Clinical Neutron Therapy System
Reference Manual

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Abstract

This document is the reference manual for the control program of the isocentric treatment unit of the Clinical Neutron Therapy System (CNTS) at the University of Washington Medical Center. It is intended primarily for cyclotron engineers and software developers, and may also be useful to technicians, physicists, and therapists. This manual describes the functions used to treat patients, perform calibrations, measure physics data, and troubleshoot the treatment equipment. It provides a comprehensive description of the CNTS user interface including the function of each key and dialog, and the meaning of each screen, indicator, and message. It describes program behavior that cannot be directly observed by the operator, including sequencing and communication with each of the attached device controllers. It describes the data files and their contents and explains when each file is read and written. This document is sufficiently thorough to serve as the specification for the control program for the isocentric unit.

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Introduction

This document is the reference manual for the control program of the isocentric treatment unit of the Clinical Neutron Therapy System (CNTS) at the University of Washington Medical Center. It is intended primarily for cyclotron engineers and software developers, and may also be useful to technicians, physicists, and therapists. This manual describes the functions used to treat patients, perform calibrations, measure physics data, and troubleshoot the treatment equipment. It provides a comprehensive description of the CNTS user interface including the function of each key and dialog, and the meaning of each screen, indicator, and message. It describes program behavior that cannot be directly observed by the operator, including sequencing and communication with each of the attached device controllers. It describes the data files and their contents and explains when each file is read and written. This document is sufficiently thorough to serve as the specification for the control program for the isocentric unit.

A separate therapist's guide [5] provides an orientation to the control console, screen and keyboard and explains how to use the control program to treat patients. That material is not repeated here, so you should read the therapist's guide before tackling this more detailed reference manual. A separate system description [9] provides an overview of CNTS and introduces some vocabulary which is used in this manual.

A separate operations manual [1] explains how to install, configure, and maintain the control computer and software. That manual also describes the location, ownership, protection and format of every control program data file. A separate programmer's manual [2] provides information that would be needed to modify the program.

The present manual is sufficiently thorough to serve as the specification for the control program for the isocentric unit. It replaces earlier versions of the specification.

It may be useful to know the project history. The overview [6] was written first, then the user interface specification [7], then the device interface specification [3]. The formal specification in Z ([4] and several unpublished fragments) was based on those earlier reports. Then the program code was written, based initially on the formal specification, but also incorporating many additions and revisions based on experience with the program. Finally this manual was written, to provide a comprehensive reference that is consistent with the program version in clinical use.

Conformance of the control program to this manual has been confirmed by inspection of the control program code and by operational experience.

Notational conventions

Identifiers and values that appear on the control program display appear in sans-serif font (for example CAL GAIN 1, No operator). Terms with a special meaning in this document appear in italics when first defined (*therapy parameters*, *treatment phases*). Operations that the user invokes by pressing keys or buttons appear in bold (**START**, **Auto Setup**). Messages written by the control program or the controllers appear in typewriter font (`TREATMENT FINISHED ...`, `INP MAXPOS 08`), as do file names (`prescr.dat`).

Chapter 1

Control program state variables

The state of the therapy equipment and the treatment session is represented in the control program by variables called *session variables*, *therapy parameters*, *field flags*, *calibration constants and factors*, *interlocks*, *status bits*, *treatment phases*, and *timers*. Related state variables are grouped together in *subsystems*.

This chapter defines all of the variables and subsystems and introduces much of the vocabulary used in the rest of the manual. It describes the values that each variable can assume and explains what the values mean (what they indicate about the condition of the machine or treatment session). However the details of how and when the variables change value during treatment operations are deferred until later chapters. The details of where variables are displayed and how their values are represented on the screen are deferred as well. Therefore this chapter contains many forward cross-references to content in later chapters.

The collection of variables and their values are largely determined by the therapy equipment or the treatment procedure and are unlikely to change much, even when the program is changed. Therefore they are described here in their own chapter. The remaining chapters describe features that result from program design decisions which might have been made differently and could change in the future.

1.1 Session variables

The session variables represent aspects of the treatment session that concern access to the prescription database, including authorization. They are *operator*, *mode*, *patient* (or experimental *study*),

and *field*.

The values of the session variables are always visible on the display.

The *operator* identifies the therapist (or technician, engineer, or physicist) on duty. Each operator is either a *therapist* or a *physicist*. The list of operators and and their authorizations appear in the file `oper.dat` (see [1] for the exact contents, format, location, ownership and protection of this and all other data files). When no operator is logged in, this variable has value No operator.

The *mode* is either *therapy* or *experiment*. In therapy mode the control program accesses a database of patients and therapy field setups which are stored in the files `prescr.dat` and `accum.dat`. In experiment mode the program accesses a database of studies and experimental field setups in `exper.dat`. In experiment mode the program performs fewer checks and keeps fewer records. The program can be in experiment mode only when the operator is a physicist.

The *patient* identifies the patient under treatment, and is associated with a particular collection of therapy fields in the database. In experiment mode, there is a *study* instead of a patient. When no patient (or study) is selected, this variable has value No patient.

The *field* identifies the treatment (or experiment) field being set up or delivered. It is associated with a particular collection of therapy parameters (fewer in experiment mode) and their prescribed values. The current field is selected from the fields associated with the current patient (or study). When no field is selected, this variable has value No field. When patient is No patient, field is No field.

1.2 Therapy Parameters

Therapy Parameters are variables that appear in prescriptions (Table 1.1). Each parameter is assigned to a subsystem and is associated with a controller that the program uses to read and set the parameter values (Table 1.2).

There are three types of parameters: *scales*, *indicators* and *counters* (Table 1.1). *Scale* parameter values, for example leaf settings, are digitized versions of analog values that vary continuously over a range. *Indicator* parameters, for example wedge selection, take on a few discrete values. *Counter* parameters, for example total dose, have values that accumulate over the course of a single run or the entire course of treatment. The range of each parameter that is permitted in prescriptions appears in the table and the coordinate system conventions (rotation directions etc.) appear in Appendix B of [8]. In addition to the values in the table, each parameter may have the value blank to indicate that the value is uninitialized or unavailable. The blank value and other erroneous or out-of-range

values is indicated on the screