is at isocenter, measurement at D_{max}). The display is automatically loaded with the prescribed dose after the therapy console operator selects a stored treatment field specification, as described in chapter 8.

The beam automatically turns off when the measured dose displayed on either the DOSE A or DOSE B display reaches the PRESET DOSE value.

6.2.2 Dose A, Dose B

These two displays show the cumulative doses measured by two independent dosimetry channels, both measured in MU. Both displays are reset to zero after the self-test before the therapy run. Subsequently, each records the cumulative dose measured by one of the dosimetry channels since the display was reset. When the beam is on, both displays count up at a rate proportional to the dose rate. Even when the beam is off, the displayed values may occasionally increment due to residual radiation from components in the treatment head.

The beam automatically turns off when the dose displayed on either the DOSE A or DOSE B display reaches the value shown on the PRESET DOSE display.

Both displayed values should agree closely. If they do not, the DMC considers this a fault condition, the beam turns off if it is on, and the THERAPY I-LOCK lamp turns on. This fault can be cleared only by resetting the DMC and repeating the self-test.

6.2.3 Preset time

This display shows the estimated upper limit on the duration of the treatment, measured in minutes and hundredths of minutes. It is automatically calculated by dividing the preset dose (described above) by the nominal dose rate of the machine, and then adding an additional interval to account for the possibility that the dose rate may decrease. The nominal dose rate of the machine is entered by the cyclotron operator every day, using a procedure described in chapter 4.

This display is automatically loaded with the estimated treatment duration after the therapy console operator selects a stored treatment field specification, as described in chapter 8, but before the therapy interlock lamp turns off. Once the system is ready to run (the THERAPY I-LOCK lamp is off) the preset time value cannot be changed.

The beam automatically turns off if the beam on time shown on the TIME ELAPSED display reaches the value shown here. This is a safety back-up feature; normally the beam turns off when one of the dose channels reaches the preset dose.

6.2.4 Time elapsed

This display shows the cumulative elapsed beam-on time measured by a timer, measured in minutes and hundredths of minutes. The display is reset to zero before the THERAPY I-LOCK lamp turns off. Subsequently, it records the cumulative time that Faraday Cup 1 has been open since the THERAPY I-LOCK lamp turned off. It is assumed that the beam is on in the treatment room when the THERAPY I-LOCK lamp is off and Faraday cup 1 is open.

When Faraday Cup 1 is open, the timer counts up; when the cup is closed, counting stops. Closing the cup (as a result of pressing BEAM OFF) stops counting but does not cause the count to reset; instead, the count holds at the same value and resumes counting up if the cup opens again (as a result of pressing START again).

The count is sometimes observed to increment at a slightly varying rate because the controller that updates the display sometimes lags slightly behind the actual measured time.

The beam automatically turns off when the time displayed here display reaches the value shown on the PRESET TIME display, if it has not already been turned off by one of the dosimetry channels.

6.2.5 Dose rate, target current, target charge

These three displays show measured quantities that are not used to turn off the beam, but provide useful information for diagnostic purposes. DOSE RATE shows the instantaneous dose rate measured in dosimetry channel A. TARGET CURRENT measures the current in the target assembly created by the proton beam; it should be roughly proportional to DOSE RATE. TARGET CHARGE is obtained by integrating TARGET CURRENT and should be roughly proportional DOSE A and DOSE B. TARGET CHARGE is reset at the same time as DOSE A and DOSE B.

6.3 Interaction with the treatment operations terminal

The dedicated controls on the treatment console are largely independent of the the treatment operations terminal. The few interactions are summarized here.

6.3.1 Logging in, logging out

When no operator is logged in at the treatment operations terminal, pressing the START button on the treatment console has no effect.

The START button is the only console control that is disabled when no operator is logged in. The line select and release buttons are enabled whenever the console keyswitch is turned on. The BEAM OFF button is always enabled.

Turning off the treatment console keyswitch disables most terminal operations, as described in section 6.1.1 and table 6.1. Interactions between the keyswitch and the operations terminal are described in more detail in chapter 8.

6.3.2 Selecting prescribed treatment fields

Before a patient can be treated, a prescribed treatment field description must be selected at the therapy operations terminal. The THERAPY I-LOCK is only cleared when the system has checked that the treatment equipment is set up to conform to the description. The procedure for selecting a stored field description is given in chapter 8.

6.3.3 Disabling operations during runs

Many therapy terminal operations are disabled while a run is in progress. As a rule, operations that only display the state of the system remain enabled, but operations that can change the state of the system are disabled. The complete list of operations that are disabled appears in chapter 8.

The state of the system is considered to include the volatile data within the system, such as the current stored field description. Of particular importance for patient safety are the DOSE A and DOSE B values stored in the DMC, because these record the actual dose delivered to the patient. The DMC must not be reset or loaded with new values before this information has been recorded. This is in part accomplished by disabling operations, such as field selection, that might cause the DMC to be reset or reloaded.

For the purposes of this requirement, a run is considered to be in progress from the time the therapy console operator presses the START button until the THERAPY I-LOCK lamp turns on after the DMC has terminated the treatment. In fact this may include some intervals when the beam is actually off and Faraday cup 1 and the beam path are closed,

for example if the operator presses BEAM OFF and then START. It may also include some intervals when the THERAPY I-LOCK lamp is on, for example if the therapy room door is opened. The run is not considered to be finished until the DMC terminates the run. This definition only includes runs that are initiated from the therapy console, while the system is in TREAT mode. This definition does not include runs initiated from the cyclotron console in TEST mode.

6.3.4 Cancelling an incomplete run

It may sometimes be necessary to cancel a treatment or experiment after the run has begun, that is, after START has been pressed. At this point, some dose (less than the prescribed dose) may have been delivered. It may not be possible to allow the DMC to terminate the run by delivering the prescribed dose, or allowing the DMC timer to count up to the PRESET TIME value. Nevertheless, it must be possible to store a record of the treatment (including the dose that was delivered) in the treatment record file, and then proceed to the next field, or the next patient.

Therefore, a therapy console operation is provided to cancel an incomplete run. This operation has the effect of logging a record of the incomplete run and then allowing normal operations to proceed. It is described fully in chapter 8. It is a necessary exception to the general rule that operations that change the state of the system are disabled during runs.

6.3.5 Appearance of the terminal in TEST mode

The treatment operations terminal displays appear different when the line has been selected in TEST mode. Details appear in chapter 8. Therapy technologists should not take a patient into the treatment room under this condition.

6.4 Interaction with cyclotron operations

6.4.1 Selecting beam lines

Although the beam can only be turned on in TEST mode from the cyclotron console, the line can only be *selected* for TEST mode at the treatment console. The treatment operator does not have to be logged in to select the line in TEST mode; it is only necessary that the treatment console keyswitch be turned on.

If it is necessary for cyclotron operators to run the beam on target in TEST mode, they must request that the therapy technologist select the line, or go to the treatment console to select the line themselves. Either option requires cooperation between operators and helps to ensure that a line will not be placed in TEST mode when a patient is in the treatment room.

The line can be selected for TREAT mode either from the appropriate therapy console or from the cyclotron console. The line can be released both from the appropriate therapy control console or from the cyclotron control console.

6.4.2 Turning on the therapy beam

The cyclotron operator indicates to the therapy technologists that the cyclotron is ready to deliver a beam suitable for therapy to the treatment room by pressing the CYCLOTRON READY FOR TREATMENT button on the cyclotron console. The PROTON BEAM I-LOCK lamp on the treatment console does not turn off unless the CYCLOTRON READY FOR TREATMENT lamp is on at the cyclotron console.

Treatments can be performed without the intervention of a cyclotron operator. As long as the PROTON BEAM I-LOCK lamp remains off, therapy technologists can turn the beam on and off without the cyclotron operator's assistance. However, if the PROTON BEAM I-LOCK lamp turns on for any reason, the cyclotron operator must correct the problem and press CYCLOTRON READY FOR TREATMENT again. This can happen, for example, when the beam is shut off automatically because the beam losses measured on a stray beam detector became excessive.

6.5 Some typical treatment operations

This section describes some typical scenarios at the the treatment console. Many other operation sequences are possible.

6.5.1 A typical treatment sequence

1. Once the cyclotron operator has decided that the cyclotron and beam lines are properly tuned, he presses CYCLOTRON READY FOR TREATMENT. The proton beam can be on or off at this moment. The ion source is set to a value which produces 8 to

15 μA on FC1 when the beam is on.

The PROTON BEAM I-LOCK lamp turns off on the therapy console.

2. A therapy technologist selects one of the patient's stored treatment field descriptions at the therapy operations terminal, as described in chapter 8.

The dosimetry system goes through its self-test and the dosimetry parameters for the field are loaded.

3. A therapy technologist automatically sets up the collimator leaves, wedge and flattening filter at the therapy operations terminal, as described in chapter 8.

4. The therapy technologists enter the treatment room with the patient and manually set up the external treatment motions, including table position, table angle, gantry angle and collimator angle, using the mobile control pedestal and the hand pendant. They confirm the setup using the light field, alignment lasers, and SSD projector.

Verification films using X-rays may also be made at this time.

When the technologists are satisfied with the setup, they leave the treatment room and close the door.

5. After steps 2, 3 and 4 have all been properly completed, the THERAPY I-LOCK lamp on the treatment console turns off. The LED displays on the dose monitoring panel are lit. PRESET DOSE and PRESET TIME show the prescribed dose and the estimated treatment time, TIME ELAPSED shows zero, and DOSE A and DOSE B both show zero.

6. When both the THERAPY I-LOCK and PROTON BEAM I-LOCK lamps are off, a therapy technologist presses the START button on the treatment console.

If at this time the cyclotron RF drive is not on, it turns on, and the proton beam turns on and reaches Faraday cup 1.

The path begins to open. The PATH OPEN lamp on the treatment console blinks and then remains on when the path is open. Faraday Cup 1 opens, the proton beam reaches the target and the neutron beam comes on in the treatment room. The NEUTRON BEAM ON lamp turns on. TIME ELAPSED, DOSE A and DOSE B begin counting up.

The initial intensity of the beam corresponds to the values set by the cyclotron operator. A servo system in the DMC increases the intensity until the preset "dose rate of the day" is reached.

7. The neutron beam remains on in the treatment room. As the therapy run progresses, TIME ELAPSED, DOSE A and DOSE B continue to count up.

8. A typical therapy run lasts 1 to 3 minutes. Normally the run ends when DOSE A or DOSE B reaches PRESET DOSE.

The THERAPY I-LOCK lamp turns on and the RF drive turns off immediately, so the proton beam and the neutron beam turn off. The NEUTRON BEAM ON lamp turns off.

Faraday cup 1 closes and the path begins to close. The PATH CLOSED lamp blinks and then remains on when the path is closed. The PROTON BEAM I-LOCK lamp comes on while the path is closing and turns off once the path is closed to indicate that the cyclotron is ready for the next run.

9. A record of the run, including the dosimetry information measured by the DMC, is stored in a treatment record file on the control system support host.
10. The ONE MINUTE DELAY lamp turns on to remind the technologists of the radiation present in the room. While they are waiting for the delay the technologists complete their manual log entries.
11. As soon as the DMC information has been stored in the treatment record file, the DMC goes through its termination self-test. Pulses are fed to the dose counter which has not yet terminated to check if it would have turned off the beam if it had been first to reach the PRESET DOSE. The timer also continues counting to check if it would have turned off the beam after reaching PRESET TIME. Then the LED displays of the DMC become dark.
12. The technologists may select the next field while the DMC termination self-test is in progress. In that case, the termination self-test is aborted and the startup self-test begins. This amounts to resuming the treatment sequence at step 2.
13. The technologists enter the room to set up the next field or remove the patient.

The therapy technologists repeat steps 2 through 13 for each field.

Steps 5 through 11 must always proceed in sequence in the order given here. However, the preparatory steps 1 through 4 may proceed in almost any order with respect to each other, may be repeated as often as necessary, and may even be performed simultaneously. The only restriction is that step 3 cannot precede step 2.

Several variations on the preceding sequence are described in the following sections.

6.5.2 An interrupted treatment: proton interlock

If there is a problem with the cyclotron while the beam is on, the beam turns off, PROTON BEAM I-LOCK turns on, the NEUTRON BEAM ON lamp turns off, and the PATH

CLOSED lamp blinks and then remains on once the path is closed. TIME ELAPSED, DOSE A and DOSE B stop counting up. Nothing else changes at the treatment console.

If this happens, it is necessary to wait for the cyclotron operator to repeat step 1 in the sequence. After the PROTON BEAM I-LOCK lamp turns off, the therapy technologist may resume at step 6 by pressing the START button again.

6.5.3 An interrupted treatment: patient requires assistance

While the beam is on, therapy technologists observe the patient over the TV monitors and the intercom. If the patient moves or requires assistance, a technologist presses the BEAM OFF button. The neutron beam turns off, and the beam path closes. TIME ELAPSED, DOSE A and DOSE B stop counting up. The ONE MINUTE DELAY lamp comes on. Nothing else changes at the treatment console. PROTON BEAM I-LOCK and THERAPY I-LOCK remain off.

At this point a technologist could resume the treatment at step 6 by pressing the START button again; nothing else need be done. If it is necessary to enter the treatment room to assist the patient, the THERAPY I-LOCK lamp turns on as soon as the door begins to open. Usually, it is necessary to get the patient back into position. After the technologists have left the room and closed the door, the THERAPY I-LOCK lamp turns off again if the equipment setup still matches the prescription. A technologist may then resume the treatment at step 6 by pressing the START button.

6.5.4 An incomplete treatment: timer turns off beam

A treatment proceeds as described above through step 7. However, the dose rate is lower than expected. TIME ELAPSED exceeds PRESET TIME before either DOSE A or DOSE B reaches PRESET DOSE. Except for this one difference, the beam turns off, the treatment run is logged and the DMC operation terminates exactly as described in steps 8 through 11.

It is necessary to perform another treatment run with the same setup in order to deliver the prescribed dose. It is also necessary to reset and restart the DMC. This is accomplished by reselecting the same field description at the therapy operations terminal. The prescribed dose for the field is reduced by the amount already delivered, as described in chapter 8.

6.5.5 An incomplete treatment: prescribed dose cannot be delivered

While the treatment run is in progress, it is interrupted for some reason and it becomes clear that it will not be possible to deliver the prescribed dose during that treatment session. Perhaps there is a problem with the equipment which cannot be fixed quickly, or the patient is unable to complete the treatment.

At this point, the therapy technologist uses a therapy terminal operation to cancel the run, as described in chapter 8. This has the effect of storing a record of the incomplete treatment (including the dose that was delivered) in the treatment record file, and allowing operations to proceed.

6.5.6 Taking an X-ray port film

The technologists set up the patient as described in step 4. After achieving a satisfactory setup, installing an X-ray film in the film holder attached to the collimator, and putting the treatment equipment in X-RAY mode by pressing a button on the mobile pedestal in the treatment room, they leave the room. They do *not* close the door, since this is not necessary for safety and saves considerable time. They control the X-ray exposure from the X-ray generator located in the control room, near the treatment consoles (a single generator serves both rooms).

In order to show the surrounding anatomy a second exposure on the same film is usually taken, this time with fully open collimator. The collimator can be opened from the control room, and there is an indication when the fully opened position has been achieved.

After exposing the X-ray, they return to the treatment room to retrieve the film and take the treatment equipment out of X-ray mode. If they choose to treat the patient with this setup they can leave the room and close the door, resuming the usual treatment sequence at step 2, field selection. At the treatment operations terminal, they set the collimator back to the prescribed treatment field shape and reset and reload DMC, which is necessary to clear the effect of the X-rays (The X-rays are detected by the dose monitors and the DMC indicates a fault).

6.5.7 Taking a neutrogram port film

There are some discrepancies between the X-ray beam simulation and the actual neutron beam because the X-ray tube is not positioned exactly at the Beryllium target location, for

technical reasons.

In order to get a more accurate record of the field outline the neutron beam can be used directly to expose a verification film. The neutron beam can only be turned on with the dosimetry system properly set up. Therefore, such a neutrogram can only be taken by going through all the steps for a regular therapy run. To get proper film exposure, only 3 to 5 monitor units are required, far fewer than are delivered in any treatment. An easy way to achieve this is to interrupt a treatment run 3 to 5 MU before the end by pressing BEAM OFF. The technologists then enter the room to set up the film, leave, close the door, press START, and complete the treatment with the film in place.

An X-ray exposure with a fully open collimator can be superimposed on the neutrogram to show anatomical features in relation to the neutron field.

Chapter 7

Treatment room equipment

This chapter describes the controls and indicators located in the treatment rooms: the mobile pedestal, the hand pendant, and the wall display. The isocentric room and the fixed beam are both equipped with these items. Other treatment room equipment is described in [1].

Fig. 7.1 shows a view of the isocentric treatment room, including the mobile pedestal.

7.1 Mobile pedestal

The *mobile pedestal* (Fig. 7.1) is a small local control console which can be rolled around in the treatment room and which is used to locally control the equipment. Fig. 7.2 shows the controls and indicators on the mobile pedestal. In the figure, rectangles labelled “Ready” are indicator lamps only; all other rectangles (except “Emergency off”) are pushbuttons with lamps; the lamp is lit when the condition or action invoked by pressing the button is in effect.

The larger buttons and lamps are used for settings that are usually set up manually. The smaller buttons and lamps are used for settings that are usually set up automatically; additional buttons are provided to switch these controls between manual and automatic mode.

(Insert isocentric treatment room illustration)

Figure 7.1: Isocentric treatment room showing gantry, patient support assembly and mobile pedestal

(Insert isocentric treatment room illustration)

Figure 7.2: Mobile pedestal control panel

7.1.1 Emergency off

There is an emergency off switch that works the same way as the ones on the therapy control consoles and treatment room walls. It removes power from the gantry components and moving floor, so it can be used to stop external motions. It also turns off the beam by removing power from the ion source (this is different from the usual mechanism, which is to open a switch in the HSIS). However, this switch does not turn off the facility's main power.

After the emergency power-off switch has been pressed, it must be reset with a key, and the ion source power supply must also be reset in order to turn on the beam.

7.1.2 Lights

There are buttons to turn on the alignment lasers, the SSD projector, and the beam defining lamp. The main room lights turn off when the beam defining lamp turns on and the room is then lit only by dimmable incandescent downlights. This function, where the room lights are slaved to the beam defining lamp, can be selected or deselected via a switch in the gantry support area. The beam defining lamp can also be switched on and off remotely from a button on the therapy control console.

7.1.3 Enable key

The pedestal enable key must be turned on to enable most pedestal controls and the hand pendant.

The only pedestal controls that do not require the enable key are the emergency off switch, the lamp test button, and the buttons that turn on the alignment lasers, the SSD projector, and the beam defining lamp.

The usual procedure is for the therapy technologists to turn on the key when they enter the room to set up a treatment field, use the pedestal controls and hand pendant to set up the field, and then turn off the pedestal key before they leave. The treatment room door cannot close when the pedestal enable key is turned on. The pedestal enable keyswitch uses the same key as is required to turn on the X-ray generator from its control panel in the control room, so the key must be turned off and removed from the pedestal in order to shoot a port film.

When the pedestal enable key is turned on, the auto enable button at the therapy console is disabled (that button is used to enable automatic external motions such as gantry rotations during arcs).

The enable key must be turned on in order to switch filter selection, wedge orientation and leaf motion controls between manual and automatic mode (the usual mode is automatic). When the key is turned off, these controls remain in whatever mode was set; in particular, controls do not revert from manual back to automatic mode when the enable key is turned off.

7.1.4 Filter controls

A group of similar controls and indicators are provided for each of three kinds of filter selection: flattening filter selection, wedge type selection, and wedge orientation selection.

Usually, these selections are made in automatic mode: the appropriate selection is performed under computer control. In this mode the filter selections are automatic in the sense that the selections are determined by the control system from data stored in a prescription file; however, the control system only sets the selection when an operator at the therapy operations terminal invokes the auto setup operation, as described in chapter 8. In automatic mode, the SELECT lamp is on while computer-controlled filter motion is enabled.

Alternatively, a technologist in the treatment room may perform the selection manually by first pressing the button to place the selection in manual mode, and then pressing one of the selection buttons.

In manual mode, the lamp under the selection button turns on as soon as the button is pressed, remains on while the filter is in motion, and turns off when the filter achieves the selected position (or, rarely, when a fault prevents the selected position from being achieved and the control system stops trying).

For each selection, a series of ready lamps indicates which selection is currently in effect. Usually one ready lamp in each group is on, but all lamps are off when a filter is in transition between selections.

For the flattening filter, the available selections are no filter, the filter for small fields, and the filter for large fields.

For wedge type, the available selections are none, the 30 degree wedge, the 45 degree wedge and the 60 degree wedge.

For wedge orientation, the available selections are the 270 degree orientation, the 0 degree orientation, the 90 degree orientation, and 180 degree orientation.

7.1.5 Leaf collimator controls

There are buttons to switch all collimator leaves between automatic and manual control modes. When the leaves are in manual mode, the position of each leaf can be manually controlled by its switch. The forty switches, one for each leaf, are mounted on the collimator itself (not the pedestal).

7.1.6 X-ray drawer controls

There is a button to select each of the three X-ray drawer positions: safe, treat, and X-ray. Usually the X-ray drawer is automatically moved from the safe to the treat position when the beam turns on and automatically moved back again when the beam turns off. Therapy technologists may use the Select X-ray button to move the X-ray tube on the beam central axis in preparation for making an X-ray port film. The manual “treat” selection is only used for maintenance purposes.

7.1.7 External motions: therapy settings

There is one button for each of six external therapy motions: gantry rotation, collimator rotation, table height, table longitudinal position, table lateral position, and PSA turntable rotation. If the pedestal enable key is on, pressing one of these buttons will enable the motion named on the button to be manually controlled from the hand pendant (section 7.2). The lamp under the button lights to indicate that motion is connected to the pendant.

There are two additional motions of the couch which are not motorized and therefore have no control buttons. One is the couch top rotation about the support pillar, and the other is an end-over-end rotation of the couch top.

7.1.8 External motions: moving floor

Usually the floor moves automatically to track the gantry and PSA support beam. If the pedestal enable key is on, the operator may switch floor controls into manual mode. In

manual mode, pressing one of the four buttons (left floor, right floor, left beam or right beam) will cause that motion to be manually controlled from the hand pendant.

7.1.9 Auto enable

The auto enable button may provide an alternative to manually setting up external motions with the hand pendant. In some situations, the control software can automatically set external motions to their prescribed values. The operator presses the auto enable button to start the automatic external motions. External motions proceed under automatic control only while the operator is exerting continuous pressure on the auto enable button. (The pedestal enable key must also be turned on to enable auto setup from the pedestal).

When the operator presses the Auto Enable Off button, automatic external motions are disabled. Auto Enable Local enables automatic motions from the pedestal and Auto Enable Remote enables them from the console.

7.1.10 Collision reset

If the collision detector becomes set, all external motions are disabled and this lamp turns on. It is necessary to press this button to re-enable external motions.

7.2 Hand pendant

The mobile pedestal has a hand pendant attached to it, to control the external motions of the gantry, PSA, and the moving floor. The pendant may be connected to any one of the six external therapy motions or four floor motions. The pendant is active if the pedestal enable key is on and one of the external motions has been selected by pressing its button on the pedestal. When the pendant is active, the indicator lamp for the corresponding motion is on.

There is a button and a rocker switch on the pendant. The button functions as a “dead man switch”; motion can only occur while the operator is exerting continuous pressure on this button. The rocker switch drives the motion. Pushing the switch to one side operates the motion in one direction; pushing the switch to the other side reverses the direction of motion. The operator can vary the speed of the motion by exerting more or less pressure on the switch.

7.3 Wall display

Two electronic wall displays in the isocentric treatment room shows the current numerical value (e.g., in cm or degrees) of all six gantry and collimator rotations and PSA motions. (There is only one display in the fixed beam room, and of course it does not show PSA turntable motion). These are the motions that can be controlled from the hand pendant. In addition, table top orientation is also shown (this motion is not motorized and can therefore not be driven from the hand pendant). Operators can view this display to determine whether the motions have reached their prescribed positions.

There is only one wall display unit in the fixed beam room.

Chapter 8

Therapy operations terminal

This chapter describes all of the operations that are performed at the therapy operations terminal installed in each therapy console. Technologists use these consoles for patient treatments, and clinical physicists and engineers use the same consoles to perform calibrations and other beam measurements that support patient treatments. Physicists also use these consoles to perform experiments.

This chapter describes the isocentric treatment room which is equipped with a rotating gantry and leaf collimator. The controls for the fixed beam room are the same, except that controls and indicators for gantry rotation, PSA turntable rotation, and collimator leaves are not present.

8.1 TREAT mode and TEST mode

The beam line controlled from each treatment console may be selected in two modes, as described in section 3.2.1. *TREAT mode* is used for treating patients. *TEST mode* is used by the cyclotron operator for tuning the beam and for some experimental runs. In TREAT mode, the beam can only be turned on in the treatment room from the therapy console. In TEST mode, the the beam can only be turned on in the treatment room from the cyclotron console. Because there are fewer safety checks in TEST mode, the beam line must never be in TEST mode when there is a patient in the treatment room. The terminal display appears conspicuously different in TEST mode (for example, by displaying different colors). This provides an additional mode indicator to the therapy operators, besides the dedicated lamps built into the console panels.

In addition to TEST and TREAT modes, there is also a third mode, where the line to the treatment room is not selected at all. This mode is indicated by the OTHER LINE SELECTED or RELEASED — NO LINE SELECTED lamps on the therapy operator's console. In this mode, the beam cannot be turned on in the treatment room at all, and the therapy operations terminal display screen appears as it does in TREAT mode.

When the line is not selected in TREAT mode, the THERAPY I-LOCK lamp on the therapy operator's console is lit to indicate that the beam cannot be turned on from the therapy operator's console.

All three modes selected by pressing buttons at the therapy consoles and the cyclotron console, as described in chapters 3 and 6. Mode selection is accomplished by hardwired nonprogrammable controls. The computer connected to the therapy operations terminal only monitors these mode changes.

Most therapy terminal operations work the same way in all three modes (apart from the different screen appearance in TEST mode). The only exceptions concern the dosimetry system. In TEST mode, runs can only be started and stopped by the cyclotron operator. Therefore, it is not possible to set up the dosimetry system from the therapy operations terminal in TEST mode, since that could interfere. Moreover, in TEST mode the cyclotron operator must have full control over beam steering and dose rate, so the DMC dose rate servo and steering servoes have no influence in TEST mode.

8.2 Therapy mode and Experiment mode

We also distinguish between *therapy mode* and *experiment mode*. These two modes are independent from TREAT mode and TEST mode, and all six combinations are possible (TREAT/therapy, TREAT/experiment, TEST/therapy, TEST/experiment, RELEASED/therapy, RELEASED/experiment). TREAT and TEST modes are selected by pressing buttons on the console and are implemented by hardware; therapy and experiment modes are selected at the terminal and implemented in software.

Typical activities performed in the combinations are shown in Table 8.1.

Experiment mode has fewer safeguards and therefore only a subgroup of users is authorized to use this mode. A file on the control system support host specifies which users may select experiment mode.

The differences between these two modes are:

RELEASED	Therapy	Prepare for treatments.
TEST	Therapy	Cyclotron operator tunes beam in preparation for treatments. Setup of dosimetry system from therapy console disabled.
TREAT	Therapy	Patient treatments.
RELEASED	Experiment	Prepare for experiments, physics, maintenance.
TEST	Experiment	Beam tuning; experiments, physics activities, and maintenance procedures that do not use the dosimetry system.
TREAT	Experiment	Experiments, physics activities and maintenance procedures that use the dosimetry system to turn off the beam.

Table 8.1: Activities in different modes.

- The set of available stored fields is different in the two modes.
- In therapy mode each stored treatment field is associated with a patient. In experiment mode, stored fields are not associated with patients.
- Stored therapy fields include collimator leaf positions, flattening filter selection, wedge filter selection and orientation, gantry angle, collimator angle, PSA turntable angle, PSA linear motions, the number of fractions, and the prescribed dose. In the stored fields available in experiment mode, only the collimator leaf positions and filter configuration (including wedges and flattening filters) are stored. External motion settings (gantry etc.) and prescribed dose are not stored for experiment mode fields.
- In therapy mode, the dose for each field is read from a prescription file when the field is selected. In experiment mode, the dose for each run must be entered at the console. This makes it possible to repeatedly turn on the beam to deliver different doses without selecting a new field¹.
- In therapy mode, it is necessary to enter the treatment room and use the local controls to change the filters and collimator leaf settings to values which differ from the settings prescribed in the stored fields. In experiment mode, it is possible to change wedge filters, flattening filters, and collimator leaf positions from the therapy console.

¹This is also possible in treatment mode, but it is not the usual method

- In experiment mode, it is possible to change some DMC calibration factors. For example, the ion chamber signal gain can be adjusted to compensate for daily changes. This is done during a calibration check in the morning and typically is left unchanged for the rest of the day. In therapy mode, the calibration factors remain fixed.

In experiment mode, the stored field settings are called *requested* settings, while in therapy mode they are called *prescribed* settings. These terms are used in captions on screen displays.

The characteristics of TREAT mode, TEST mode, therapy mode and experiment mode are summarized in table 8.2.

8.3 The current field

In both therapy mode and experiment mode, the usual way to set up the machine for a run is to use the SELECT FIELD operation to select a pre-stored field description, which includes most of the treatment unit settings. The collection of settings most recently selected in this way is called the *current field*, whether or not the actual treatment unit settings conform to the prescription. The control system is designed to prevent the beam from being turned on if the actual settings differ from the stored settings. This is called the *check-and-confirm* facility.

TEST mode and TREAT mode describe the status of hardwired control system components. Therapy mode and experiment mode describe the status of the control system software.

TREAT mode	TEST mode
<p>Hardwired interlocks include check and confirm, dosimetry</p> <p>Beam cannot be stopped on FC3</p> <p>Beam turned on from therapy console</p> <p>Beam normally turned off by dosimetry</p> <p>DMC Auto Setup enabled</p> <p>DMC dose rate and steering servoes in effect</p>	<p>Hardwired interlocks do <i>not</i> include check and confirm, dosimetry</p> <p>Beam can be stopped on FC3</p> <p>Beam turned on from cyclotron console</p> <p>Beam turned off by cyclotron operator</p> <p>DMC Auto Setup disabled</p> <p>DMC dose rate and steering servoes have no effect</p>

Therapy mode	Experiment mode
<p>Software selection of patient fields; stored settings called "prescribed"</p> <p>Prescribed settings include external motions (Gantry/PSA)</p> <p>Wedge, filter, leaf settings read from prescription file cannot be changed at console</p> <p>Dose read from prescription file (can be edited at keyboard)</p> <p>DMC calibration factors fixed</p>	<p>Software selection of experimental fields; stored settings called "requested"</p> <p>Requested settings do not include external motions</p> <p>Requested wedge, filter, leaf settings can be changed at console</p> <p>Dose entered at keyboard</p> <p>DMC calibration factors can be changed</p>

Table 8.2: TREAT mode, TEST mode, therapy mode and experiment mode

8.4 Treatment subsystems

The apparatus controlled from the therapy console includes five subsystems:

Gantry/PSA comprises all external motions of the therapy apparatus: linear and rotational motions of the patient support assembly (PSA), gantry rotation and collimator rotation.

Filters/Wedges comprises selection and orientation of flattening filters and wedge filters.

Leaf Collimator comprises all 40 leaves.

Dosimetry comprises both dose monitoring channels.

Therapy Interlocks includes all interlocks that are the responsibility of the therapy console operator: doors, keys, etc.

In addition, information is provided about a sixth subsystem which is not under the therapy operator's control:

Proton Beam Interlocks includes the cyclotron and all parameters and interlocks that are the responsibility of the cyclotron operator.

Each of the first four subsystems may be in one of the three states READY, OVERRIDE or NOT READY. The therapy and proton beam interlock systems can only be READY or NOT READY. The user may turn on the beam from the therapy console if all six subsystems are either READY or OVERRIDE. The beam cannot be turned on from the treatment console if any subsystem is NOT READY.

A subsystem is READY if the apparatus conforms to the prescribed settings in the current field (or the requested settings, in experiment mode), and all of its interlocks are clear. In experiment mode external machine motions are not part of the stored field settings, so in this mode the Gantry/PSA subsystem is READY whenever all of its interlocks are clear.

A subsystem is NOT READY if it is not in OVERRIDE and the prescribed (or requested) and actual values of any of its settings differ by an amount greater than a predefined tolerance (which may be different for each setting). These tolerances are stored in a file on the control system support host and cannot be changed from the therapy operations terminal.

A subsystem is NOT READY if any of its interlocks are set.

A subsystem is in the OVERRIDE state if the actual settings do not conform to the stored settings but the operator has indicated, by invoking the OVERRIDE operation at the terminal, that he or she wishes to turn on the beam with the actual settings anyway. It is necessary to invoke the OVERRIDE operation individually for each setting that differs from its stored value; it is not possible to override all the settings at once. It is not possible for the operator to override interlocks; all subsystem interlocks must be clear in OVERRIDE. If any of the actual settings change after the operator sets the OVERRIDE state, then the subsystem reverts to NOT READY. In other words, overriding settings applies only to the setting values that actual exist when the override operation is performed. The OVERRIDE state is also cancelled when a new field is selected.

The treatment record file indicates which settings were overridden when a treatment was performed.

When no field is selected, all five subsystems are NOT READY and cannot be overridden.

The Dosimetry system is NOT READY when the DMC (dose monitor controller) is in certain states, as explained more fully in section 8.9.11.

The THERAPY I-LOCK lamp on the therapy control console (chapter 6) is on when any of the subsystems other than Proton Beam is NOT READY. In this condition the START button on the therapy console is disabled and the beam cannot be turned on from the therapy console. The THERAPY I-LOCK lamp is off when all of these subsystems are READY or OVERRIDE, indicating that the beam may be turned on in the treatment room if the PROTON I-LOCK is clear.

The Therapy Interlocks subsystem is closely related to the THERAPY I-LOCK lamp; it is NOT READY when THERAPY I-LOCK lamp is on and READY when the lamp is off. This subsystem is NOT READY when any of the four subsystems Gantry/PSA, Filters/Wedges, Leaf Collimator, or Dosimetry is NOT READY. It is also NOT READY when any of several other therapy-related interlocks are set, as described in section 8.9.12. There is no OVERRIDE state for the Therapy Interlocks subsystem.

The Proton Beam Interlocks subsystem can only be READY or NOT READY; there is no OVERRIDE state for this subsystem. The PROTON I-LOCK lamp on the therapy control console (chapter 6) is on at the same time that the Proton Beam Interlocks subsystem is NOT READY and is off when the subsystem is READY.

8.5 Motion controls: local/automatic and enable/disable

Three of the treatment subsystems involve motion controls:

- Gantry/PSA
- Filters/Wedges
- Leaf Collimator

In each of these subsystems, there are potentially two control modes: local and automatic. In local mode, motions are controlled by using equipment in the treatment room: the mobile pedestal, hand pendant, and collimator leaf switches. In automatic mode, motions are controlled from outside the treatment room, at the therapy console (e.g. by calling up a specific patient prescription).

In the control system version described in this document, an automatic mode is provided for the Filters/Wedges and Leaf Collimator subsystems. For safety reasons, no automatic mode is provided for the Gantry/PSA subsystem in the initial version of this control system. Arc therapy (where the gantry automatically moves through a prescribed angle, beginning from an initial angle that is set locally) is an example of a limited automatic mode for this subsystem. All control hardware needed for fully automatic operation is in place, and we plan to provide this in future versions.

Operators manually switch a subsystem between automatic and local mode, using local controls on the equipment in the therapy room. This is the only way that automatic mode can be selected; automatic mode cannot be selected from outside the treatment room, and cannot be switched by the control computer. Switching between local and automatic mode involves reconfiguring the hardware motion controls, so that the computer cannot cause motions in local mode.

In both modes, motions may be enabled or disabled. For safety reasons, motions are usually disabled and are only enabled when motion is explicitly requested. In local mode, motions are enabled at the equipment in the treatment room. For example, locally controlled external motions are enabled only while the operator exerts pressure on the “dead man switch” on the hand pendant. In automatic mode, motions are automatically enabled by the control system when they are requested and are disabled when the requested settings are achieved, or some fault occurs. The detailed rules for enabling each motion are described in another volume.

Enabling motions is accomplished by reconfiguring the motion control hardware. Typically this is accomplished by closing a *motion enable relay* in the motor control unit. This configuration is sensed as an interlock condition; the beam cannot turn on when any motions are enabled. There are separate motion enable interlocks for each motion (except the collimator leaves, which are all served by a single enable interlock). The motion enable interlocks are considered part of the subsystems that include the motion; none of these subsystems can be READY if its motions are enabled. In addition, the motion enable interlocks are also considered to be part of the Therapy Interlocks subsystem. If any motion is enabled in any subsystem, the Therapy Interlocks subsystem is NOT READY. All motions must be disabled in order for this subsystem to be READY. The subsystem can be READY regardless of whether motions are controlled in local or automatic mode, as long as motions are disabled.

8.6 Treatment operations display

The display screen on the treatment operations terminal always shows a status region and an operations region, as described in section 2.2 and shown here in Fig. 8.1.

The status region includes some special features (fig. 8.1). The top of the status region always shows the therapy console operator's user ID (a username) and the name of the current field, or NONE if no field has been selected. In therapy mode, the status line also shows the name of the current patient, or NONE if no patient has been selected. In experiment mode, this portion of the line says EXPERIMENT. The items are automatically updated on the screen as they are changed.

The status line is highlighted differently in therapy mode and experiment mode.

The rest of the status region is divided into six sections that behave like control panel lamps. These indicators represent the six major subsystems that determine whether it is possible to turn on the beam. Three different kinds of highlighting or color are used to depict the indicators, to show whether the indicated subsystem is READY, NOT READY, or OVERRIDE.

An operations region shows information about the operation that is currently underway. Different displays appear when the operator invokes different operations.

In addition to the status region and operations region, the screen may show other regions, such as a message region, a log region, a confirmation region, or a query region, as described in section 2.2. These regions are not required to always be visible; they may appear only when needed.

OPERATOR: None		PATIENT: None		FIELD: None	
GANTRY /PSA	FILTER /WEDGE	LEAF COLLIM	DOSI- METRY	THERAPY INTLKS	PROTON BEAM
LOGIN					
UNIVERSITY OF WASHINGTON CLINICAL NEUTRON THERAPY SYSTEM TREATMENT OPERATIONS TERMINAL LOG IN					

Figure 8.1: Treatment operations terminal screen showing status region with subsystem “lamps” and operations region with login display

8.7 Keyswitch

When the therapy console enable keyswitch is turned off, the operations region of the display clears and this message appears:

```
THIS CONSOLE HAS BEEN DISABLED  
TURN KEYSWITCH TO ENABLE CONTROLS
```

If the keyswitch is turned off while an operator is logged in, the operator is not logged out.

Turning on the keyswitch again simply erases the above message and restores the display to its state before the keyswitch was turned off.

When the keyswitch is turned on and no operator is logged in, the login sequence proceeds as described in Section 2.5.3.

The effect of the keyswitch, and of logging in and out, on the dedicated therapy console controls is given in chapter 6.

8.8 Treatment operations summary

The following operations are available at the therapy operations terminal. Operators might invoke operations by pressing functions keys on the terminal keyboard, by selecting items from an on-screen menu using a graphic cursor and a “mouse,” or even by pressing dedicated buttons built into a control panel.

The WRITE LOG MESSAGE and LOGOUT operations work as described in section 2.5; any details specific therapy are described below. The operations SELECT PATIENT, SELECT FIELD, STORE FIELD, and EXPERIMENT MODE control the context of the terminal session. Other operations select a subsystem (a group of related settings) for display in the operations region and for possible subsequent modification: FIELD SUMMARY, GANTRY/PSA, FILTERS/WEDGES, LEAF COLLIMATOR, and DOSIMETRY/THERAPY INTERLOCKS. The EDIT, OVERRIDE and AUTO SETUP operations apply to the settings that appear on the subsystem displays.

If all goes well, a typical treatment sequence is simple: the operator invokes SELECT PATIENT, then SELECT FIELD. At this point the prescribed settings for the newly selected

field usually do not match the actual settings, so all five therapy subsystems are NOT READY. The operator invokes FIELD SUMMARY and then AUTO SETUP. While the leaves, filters, and dosimetry system are being automatically set up, the operator enters the treatment room and manually sets up the external motions using the local controls. The operator leaves the treatment room and closes the door; if the setup is accurate and the cyclotron is running well, all subsystems are READY. The operator presses the START button on the console to begin the run. When the prescribed dose has been delivered, the dosimetry system turns the beam off, and the DOSIMETRY/THERAPY INTERLOCKS subsystem becomes NOT READY. The operator then selects another field, or a new patient, and repeats the cycle.

8.8.1 EDIT, OVERRIDE and AUTO SETUP

These three operations can be applied to many different settings. The following conventions apply to all.

EDIT

EDIT is used to change settings. In therapy mode, prescribed settings in treatment fields can *never* be edited at the therapy console. The only way to change the prescribed settings is to prepare a new prescription (e.g. by using a treatment planning program) on the control system support host.

In therapy mode, the only values that can be changed using EDIT are the preset dose and preset time for a run. Usually these values are taken from the prescription file; however, under some circumstances it must be possible to change them, for example, to complete a run that was terminated prematurely because of a fault.

In experiment mode EDIT can be used to change requested settings in experimental fields. In experiment mode EDIT may be used to change the requested values for the flattening filter and wedge filter selections, the wedge filter orientation, and the position of each collimator leaf. In experiment mode, EDIT must also be used to enter the preset dose and time for runs that use the dosimetry system, because these are not stored in experimental field descriptions.

Changes made using EDIT only apply to the settings that are currently in effect. If another stored field is selected or the same stored field is reselected again, all the edited settings will revert to their stored values.

Using EDIT may change the status of a setting (from OVERRIDE to READY etc.); the changes are indicated on the display.

The actual physical setting of the equipment is not affected by EDIT. To change the actual equipment setting, AUTO SETUP or the manual controls must be used.

EDIT is disabled during runs, and the Therapy Interlocks subsystem is NOT READY while editing is in progress. EDIT is also disabled when no field is selected.

OVERRIDE

The OVERRIDE command changes the status of a single setting from NOT READY to OVERRIDE. The user must confirm each request to OVERRIDE a setting.

In therapy mode, none of the prescribed settings can be changed using EDIT. If the operator wishes to proceed with a treatment where the the actual settings do not match the prescribed settings, it is necessary to use OVERRIDE. The treatment record file indicates which settings were overridden when a treatment was performed.

Invoking OVERRIDE for a setting whose status is already OVERRIDE changes it back to NOT READY (this is done without asking for confirmation). Invoking OVERRIDE for a setting whose status is READY has no effect.

The values of the various settings are continuously monitored. If a value changes from the value which was in place when OVERRIDE was invoked, the setting status reverts to NOT READY. Whenever a new field is selected, all settings will either be READY or NOT READY; none will be OVERRIDE.

AUTO SETUP

The AUTO SETUP command automatically sets some settings to their prescribed (or requested) values. AUTO SETUP is only enabled when a field is selected, a run is not in progress, and the controls for the affected settings are in automatic mode.

AUTO SETUP can be used on an individual subsystem (e.g. the leaf collimator) by invoking it while the display for that subsystem is shown in the operations region. AUTO SETUP can be simultaneously applied to all settings which allow AUTO SETUP by invoking it when the FIELD SUMMARY display is shown.

AUTO SETUP only attempts to change settings that are NOT READY. It does not attempt to change settings that differ from their prescribed (or requested) values but have been set to OVERRIDE.

When AUTO SETUP is invoked, the system checks that all requirements for the operation are satisfied. If not, an explanation appears in a message region, for example,

```
AUTO SETUP not enabled --- collimator in local mode.
```

and the operation terminates. Otherwise, a message appears

```
AUTO SETUP of collimator leaves beginning.
```

Most AUTO SETUP operations accomplish internal machine motions such as flattening filter selection or collimator leaf positioning. When AUTO SETUP is invoked, the requested motions are enabled, the mechanical motion takes place, and then the motion is disabled again. The progress of the auto setup operation is displayed in the operations region as the indicator for the relevant settings switch from DISABLED to ENABLED and back again, and their actual values update on the screen as they change. When AUTO SETUP terminates, either by achieving the setting, detecting a fault, or timing out, the relevant motions are disabled again.

AUTO SETUP must also be used to set up the DMC for each run. Details appear in section 8.9.11.

Some AUTO SETUP operations may take an appreciable time (30 seconds or more). After invoking AUTO SETUP, the user may invoke other operations; it is not necessary to wait for the automatic setup operation to complete.

All AUTO SETUP operations are expected to complete within a certain time that is stored in a file on the support host. If an operation fails to complete within its allotted time, it is terminated; it is said to have *timed out*. If any operations fail or time out, one or more of these messages appears in a log region and is also written to the error log file:

```
<date, time> <setting> did not reach prescribed value.
```

When the AUTO SETUP operation is in progress, the subsystem that contains the affected settings as well as the Therapy Interlock subsystem are NOT READY.

AUTO SETUP is disabled when no field is selected, or a run is in progress, or motion controls for the affected settings are in local mode.

8.8.2 Disabling operations when a run is in progress

Most therapy terminal operations are available whenever the keyswitch is turned on and a user is logged in. However, some operations are disabled when a run is in progress. As a rule, operations that only display the state of the system remain enabled, but operations that can change the state of the system are disabled. The state of the system is considered to include the volatile data within the system, such as the current field description.

A run is considered to be in progress from the time the therapy console operator presses the START button until the THERAPY I-LOCK lamp turns on after the DMC has terminated the treatment. This definition only includes runs that are initiated from the therapy console, while the system is in TREAT mode.

A complementary requirement is that a run cannot be started when an operation that can change the state of the system is in progress. To ensure this, the Therapy Interlocks subsystem is placed in the NOT READY state while these operations are underway. This is similar to the effect of the (hardware) motion enable interlocks.

The operations that are disabled when a run is in progress are SELECT PATIENT, SELECT FIELD, STORE FIELD, LOGOUT, EDIT, AUTO SETUP and OVERRIDE.

8.9 Therapy terminal operations

The following subsections describe each therapy terminal operation in turn.

8.9.1 Login procedure

When the keyswitch is turned on and no operator is logged in, or after the LOGOUT operation is performed, the login sequence proceeds as described in section 2.5.3.

The first time an operator logs in after the system is started up, the console is in therapy mode, and no patient and no field are selected. Subsequently, when an operator logs in, the patient and field remain as they were when the last operator logged out. The terminal session mode (therapy mode or experiment mode) remains as it was when the last operator logged out, unless the console was in experiment mode and the current operator is not authorized for experiment mode. In that case, the console reverts to therapy mode, and no patient and no field are selected.

8.9.2 LOGOUT

LOGOUT works as described in section 2.5.2.

When no operator is logged in, the Therapy Interlock subsystem is not ready, so the THERAPY I-LOCK lamp on the console is on, and the beam cannot be turned on from the therapy console.

LOGOUT is disabled during runs.

8.9.3 SELECT PATIENT

Invoking this operation causes a list of patients for whom field prescriptions are available to appear in the operations region, so that one may be selected (Fig. 8.2).

The list may be displayed at any time, but if the operator attempts to actually select a patient while a run is in progress, a message region displays:

```
Therapy run in progress - new patient cannot be selected
```

In this case, the patient list remains on the screen.

If a run is not in progress and the operator does select a patient, the information in the status region of the display is updated. This message appears in a log region and is also written to a log file:

```
<date, time> Selected patient <nn> <name> <hospital id>
```

The patient list remains in the operations region until the user selects another operation.

When the selected patient is changed, the current field is canceled and no field is selected.

If SELECT PATIENT is invoked when in experiment mode, the session automatically changes back to therapy mode and then the operation proceeds as usual.

OPERATOR: Jon Jacky		PATIENT: None		FIELD: None	
GANTRY /PSA	FILTER /WEDGE	LEAF COLLIM	DOSI- METRY	THERAPY INTLKS	PROTON BEAM
PATIENTS					
243	Doe, Jane	17-Sep-1992	09:34	12-3456-78	
242	Smith, Adam	16-Sep-1992	15:01	23-4567-89	
241	Doaks, Joe	14-Sep-1992	08:12	34-5678-90	
			:		
			etc.		
			:		

Figure 8.2: Terminal screen showing SELECT PATIENT operation.

8.9.4 SELECT FIELD

This operation works much like SELECT PATIENT. Invoking this operation causes a list of field prescriptions for the current patient to appear in the operations region, so that one may be selected (Fig. 8.3).

GANTRY /PSA		FILTER /WEDGE		LEAF COLLIM		DOSI-METRY		THERAPY INTLKS		PROTON BEAM	
OPERATOR: Jon Jacky PATIENT: Adam Smith FIELD: None											
FIELDS											
	Field	Fractions	To date	MU	Total	Expected	To date				
1	Anterior	16	12	122	1952	1464	1464				
2	Left Lateral	16	12	139	2224	1668	1668				
3	Posterior	16	11	124	1984	1364	1364				
4	Right Lateral	16	11	135	2160	1485	1413				

Figure 8.3: Terminal screen showing SELECT FIELD operation.

These field descriptions are stored in files in the control system support host, and are prepared using facilities on that computer (such as a suite of radiation treatment planning programs). There are no facilities for creating files of field prescriptions at any control system console².

The list may be displayed at any time, but if the operator attempts to actually select a field while a run is in progress, a message region displays:

²There is one exception: the STORE FIELD operation adds the current actual machine settings as a new field for the current patient, or (in experiment mode) to the list of experimental fields.

Therapy run in progress - new field cannot be selected

In this case, the list of fields remains on the screen.

If a run is not in progress and the operator does select a field, the information in the status region of the display is updated. This message appears in a log region and is also written to a log file:

```
<date, time> Selected field <nn> <name>
```

The list of fields remains in the operations region until the user selects another operation.

Dose and treatment time

In therapy mode, the prescribed dose for the new treatment field is usually set to the value specified in the prescription file and the operator does not need to enter anything. The system calculates the treatment time from the prescribed dose. In experiment mode, there are no prescribed doses in the file of stored fields. The operator must use EDIT to enter the preset dose and time for each experimental run.

An exceptional case occurs when the operator attempts to treat the same patient with the same treatment field more than once in the same day. This is necessary if a previous attempt to deliver the field ended before the prescribed dose was delivered (because the run timed out due to a low dose rate, or a fault terminated the run). If a field is selected again, and the prescribed daily dose for that field has not yet been delivered, this message appears in a query region:

```
<Field name> has already been delivered today.
```

```
Prescr. daily dose: <nnn.n>   Delivered today: <mmm.m>   Difference: <iii.i>  
Enter preset dose for this run
```

The default dose is the difference value. If the user does not accept the default, this message appears in a confirmation region:

```
This run will not deliver the prescribed daily dose.  
Are you SURE?
```


If the user answers no, the current field is not changed. If the user indicates yes, the field is selected. When the Dosimetry subsystem has loaded the preset dose it will assume the state `OVERRIDE`, instead of `READY`, and the the treatment record file will indicate that the treatment prescription has been overridden.

If the technologist selects a field for which the prescribed number of fractions or prescribed daily total or grand total number of monitor units have already been delivered, one of the following messages appears in a confirmation region:

```
The prescribed number of fractions have already been delivered.  
Are you SURE?
```

```
The prescribed daily number of monitor units have already been delivered.  
Are you SURE?
```

```
The prescribed total number of monitor units have already been delivered.  
Are you SURE?
```

If the operator indicates no, the current field is not changed. If the reponse is yes, this message appears in a query region:

```
Enter preset dose
```

There is no default preset dose. The user must enter a valid daily dose, in monitor units (MU). The system calculates the treatment time for that dose. The Dosimetry Interlock subsystem will be set to `OVERRIDE` and the treatment record file will indicate that the treatment prescription has been overridden.

Selecting rectangular fields in experiment mode

In experiment mode it is possible to create centered rectangular fields ad-lib. This is an alternative to selecting a field from the list of stored field prescriptions (of course, that list may also contain centered rectangular fields).

If the experimenter selects this option, a message appears in a query region:

Available field widths in cm. are

2.5, 5.0, 7.5, 10.0, 12.5, 16.5, 20.5, 24.5, 28.5, 32.5

Enter field width across the leaves

Because the field is formed by a leaf collimator, only a limited set of widths is possible. The default is 10.0 cm.

There is another query for height:

Enter field height in cm.

The range for height is 0.0 to 29.0 cm, and again the default is 10.0 cm:

When a valid field height has been entered, this is made the current field. The system selects the appropriate flattening filter for this field size, and no wedge is used. If the operator wishes to select a different flattening filter or add a wedge, this can be done using the Filter/Wedge operation (section 8.9.9).

Fields created in this way are not automatically stored in the list of fields on the host computer, but the operator may save the field with the STORE FIELD operation.

8.9.5 STORE FIELD

This operation provides a way to record the current treatment unit settings and enter them into the collection of stored field settings. In therapy mode, fields stored in this way are labelled to distinguish them from those created the usual way, by preparing a treatment plan on a remote computer.

When this operation is invoked, the prescribed settings (or requested settings, in experiment mode) are set equal to the current actual machine settings, whatever they are. The current field is replaced by a new current field consisting of all the actual machine settings. This new current field is stored in the collection of fields for the current patient on the control system support host, so it can be recalled later, in exactly the same way as fields whose prescriptions were prepared in the usual way.

If in therapy mode, the collection where the field is stored is all the fields for the current patient; if in experiment mode, it is the single collection of requested experiment mode

fields. The appropriate data items are stored, depending on the mode: external machine motions are not stored in experiment mode. In therapy mode, prescribed dose is set to zero and the number of fractions to one; this requires operators to specify the dose each time they attempt to treat with this field.

When this operation is invoked, a confirmation region appears to give the user the opportunity to cancel the request. If the user confirms that the settings should be stored, a message appears in a query region:

```
Enter field name
```

The system stores the field settings under the name that the user enters and assigns the field a unique identification number. The current treatment unit settings become the current field. The status region of the display is updated with the new field name. The subsystems Filter/Wedge, Leaf Collimator (and in therapy mode, Gantry/PSA) are set to READY. The prescribed dose is set to zero and the Dosimetry subsystem is set to NOT READY, therefore the Therapy Interlocks subsystem is also NOT READY.

This operation is disabled when a run is in progress.

8.9.6 EXPERIMENT MODE

If this operation is invoked while the console is in therapy mode, the system switches to experiment mode.

This operation is only enabled when certain users are logged in (they are identified in a file on the control system support host). When other users are logged in, invoking this operation results in a message appearing in a message region:

```
<user ID> not authorized for experiment mode.
```

If the operator logs out when the console is in experiment mode, the system remains in experiment mode when the next operator logs in at the same terminal, provided that user is authorized for experiment mode. This makes it easy to change operators during experiments. However, if the next user is not authorized for experiment mode, the console reverts to therapy mode.

When the console switches to experiment mode, the current terminal operating mode remains in progress, but no field is selected. The status region changes and subsystems are

NOT READY. The operator must use SELECT FIELD to select an experiment field.

The operator can restore therapy mode by invoking SELECT PATIENT.

This operation is disabled when a run is in progress.

8.9.7 FIELD SUMMARY

This operation causes a display of field information to appear in the operations region (Fig. 8.4). It also enables certain settings to be set up automatically.

OPERATOR: Jon Jacky		PATIENT: Adam Smith		FIELD: Posterior	
GANTRY /PSA	FILTER /WEDGE	LEAF COLLIM	DOSI- METRY	THERAPY INTLKS	PROTON BEAM
FIELD SUMMARY					
POSTERIOR					
SETTING	PRESCR.	ACTUAL	MOTION		STATUS
GANTRY	180.0	90.0	LOCAL	DISABLED	NOT READY
COLLIM	180.0	180.0	LOCAL	DISABLED	READY
WEDGE	45	**	AUTO	ENABLED	NOT READY
W. ROT	270	180	AUTO	DISABLED	NOT READY
FILTER	SMALL	LARGE	AUTO	DISABLED	NOT READY
LEAVES			AUTO	DISABLED	OVERRIDE
MU	105.0	0.0	0.0		READY

Figure 8.4: Terminal display screen showing FIELD SUMMARY operation.

These settings are displayed:

- Field name, or “No field selected”

- Gantry angle
- Collimator rotation angle
- Wedge type. Possible wedge types are: None, 30 deg, 45 deg, 60 deg. Asterisks ** indicate In Transition.
- Wedge rotation angle. Possible angles are: 0 deg, 90 deg, 180 deg, 270 deg. Asterisks ** indicate In Transition.
- Flattening filter. Possible filters are: None, Large Field, Small field. Asterisks ** indicate In Transition.
- Leaf collimator motion controls and status (but not leaf positions)
- Monitor units (dosimetry)

For each setting, several values are shown (Fig. 8.4). The first is the setting value read from the stored field specification; this is called the *prescribed* setting for therapy fields and the *requested* setting for experimental fields. Also shown is the value of the setting measured from the machine, called the *actual* value. The actual values update on the screen as they change (e.g. as the technologist in the treatment room sets up the equipment with the control pedestal and hand pendant). The actual value for monitor units read from both dosimetry channels is displayed; they are 0.0 from the time the field is selected until the run begins; during the run they update as dose accumulates; after the run and until the next field is selected they show the total dose for the run. The state of each setting (READY, NOT READY or OVERRIDE) is also shown. For items which are motions, the status of the motion controls (local/automatic and disabled/enabled) are also shown.

If this operation is invoked when no field is selected, NONE is written in the spaces where the prescribed (or requested) settings usually appear, and all settings are NOT READY.

AUTO SETUP can be invoked if a field is selected, motion controls are in automatic, and a run is not in progress. AUTO SETUP sets the wedge type, wedge rotation angle, flattening filter, and all collimator leaves to their prescribed (or requested) values. Usually, AUTO SETUP also initializes the DMC with the prescribed dose and the preset time calculated from it. However, the DMC is never initialized by AUTO SETUP when the line is selected in TEST mode. Moreover, when a field is first selected in experiment mode, there is no requested dose, so if AUTO SETUP is invoked in this situation, the DMC is not initialized either.

EDIT and OVERRIDE are not available. If the operator wishes to edit or override settings, this must be done using one of the subsystem operations described in the following sections.

8.9.8 GANTRY/PSA

This operation causes a display of the Gantry/PSA subsystem to appear in the operations region, as shown in Figure 8.5. (The PSA is the patient support assembly, or couch). It also enables certain settings to be overridden.

OPERATOR: Jon Jacky		PATIENT: Adam Smith		FIELD: Posterior	
GANTRY /PSA	FILTER /WEDGE	LEAF COLLIM	DOSI-METRY	THERAPY INTLKS	PROTON BEAM
GANTRY/PSA					
SETTING	PRESCR.	ACTUAL	MOTION		STATUS
GANTRY	180	90	LOCAL	DISABLED	NOT READY
COLLIM	180.0	180.0	LOCAL	DISABLED	READY
TURNT	180.0	180.0	LOCAL	DISABLED	READY
TOP	180.0	180.0			
HEIGHT	-14.3	-12.7	LOCAL	DISABLED	
LAT	18.7	19.3	LOCAL	DISABLED	
LONG	23.8	27.5	LOCAL	DISABLED	

NOTE: Stored values for PSA top angle and linear motions are shown, but do not affect READY/NOT READY status.

Figure 8.5: Terminal display screen showing GANTRY/PSA operation.

These items are displayed:

- Gantry angle
- Collimator angle
- PSA turntable angle

- PSA top angle
- PSA height
- PSA lateral position
- PSA longitudinal position

The design is similar to the Field Summary display.

Prescribed values are shown for the PSA top angle and linear motions. It is useful to record these values in the prescription files, because in some treatment techniques these values should be reproducible each time the field is delivered. In particular, the values should be reproducible when the patient is fixed with respect to the treatment table, as when they are immobilized in a mask. However, in other treatment techniques these values are not expected to be reproduced in successive treatment sessions. Therefore, it is not required that the prescribed and actual settings agree, and there is no READY/NOT READY/OVERRIDE status for these items. These status entry for these settings is left blank on the display.

All Gantry/PSA settings shown on this display are external motions, so without further safeguards it would not be safe to set them up remotely³. Therefore, the Gantry/PSA motions are always in local mode, and AUTO SETUP is not available.

OVERRIDE is enabled if a field is selected and a run is not in progress. The only settings that can be overridden are gantry angle, collimator angle and turntable angle.

EDIT is never enabled, not even in experiment mode. Gantry/PSA settings are not part of the stored experiment mode field descriptions.

In experiment mode, there are no prescribed values for any Gantry/PSA subsystem items, so this subsystem is always READY in experiment mode.

8.9.9 FILTER/WEDGE

This operation causes a display of the Filter/Wedge subsystem to appear in the operations region, as shown in Figure 8.6. It also enables certain settings to be set up automatically or overridden, and in experiment mode it permits requested settings to be edited.

These items are displayed:

³In a future version these motions may be automatic as well.

OPERATOR: Jon Jacky		PATIENT: Adam Smith		FIELD: Posterior	
GANTRY /PSA	FILTER /WEDGE	LEAF COLLIM	DOSI- METRY	THERAPY INTLKS	PROTON BEAM
FILTER/WEDGE					
SETTING	PRESCR.	ACTUAL	MOTION		STATUS
WEDGE	45	**	AUTO	ENABLED	NOT READY
W. ROT	270	180	AUTO	DISABLED	NOT READY
FILTER	SMALL	LARGE	AUTO	DISABLED	NOT READY

Figure 8.6: Terminal display screen showing FILTER/WEDGE operation.

- Wedge type (None, 30 deg, 45 deg, 60 deg, ** (in transition)).
- Wedge rotation angle (0 deg, 90 deg, 180 deg, 270 deg, **).
- Flattening filter (None, Small Field, Large Field, **).

AUTO SETUP is enabled if a field is selected, motion controls are in automatic, and a run is not in progress. AUTO SETUP sets the wedge type, wedge rotation angle, and flattening filter to the currently displayed prescribed (or requested) values.

OVERRIDE is enabled if a field is selected and a run is not in progress. All three of the settings (wedge type, wedge rotation and flattening filter) can be overridden.

In experiment mode only, it is possible to EDIT the requested value for all three wedge/filter settings. By repeatedly changing the requested filters and wedges using EDIT, and then using AUTO SETUP to achieve the requested settings, an experimenter can set a sequence of wedge/filter configurations without entering the treatment room.

8.9.10 LEAF COLLIMATOR

This operation displays the status of the Leaf Collimator subsystem in the operations region. Most of the display shows all the collimator leaf positions, in a “beam’s-eye-view” out the collimator (figure 8.7). It also enables leaf settings to be set up automatically or overridden, and in experiment mode it permits requested leaf settings to be edited.

On each line, two opposed leaves are shown. For each leaf, the leaf number, the prescribed (or requested) setting and actual setting are shown in centimeters, to the nearest millimeter. In addition, the prescribed (or requested) and actual position of each leaf is represented graphically. The leaves are always shown in the same fixed orientation on the screen (with leaf 9 in the upper left corner), regardless of the actual collimator rotation angle.

The display uses two different methods to show the region of mismatch between prescribed (or requested) and actual leaf settings. One is used for regions where the prescription calls for an open field but the field is actually occluded by a leaf, and another where the prescription calls for the field to be covered but the field is open. In figure 8.7, the entire mismatch between the prescribed and actual field is of the first type; it is indicated in the figure by filling with hyphens (- - -).

Leaf motion control status (local/automatic and enabled/disabled) is also shown. There is just a single indicator for all leaves because the same status applies to all of the leaves; they are not enabled individually.

OPERATOR: Jon Jacky			PATIENT: Adam Smith			FIELD: Posterior				
PRESC	ACT	MOTION AUTO ENABLED			COLLIMATOR NOT READY			PRESC	ACT	
9	0.0	9			39			39	0.0	0.0
8	0.0							38	0.0	0.0
7	0.0							37	0.0	0.0
6	0.0							36	0.0	0.0
5	0.0	5			35			35	0.0	0.0
4	-9.0							34	7.3	0.0
3	-9.0	--			-			33	7.3	4.5
2	-9.0	--			--			32	8.2	4.5
1	-9.0	--			--			31	8.2	0.0
0	0.0	0			30			30	0.0	0.0
10	0.0	10			20			20	0.0	0.0
11	-6.0	-			--			21	8.2	4.5
12	-6.0	-			--			22	8.2	4.5
13	-6.0	-			-			23	7.3	4.5
14	-6.0							24	7.3	0.0
15	0.0	15			25			25	0.0	0.0
16	0.0							26	0.0	0.0
17	0.0							27	0.0	0.0
18	0.0							28	0.0	0.0
19	0.0	19			29			29	0.0	0.0

Figure 8.7: Terminal display screen showing LEAF COLLIMATOR operation.

OVERRIDE is enabled in both therapy and experiment modes, if a field is selected and a run is not in progress. OVERRIDE applies to all leaves at once, not to individual leaves. It causes the LEAF COLLIM subsystem to toggle between the NOT READY and OVERRIDE states if any leaf positions differ from their prescribed (or requested) values. In the graphic representation of the leaf position, the region between the prescribed and actual leaf positions is indicated differently in the OVERRIDE condition than in the NOT READY condition.

AUTO SETUP is enabled if the collimator is in automatic, a field is selected and a run is not in progress. AUTO SETUP sets all collimator leaves to their prescribed (or requested) values. When AUTO SETUP is invoked, the leaf motions are enabled, the leaves are all moved to their prescribed positions, and the motions are disabled again. If a leaf does not reach its prescribed position within a given time (20 seconds) the motions are disabled and an error message appears in a log region and is logged to a file:

```
<date, time> Leaf <nn> did not reach prescribed position
```

The Therapy Interlock subsystem is NOT READY when the AUTO SETUP operation is in progress.

In addition, an OPEN COLLIMATOR operation is provided at a dedicated pushbutton at the X-ray console. It causes all leaves to move to their fully opened position. This operation can be alternated with AUTO SETUP to make port films. OPEN COLLIMATOR is only enabled when the therapy unit is in X-ray mode (that is, the X-ray tube has been moved to the beam axis).

The collimator leaves move slowly, so the AUTO SETUP and OPEN COLLIMATOR operations may take an appreciable time (15 seconds or so). After selecting any of these, the user may invoke another operation as soon as he or she wishes; it is not necessary to wait for the operation to complete. In particular, if the leaves are in motion attempting to reach one position (e.g. OPEN COLLIMATOR) and the user selects another operation that implies different positions (e.g. AUTO SETUP), the first operation is cancelled and the leaves begin moving toward the more recently requested position.

In experiment mode only, it is possible use EDIT to change the requested value for any leaves. By repeatedly using EDIT and AUTO SETUP, an experimenter can set a sequence of collimator configurations without entering the treatment room.

8.9.11 DOSIMETRY/THERAPY INTERLOCKS: Dosimetry

Invoking DOSIMETRY/THERAPY INTERLOCKS displays the status of the both the Dosimetry and Therapy Interlock subsystems in the operations region (Fig. 8.8). Both subsystems are shown on a single screen and are displayed by invoking a single operation.

This operation also permits the preset dose and time to be loaded into the DMC, and to be overridden and edited.

OPERATOR: Jon Jacky		PATIENT: Adam Smith		FIELD: Posterior	
GANTRY /PSA	FILTER /WEDGE	LEAF COLLIM	DOSI- METRY	THERAPY INTLKS	PROTON BEAM
DOSIMETRY					
SETTING	PRESCR	PRESET	ACCUM	STATUS	
DOSE A	105.0	105.0	000.0	DMC Self-test in progress	
DOSE B	105.0	105.0	000.0	Dosimetry Not Ready	
TIME	2.09	2.09	0.00		
THERAPY INTERLOCKS					
Dosimetry		Check & Confirm		Line Released	
				Gantry/PSA Motion	

Figure 8.8: Terminal display screen showing DOSIMETRY/THERAPY INTERLOCKS operation.

These items are displayed for the Dosimetry subsystem:

- Prescribed dose (in monitor units, MU)
- Preset dose (MU)

- Accumulated dose, monitor A (MU)
- Accumulated dose, monitor B (MU)
- Prescribed treatment time (in minutes and decimal minutes)
- Preset treatment time (minutes)
- Accumulated (elapsed) time (minutes)
- A region showing several items of information about the Dose Monitor Controller (DMC), including the DMC state and any pertinent DMC error messages.

Prescribed, requested and preset values; panel displays

In therapy mode, the prescribed doses shown on the screen are the values read from the treatment prescription, measured in monitor units (MU). There is only one value in the prescription file; the same value is repeated in the rows for dose monitors A and B.

An additional column of *preset* values also appears. The preset doses are the values loaded into the two DMC dose monitor channels, also measured in MU. These two values are always equal. In therapy mode, these are automatically set equal to the prescribed dose when the field is selected; however, they may be changed if the operator uses EDIT. In experiment mode there is no prescribed dose, and the operator must always use EDIT to enter a preset dose.

The beam automatically turns off when the accumulated dose measured by either dosimetry channel reaches the preset value.

The accumulated doses are the doses actually measured by the two independent dosimetry channels, also measured in MU. These are both set to zero when the field is selected and remain at zero until the treatment run begins. When the treatment run is in progress, the values update as the dose monitors measure the accumulating dose, and when the run is finished they show the values that were actually measured by the two channels. The two values may differ slightly.

The preset time display shows the estimated upper limit on the duration of the treatment, measured in minutes and hundredths of minutes. It is automatically calculated from the preset dose, the nominal dose rate of the machine, and a “treatment time factor” which accounts for occasional drops of the dose rate below its nominal value. The beam automatically turns off if the accumulated (elapsed) treatment time exceeds this value. This is a safety back-up feature; normally the beam turns off when one of the dose channels reaches

the preset dose. The preset time value appears on the screen as soon as a field is selected and is retained until another field is selected.

The elapsed time display shows the cumulative beam-on time measured by a timer, measured in minutes and hundredths of minutes. It is set to zero when the field is selected and remains at zero until the treatment run begins. When the treatment run is in progress, it updates as the clock measures the accumulating time, and when the run is finished it shows the duration of the run that was actually measured by the clock. If a run is interrupted, the clock stops and then continues when the run is resumed.

Preset and accumulated values (but not the prescribed value) also appear on the Dose Monitor panel built into the therapy console (chapter 6). However, due to delays in communication and display, the terminal screen might sometimes lag behind the panel displays.

When the system writes treatment record files, log files and diagnostic files, the values that are stored in the files are the values that appear on the terminal display, *not* the values that appear on the panel displays. The system is intended to write treatment records when the values are stable so the screen agrees with the panel displays (e.g., after a treatment is complete). However, diagnostic or log file entries may be written while a run is in progress; these entries may lag behind the panel displays.

Editing preset values

It is possible to use EDIT to change the preset values (not the prescribed values), so the values loaded into the DMC for a run can differ from the prescribed values stored in the prescription file. This makes it possible to deliver the prescribed daily dose for a field in two or more separate treatment runs. This can sometimes be necessary, for example when exposing a neutrogram film to verify the treatment setup, or when problems cause a run to be stopped before the prescribed dose is delivered.

EDIT is enabled if a field is selected and a run is not in progress. Invoking EDIT causes a message to appear in a query region:

Enter preset dose

The default value is the current preset (which is usually the same as the prescribed dose).

If the operator accepts the default, the preset dose is kept at the same value already displayed on the screen. If the operator enters a different preset dose, the new value is displayed on

the screen in both the Dose A and Dose B rows.

After a new preset dose has been entered the system automatically calculates a preset time based on the “dose rate of the day” and the “treatment time factor.” This message appears in a query region:

```
Enter preset time
```

The default is the preset time computed from the newly entered preset dose. The operator may accept the default or enter a different preset time.

It is also possible to use EDIT to change the preset time without changing the preset dose.

The Dosimetry and Therapy Interlock subsystems are NOT READY while EDIT is in progress. If the operator changes the preset dose or time, the Dosimetry system remains NOT READY after the EDIT operation completes. The only way to clear this condition is to perform AUTO SETUP. This ensures that the DMC will be loaded with the preset values that the operator entered before a run can begin. A message such as

```
Select AUTO SETUP to load DMC
```

appears in a message region to remind the operator of this.

If EDIT is used to change the preset dose in therapy mode, then the Dosimetry subsystem will assume the state OVERRIDE, instead of READY, when the DMC is loaded. The treatment record file will indicate that the treatment prescription has been overridden (Fig. 8.9).

In experiment mode there are no dose values associated with stored fields. The preset dose and time are set to zero when experiment mode is selected, and must be changed by the operator, using EDIT. In experiment mode the preset values are not changed when a new field is selected, because experiments frequently consist of series of runs with the same dose setting.

Loading the DMC

It is necessary to load the preset dose and time into the DMC before each run. Until this is done, the Dosimetry system remains in the NOT READY state. The DMC is not

OPERATOR: Jon Jacky		PATIENT: Adam Smith		FIELD: Posterior	
GANTRY /PSA	FILTER /WEDGE	LEAF COLLIM	DOSI- METRY	THERAPY INTLKS	PROTON BEAM
DOSIMETRY					
SETTING	PRESCR	PRESET	ACCUM	STATUS	
DOSE A	105.0	48.5	0.0	DMC Ready	
DOSE B	105.0	48.5	0.0	Dosimetry Override	
TIME	3.15	1.46	0.00		
THERAPY INTERLOCKS					

Figure 8.9: DOSIMETRY/THERAPY INTERLOCKS display showing dosimetry system in override status.

loaded automatically when the field is selected; the operator must request it by invoking AUTO SETUP when the DOSIMETRY/THERAPY INTERLOCKS operation is in progress, or FIELD SUMMARY is in progress. After this has been successfully accomplished, the Dosimetry system can assume the READY state (or the OVERRIDE state, if the preset dose has been edited in therapy mode).

AUTO SETUP is enabled if a field is selected and a run is not in progress. When AUTO SETUP is invoked, the DMC is reset and its initialization self test is performed. Then the DMC is loaded with the prescribed dose and time for the new field, as well as several DMC calibration factors. The entire sequence takes about 30 seconds, mostly devoted to the self-test. The Dosimetry subsystem is NOT READY during this interval. Other operations can be invoked during this interval. If AUTO SETUP is invoked again during this interval, the self-test will be interrupted and then will start over.

By repeatedly using EDIT and AUTO SETUP, a series of runs may be delivered for the same field without entering the treatment room.

AUTO SETUP of the DMC is not enabled when the line is selected in TEST mode. In TEST mode, loading the DMC could interfere with runs initiated by the cyclotron operator.

DMC state

The DMC is the device that actually controls and reads the two dose monitoring channels. The DMC can be in several different states. The overall READY/NOT READY/OVERRIDE state of the Dosimetry system, and whether or not a run is considered to be in progress, are largely determined by the state of the DMC device, as shown in table 8.3.

The Dosimetry subsystem display shows some information concerning the DMC. In Figs. 8.8 – 8.11 these appear in the box with the title bar, STATUS. The first line of text in this box shows the DMC state.

During a normal run, the DMC goes through this sequence of states:

1. Reset
2. Self-test in progress
3. Self-test complete
4. Presets loaded

DMC state	Dosimetry system status		Run status
Reset Self-test in progress Self-test complete	Not Ready		Between runs
Presets loaded Running Stopped	Ready prescr. = preset	Override prescr. \neq preset	Run in progress
Preset dose delivered Termination self-test Idle	Not Ready		Between runs
Treatment time exceeded ERROR			Halted

Table 8.3: DMC state, dosimetry status, and run in progress

5. Running
6. Preset dose delivered
7. Termination self-test in progress
8. Idle

The sequence begins when the operator invokes `AUTO SETUP` for the Dosimetry subsystem. Usually the control system causes the DMC to go through the next three states and enter the “Presets loaded” state without further operator intervention. This portion of the sequence is called “initializing the DMC.” The DMC then waits in the “Presets loaded” state. The operator can only begin a run (by pressing `START` on the therapy console) when the DMC is in this state. Then the DMC enters the “Running” state and goes through the succeeding states without any more operator intervention. The meaning of each DMC state is described in more detail in another volume.

There are three additional DMC states. Each of these states indicates that something has occurred that requires the operator to take some action before the preset dose can be delivered.

- Stopped
- Treatment time exceeded
- ERROR

“Stopped” indicates that the beam has turned off for some reason, (e.g. the operator has pressed `BEAM OFF` on the therapy control console) but the run is still in progress and may be resumed (by pressing `START` on the therapy console, if all interlocks are clear). See Figure 8.10.

“Treatment time exceeded” indicates that the beam turned off because the elapsed time exceeded the preset time before the preset dose was delivered. The run is finished; in order to deliver the remaining dose it is necessary for the operator to reset and reload the DMC by using `AUTO SETUP`.

“ERROR” indicates that the DMC has detected some error or fault; the error message most recently issued by the DMC is also displayed. In this state the beam is off and cannot be turned on. If a run was in progress when the fault was detected, it is finished. The only way to clear the DMC “ERROR” state is to reset and reload the DMC using `AUTO RESET`.

OPERATOR: Jon Jacky		PATIENT: Adam Smith		FIELD: Posterior		
GANTRY /PSA	FILTER /WEDGE	LEAF COLLIM	DOSI- METRY	THERAPY INTLKS	PROTON BEAM	
DOSIMETRY						
SETTING	PRESCR	PRESET	ACCUM	STATUS		
DOSE A	105.0	105.0	56.5	DMC Stopped		
DOSE B	105.0	105.0	56.2	Dosimetry Ready		
TIME	2.09	2.09	1.17	Therapy run in progress		
THERAPY INTERLOCKS						
<table border="1"> <tr> <td>Door</td> </tr> </table>						Door
Door						

Figure 8.10: DOSIMETRY/THERAPY INTERLOCKS display showing DMC stopped while a therapy run is in progress. The technologists have entered the room to check the patient setup.

When the DMC state is “ERROR,” the error code from the DMC is displayed in the first line of the STATUS box (Fig. 8.11).

OPERATOR: Jon Jacky		PATIENT: Adam Smith		FIELD: Posterior	
GANTRY /PSA	FILTER /WEDGE	LEAF COLLIM	DOSI- METRY	THERAPY INTLKS	PROTON BEAM
DOSIMETRY					
SETTING	PRESCR	PRESET	ACCUM	STATUS	
DOSE A	105.0	105.0	56.5	DMC ERROR 40	
DOSE B	105.0	105.0	54.2	Dosimetry Not Ready	
TIME	2.09	2.09	1.17	Allowed dose difference exceeded	
THERAPY INTERLOCKS					
<div style="border: 1px solid black; padding: 5px; display: inline-block;">Dosimetry</div>					

Figure 8.11: DOSIMETRY/THERAPY INTERLOCKS display showing DMC error.

Dosimetry system status

The second line in the STATUS box in the Dosimetry subsystem display shows the Dosimetry system status. This is the same status as indicated by the DOSIMETRY “lamp” in the status region; however, in the box the status is spelled out.

In therapy mode, the dosimetry system status is READY when the DMC state is Presets Loaded and the preset dose and time are the same as the prescribed dose and time. The dosimetry system status is also READY if the DMC state is Running or Stopped and the status was READY when the DMC entered the Running state. The dosimetry system status is OVERRIDE if the DMC state is Presets Loaded and the preset dose or time

differs from the prescribed value, or if the DMC state is Running or Stopped and the status was OVERRIDE when the DMC entered the Running state. In all other conditions, the dosimetry system status is NOT READY. See Table 8.3.

There is no prescribed dose in experiment mode, so the dosimetry system status is READY when the DMC state is Presets Loaded, Running or Stopped and NOT READY otherwise. See Table 8.3.

Run status

The third line in the STATUS box in the Dosimetry subsystem display shows whether a run is in progress. There are three possibilities for the run status (Table 8.3).

The system is between runs when the DMC is in any state except Running, Stopped, Treatment Time Exceeded, and ERROR. When the system is between runs, the third line in the status box is blank (Figs. 8.8, 8.9).

A run is considered to be in progress if the DMC status is Running or Stopped, regardless of the state of other interlocks, so a run may be in progress when the Interlock subsystem — or any other subsystem — is NOT READY. When a run is in progress, the message **Therapy run in progress** or **Experimental run in progress** appears in the third line of the STATUS box (Fig. 8.10).

The third run status occurs when the DMC is in the ERROR or Treatment Time Exceeded state. In this case an appropriate message (for example, the meaning of the error code issued by the DMC) appears in the third line of the STATUS box (Fig. 8.11). The run cannot be resumed from this condition; it is necessary to start over.

CANCEL RUN

The CANCEL RUN operation provides the operator with a way to cancel an incomplete run, allowing normal operations to proceed. Many operations are disabled when a run is in progress, so it may sometimes be necessary to cancel a run after it has begun, that is, after START has been pressed but the preset dose has not been delivered and the treatment has not been stopped by the backup timer or a DMC error. Using CANCEL RUN makes it possible to go on to other operations which are disabled when a run is in progress, such as selecting another field. CANCEL RUN also has the effect of logging a record of the incomplete run.

CANCEL RUN is disabled when the beam is on. An incomplete run can be cancelled by invoking CANCEL RUN when the DMC status is Stopped. The operator can always force the DMC into its Stopped status by pressing BEAM OFF on the therapy console. Invoking CANCEL RUN results in this message appearing in a confirmation region:

```
Are you SURE you want to cancel the rest of this run?
```

If the operator answers yes, a record of the incomplete run is written to the treatment record file and then the DMC is placed in its reset state. A run is no longer considered to be in progress and any operation may be selected, including SELECT FIELD.

8.9.12 DOSIMETRY/THERAPY INTERLOCKS: Interlocks

When the operator invokes DOSIMETRY/THERAPY INTERLOCKS, the operations region also shows the names of all of the treatment interlocks that are currently set (Figs. 8.8, 8.10, 8.11). Some of these are switches or interlock relays in the hardwired safety interlock system (HSIS); others are conditions that effectively act as interlocks. This list includes any interlock that can cause the THERAPY I-LOCK lamp on the therapy console to be on; when the THERAPY I-LOCK lamp is off, the list is empty.

These are the therapy interlocks:

- Therapy console enable key not turned on.
- No operator logged in at the therapy console.
- Line selected in TEST mode.
- Line not selected (other line selected or no line selected).
- Treatment room door open.
- Mobile pedestal (in treatment room) enable key turned on.
- Dosimetry system not ready. This means that the DMC is in a state other than ready, running, or stopped.
- Dosimetry timed out. This means that the DMC remained in the ready and/or stopped states (but not the running state) for a total of more than 15 minutes after first entering the ready state. Whenever this interlock is set, the Dosimetry System

Not Ready interlock is also set. This interlock can only be cleared by performing AUTO SETUP. When the dosimetry system times out, messages appears in a log region and in the DMC status region, and are also written to a log file.

- Check-and-confirm not ready. This means that at least one setting in one of the three subsystems Gantry/PSA, Filter/Wedge, or Leaf Collimator is NOT READY.
- Gantry/PSA motion enabled. This means that any of the individual Gantry/PSA motions is enabled.
- Filter/Wedge motion enabled. This means that any of the individual Filter/Wedge motions is enabled.
- Filter/Wedge motion fault. This means there is no positive indication of some filter or wedge setting, and the motion is disabled. This condition is indicated by ** on the Filter/Wedge display.
- Leaf collimator motion enabled.
- Pressure/temperature correction factor out of range. Automatic pressure/temperature correction for the dose monitors has been selected, but the correction factor differs from the nominal value by too great an amount, or the nominal value is out-of-date (see section 8.9.13).
- Collision detected.
- Update in progress. This means that some therapy terminal operation is in progress that might cause settings or status to change. These operations are SELECT PATIENT, SELECT FIELD, STORE FIELD, LOGOUT, EDIT, OVERRIDE, and AUTO SETUP.

Most of these appear on the Dosimetry/Therapy Interlocks display when they are active. Obviously, the Dosimetry/Therapy Interlocks screen will not be visible at the therapy console if the console key is not turned on or no operator is logged in, so these two interlocks do not appear on this display. They are included in this list for completeness, because they can cause the THERAPY I-LOCK lamp to turn on. Similarly, active interlocks are not shown on the display screen during other operations that use the screen, such as SELECT PATIENT etc., but the THERAPY I-LOCK lamp remains on.

An interlock name appears on the display only if the corresponding interlock is set. If the interlock is clear, its name does not appear on the screen. If any of these interlocks are set, the Treatment Interlock subsystem status is NOT READY.

All of these interlocks are effective in TREAT mode, but some have no effect in TEST mode. Table 8.4 lists all the therapy interlocks; an X indicates each interlock that is also effective in TEST mode.

TEST MODE	THERAPY INTERLOCK
X	Therapy console enable key not turned on No operator logged in at the therapy console Line selected in TEST mode
X	Line not selected (other line selected or no line selected)
X	Treatment room door open
X	Mobile pedestal (in treatment room) enable key turned on Dosimetry system not ready Dosimetry timed out Check-and-confirm not ready
X	Gantry/PSA motion enabled
X	Filter/Wedge motion enabled
X	Filter/Wedge motion fault
X	Leaf collimator motion enabled
X	Pressure/temperature correction factor out of range
X	Collision detected
X	Update in progress

Table 8.4: Therapy interlocks and TEST mode

8.9.13 CALIBRATION FACTORS

This operation displays the following dosimetry-related calibration factors:

- Dose rate of the day
- Treatment time factor
- Standard calibration voltage 1
- Standard calibration voltage 2
- CALVOLT 1
- CALVOLT 2
- Pressure/temperature correction factor of the day
- Automatic pressure/temperature correction factor
- Automatic pressure/temperature correction within range (yes/no)
- Automatic pressure/temperature correction factor in use (yes/no)

The *dose rate of the day* is the dose rate in monitor units per minute that the DMC ion source servo will attempt to achieve. At system startup it is set to a default value stored in a table on the control system support host. The usual value is 50 MU per minute.

The preset treatment time for each field is automatically calculated by dividing the preset dose by the dose rate of the day, and multiplying by a *treatment time factor* that is stored in a file on the control system support host. A reasonable value for this treatment time factor is 1.5.

The *standard calibration voltages* refer to the gain settings of the two dosimetry channels. They can be changed to adjust for differences in the sensitivity of the two channels. The *standard* settings refer to the settings for standard barometric pressure and temperature (1013 mbar and 22 deg C). The actual calibration voltages loaded into the DMC for each run are calculated from these. The calibration voltage numbers range from 500 to 700 on an arbitrary linear scale.

CALVOLT 1 and CALVOLT 2 are the calibration voltages currently in effect. If a run is in progress, these are the values that were actually loaded for that run. These values are obtained from the standard calibration voltages by adjusting the standard calibration

voltage by a barometric pressure/temperature correction factor. The calibration formula and correction factor are defined in another volume.

The CALVOLT 1 and CALVOLT 2 numbers are loaded into the DMC after each self test. The values in the DMC then stay fixed during the run.

The *barometric pressure/temperature correction factor of the day* is computed from readings from a thermometer located near the ion chamber in the treatment head and a barometer located near the treatment area. The readings are made by the operator and manually entered into the computer at the beginning of each day. This entry shows the temperature and pressure that the operator entered as well as the computed correction factor and the date and time when the data were entered. This item is highlighted if the data were entered more than twelve hours ago.

The *automatic pressure/temperature correction factor* is automatically calculated from sensor readings at periodic intervals. This entry shows the temperature and pressure reported by the sensors as well as the computed correction factor. They update on the screen as sensor readings change. The values are displayed whether or not the automatic factor is in use.

Automatic pressure/temperature correction factor in use indicates whether the cyclotron operator has indicated that the automatic pressure/temperature correction factor should be used. If not, the factor of the day is used for each run.

Automatic pressure/temperature correction factor within range is true if automatic pressure/temperature correction factor has been selected by the cyclotron operator and the most recently calculated value is sufficiently close to the factor of the day (e.g within 1 percent).

If the automatic factor is in use but is not within range, or if the factor of the day was entered more than 12 hours previously, the pressure/temperature correction factor out of range therapy interlock is set. If this condition becomes true while a treatment is in progress the run will not be stopped; the interlock will only be set after the run has terminated. Subsequently, it will not be possible to begin another treatment until the interlock is cleared. The cyclotron operator can do this by turning off automatic pressure/temperature correction and reverting to the correction factor of the day, or by entering a new factor of the day.

In therapy mode, this operation acts as a status display. The calibration factors are displayed but cannot be changed.

Experiment mode

When the CAL FACTORS operation is invoked in experiment mode, suitably authorized users may change the settings. Every item that is displayed can be changed except automatic pressure/temperature correction factor, automatic pressure/temperature correction within range (which are calculated in real time from sensor readings) and CALVOLT 1 and CALVOLT 2 (which are automatically calculated for each run).

Authorized operators can use EDIT to select a calibration factor and enter a new value (or to toggle selection of the automatic pressure/temperature correction factor).

The ranges used to check for valid values of each item are stored in a file on the control system support host and cannot be changed at any control system console.

Editing calibration factors is disabled when a run is in progress. The Therapy Interlock subsystem is NOT READY while editing calibration factors is in progress.

AUTO SETUP is not enabled. It is not necessary, because the calibration factors are applied as soon as they are entered, or are loaded into the DMC when the next field is selected. OVERRIDE is not necessary and is not enabled.

There are other DMC calibration factors that cannot be changed at any control system terminal. They must be changed by editing a file on the control system support host:

- Ion source servo feedback constant
- Beam position current servo feedback constant in x-direction and y-direction
- Beam position rate servo feedback constant in x-direction and y-direction
- Ratio of neutrons to protons, low limit and high limit
- Beam position current servo, low limit and high limit
- The selection of five parameters whose values are displayed on the DMC front panel displays in the power supply room (these are useful for troubleshooting the DMC).

Chapter 9

Diagnostic and maintenance operations

This chapter describes characteristics of the terminals available for diagnostic and maintenance operations.

9.1 Diagnostic terminals and locations

There are two diagnostic terminal ports that can be used simultaneously. Exactly the same set of operations is offered at both ports. One is in the power supply room, the other is in the control room. A terminal can be mounted on a cart and equipped with a long power cord and a long terminal communications cable¹. This terminal can be plugged into the port in the power supply room and wheeled among the equipment racks. Alternatively, it can be plugged into the port in the control room. It can be used there, or be wheeled into either treatment room, next to the treatment heads or other equipment.

In addition to the two diagnostic terminals on site, there is a terminal line connected to a modem that can be accessed through the telephone system. To ensure safety and security, it is not possible to operate the facility from off site. The dial-up terminal only offers status displays. It works very similarly to the status display terminal in the control room, except that it is necessary to log in before any status displays can be selected. This ensures that all logins from off site will be logged.

¹An RS-232 cable or Ethernet cable, depending on the terminal type

9.2 Diagnostic display

The status region on a diagnostic terminal always includes the ID (username) of the person who is logged in (or “none” if no operator is logged in). In addition, the status region includes a depiction of “lamps” that behave exactly as the Standby 1 and Standby 2 lamps on the cyclotron control console, and an additional “lamp” to indicate the currently selected line and mode; this lamp corresponds to the lamp which is currently lit on the beam line status panel on the cyclotron control console (chapter 3). These lamps are automatically updated on the screen when they are changed. See Figure 9.1.

9.3 Keyswitch

These diagnostic terminal operations are available regardless of the state of any keyswitches, or whether or not any operators are logged in at the console terminals in the control room.

9.4 Diagnostic operations summary

Diagnostic operations are classified into five groups:

- Generic operations
- Cyclotron console operations
- Parameter control operations
- Status display operations
- Controller operations

9.5 Generic operations

The generic operations LOGOUT, the Login procedure, and WRITE LOG MESSAGE work exactly as described in section 2.5 at all diagnostic terminals, including the off-site terminal.

9.6 Cyclotron console operations

These operations emulate the functions of buttons on the cyclotron control. The buttons whose functions are provided are:

- Standby 1 (SB1)
- Standby 2 (SB2)
- Reset
- Global Reset

These operations work similarly to the buttons described in chapter 3, almost as if the diagnostic terminal had dedicated buttons wired in parallel with the actual cyclotron console buttons. This means that if the system has been placed into Standby 2 at the cyclotron console, it can be toggled back to Standby 1 from the diagnostic terminal (etc.).

The only difference is that when any of these operations is selected, the operator must confirm the request:

```
Begin transition to Standby 1. Are you SURE?
```

None of these operations are provided at the dialup terminal.

It is possible that different users at the cyclotron console and a diagnostic terminal might request the same (or conflicting) operations at almost the same time. If this unlikely event occurs, the control system will enter a state consistent with one request or the other; it will not “crash,” “hang,” or enter some inconsistent state.

9.7 Cyclotron parameter operations

The SET VALUES operation is provided at the on-site diagnostic terminals (but not the off-site terminal). This operation works exactly as it does at the cyclotron operations terminal (chapter 4).

It is possible that different users at the cyclotron operations terminal and a diagnostic terminal might request the same (or conflicting) operations at almost the same time. In that

case, the control system will enter a state consistent with one request or the other; it will not “crash,” “hang,” or enter some inconsistent state.

9.8 Status display operations

The SELECT STATUS DISPLAY operation is provided at all diagnostic terminals, including the off-site terminal. This operation works exactly as it does at the cyclotron status display terminal (chapter 5).

9.9 Controller operations

The on-site diagnostic terminals provide special facilities for communicating with the auxiliary controllers, including the dose monitor controller (DMC) and treatment motion controller (TMC) for each treatment room, the leaf collimator controller (LCC) for the isocentric room and the tuning module controller (TUM) for the cyclotron control console. These controllers are described more fully in [1].

Each controller is operated by sending commands (which are strings of text) over a terminal communications line². When a controller receives a command, it usually performs some action, and may also respond by sending acknowledgement messages, error messages, and status information (also strings of text) back over the terminal line. Normally, command strings are constructed and sent and responses are received and processed by the programs running on the cyclotron main computer (CMC) that also drives all the terminals; this activity is not seen by users. However, it is sometimes useful for engineers to observe the controller communications, or to type control strings and observe responses.

The on-site diagnostic terminals provide a *monitoring and pass-through* facility for each controller. Engineers may observe the communications traffic between the CMC and each controller on a diagnostic terminal. Engineers may type commands at a diagnostic terminal; the pass-through facility passes the commands to the appropriate controller and also displays any response from the controller on diagnostic the terminal.

There is a separate operation to invoke the monitor and pass-through facility for each controller:

- Isocentric room dose monitor controller

²This may be an RS-232 line or the Ethernet, depending on the controller.

- Isocentric room treatment motion controller
- Isocentric room leaf collimator controller
- Fixed beam room dose monitor controller
- Fixed beam room treatment motion controller
- Tuning module controller

When the engineer invokes one of these facilities, the operations region clears and displays a banner that names the controller. A new file is opened on the control system support host, to record the dialog with the controller, and a message **Log file <filename> opened.** appears in a log region.

Subsequently, the operations region displays the ongoing communications between the CMC and the controller. The dialog appears just as it would at a terminal connected to the communications line to the controller, except each string from the CMC is preceded by the label **CMC>** and each string from the controller is also labelled (e.g. **DMC>**). The operations region scrolls as communications proceed (Fig. 9.1).

The engineer types strings in a query region; usually the string is passed through to the controller. The pass-through facility does not perform any syntax checking or other error checking at this point; whatever the engineer types is passed through to the controller.

If the string is passed through to the controller, it also appears in the operations regions, prefixed by a label based on the engineer's user ID (e.g. **JON>**). The controller's response also appears in the operations region, prefixed in the usual way. The pass-through facility ensures that commands from the engineer and from the usual control programs do not become scrambled together, but are sent in sequence. It also ensures that the required communications protocol with the controller is observed (for example, that a command is not sent until the response for the previous command has been received).

Everything that appears in the operations region, including all the traffic between the CMC and the controller, whether it was initiated by the CMC software or the engineer, is copied to the log file on the control system support host.

If the first character that the engineer types is an exclamation point (!), then the entire line of text is not passed through the controller, however it does appear on the display and is logged in the file. This allows the engineer to annotate the dialog with comments.

The query region also offers the engineer the option of closing the dialog. If the engineer selects this option, the log file on remote host is closed, and a message appears in a log

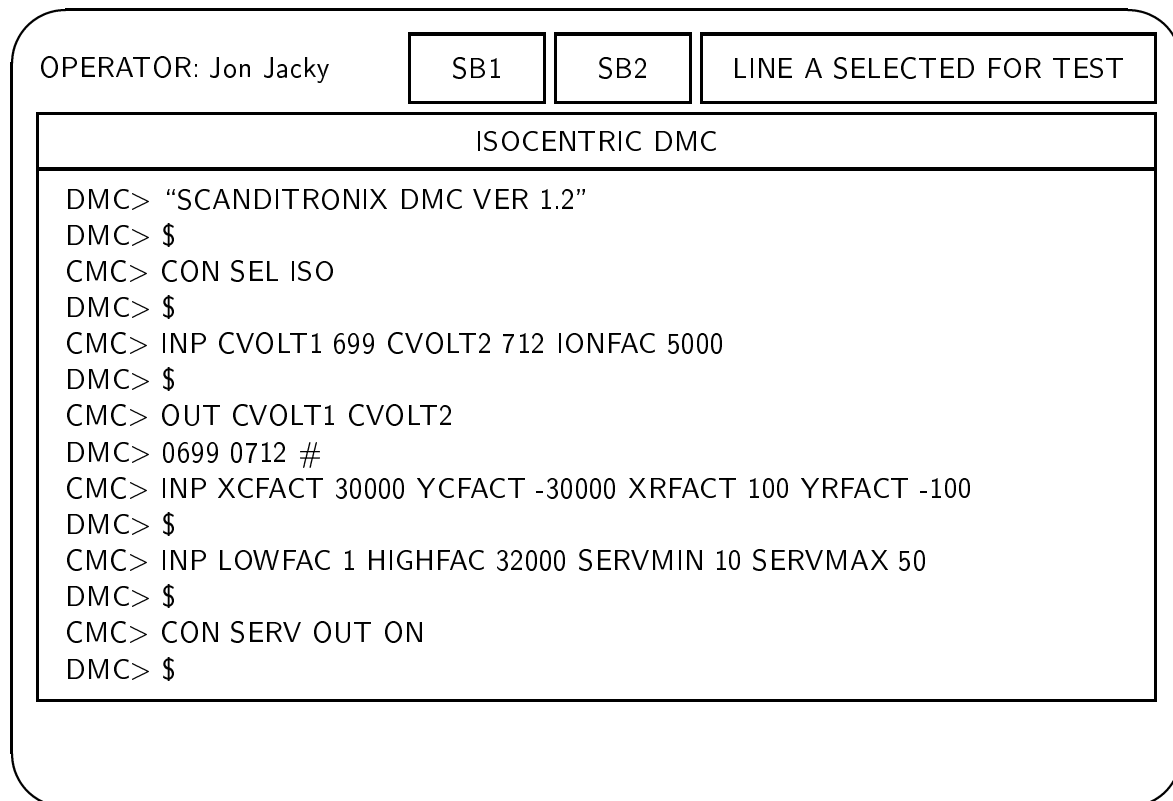


Figure 9.1: Diagnostic terminal screen showing monitor/pass-through facility in use

region, `Exit from monitor/pass-through session. Log file <filename> closed.`

The monitoring and pass-through facility is available while the system is running and while other terminals are in operation, subject to certain safety limitations.

9.9.1 Safety limitations

There are potential safety hazards in sending commands to controllers while treatments are in progress. Therefore, the pass-through facility will only permit certain commands to be passed to a controller when the associated line is selected in TREAT mode. The only commands which are permitted are those that cause the current values of internal controller parameters to be transmitted back on the communications line, but do not otherwise change the state of the controller or the controlled equipment. In every controller, these are called OUTPUT commands.

When the line associated with the currently selected controller is selected in TREAT mode, the query region where the engineer types commands indicates that only comments and OUTPUT commands can be entered. If the engineer types any other strings, these are not passed through (and do not appear on the screen or in the log file).

9.9.2 History log

Every message between each controller and the main control computer (including dialog originating from both the engineer and from the control programs) is saved in a *history log* in the control computer memory. Unlike the log files written when the pass-through facility is selected, which just record the traffic for a single controller, the traffic between the CMC and *all* the controllers is logged, with all messages (labelled as to source) in consecutive order. Old messages are deleted from the history log to make room for new ones, so the history log always contains the most recent messages. The capacity of the log is at least large enough to save all the messages required to treat a patient with four fields. If possible, the history log should be made large enough to record a day of activity (50 to 100 fields).

Inspecting the history log may be useful for troubleshooting. Invoking the SAVE HISTORY operation causes the entire contents of the history log in memory to be written out to a file on the control system support host; the history log in memory is then cleared so it can begin filling up again. The message `History saved in file <filename>` appears in a log region.

Chapter 10

System startup and shutdown

10.1 Startup

The startup procedure described here takes place when any one of the following happens:

- The “reset” button is pressed on the CMC (cyclotron main control computer, see chapter 4 in [1]).
- The electrical power to the CMC has been turned off and is turned on.
- A software or hardware failure occurs, causing the CMC to halt and restart.
- The “bootstrap” command is typed at the CMC system console.

At startup, no data transfer to the IOS (Input/Output system, see chapter 4 in [1]) will take place until system initialization proceeds beyond the point where a valid parameter set is established in memory.

The startup procedure will require that the control system support host and the Ethernet link are operating. The console terminal must be on and paper loaded. All CRT terminals and other equipment connected to the control system computer should also be powered on. When the system starts the following lines of information will appear on the CMC console hardcopy terminal in the power supply room:

CNTS Version 1.0 25-MAR-1992

University of Washington Clinical Neutron Therapy System

The date and time are: 23-NOV-1992 09:17:05.32

Date and time (DD-MMM-YYYY HH:MM) [23-Nov-1992 09:17]:

In addition all terminal screens connected to the cyclotron control system are erased and the message

CYCLOTRON CONTROL SYSTEM STARTUP IN PROGRESS

appears in the operations region of each terminal screen.

At this point the operation pauses for action by the cyclotron operator (or whoever is responsible for restart). If the operator merely presses the RETURN key on the CMC console keyboard, the indicated date and time are assumed correct. If the operator enters a new time or date (or both) and presses the RETURN key, the system time-of-year clock is reset and entered time/date is used. If the operator enters data that the system does not recognize as a valid time or date, the prompt is repeated. The time is displayed with seconds and hundredths but entered only to the nearest minute.

If an operator is not present the startup procedure will wait indefinitely at this point. This prevents the system from starting or restarting without the active intervention of an operator in the power supply room.

Next, the following messages appear and are written into a newly created operations log file (on the remote computer system). For example:

```
23-NOV-1992 09:21:07.17 CMC software loaded
23-NOV-1992 09:21:07.53 Operator log initialized
23-NOV-1992 09:21:08.24 Operating data loaded
23-NOV-1992 09:21:08.57 Treatment data loaded
23-NOV-1992 09:21:09.42 Calibration data loaded
...
```

These messages indicate that the CMC has read into its working memory all the data needed from the control system support host disk files in order to run the cyclotron and treatment operations.

Then there is a dialog where the operator indicates whether the last setting (saved in the checkpoint file) should be restored, or another setting should be used.

Then the selected setting is established as the current setting. If the selected setting was the one from the checkpoint file, then the saved setting in the checkpoint file is made the (memory resident) saved setting. Otherwise, the current setting is also made the saved setting. All tuning modules are disabled. The startup procedure compares the digital and analog input channel data and status bits with the settings and control bits and resolves inconsistencies where not prevented by interlocks.

Then there is a dialog where the operator indicates whether the system should be brought up in Standby 1 or Standby 2. The control system starts up all necessary power supplies which are not already running at their correct settings. After the last active setting is established, the terminals at the cyclotron console and therapy control consoles become operational. A message indicating the setting used by the startup process is written to the operator log file and to the dialog region of the cyclotron operations terminal as in the following example:

```
23-Nov-1992 09:23:40.05 Active setting < ... > established
```

Then the following message is written to the operator log file and to the dialog region of the cyclotron operations terminal:

```
23-Nov-1992 09:23:42.39 System initialization completed
```

10.2 Shutdown

To perform an orderly shutdown procedure, the cyclotron operator should first bring the system into Standby 1. The CMC can be shut down by typing `<ctrl-D>` at the control system computer console terminal in the power supply room. Then the system prompts:

```
Are you SURE you want to shut down the control system (y,n) [n]?
```

If the user answers yes, the control system software updates and closes the checkpoint file, updates and closes the treatment data files, and writes the following message to the operator log file,

23-NOV-1992 17:34:12.45 Operator requested shutdown

Then the operator log file is closed, all CRT screens are cleared and disabled, and the CMC halts.

Shutting down the CMC does not change the values of any parameter settings or control bits. These remain stored in the device registers of the IOS, unless IOS power is lost.

Bibliography

- [1] Jonathan Jacky, Ruedi Risler, Ira Kalet, and Peter Wootton. Clinical neutron therapy system, control system specification, Part I: System overview and hardware organization. Technical Report 90-12-01, Radiation Oncology Department, University of Washington, Seattle, WA, December 1990.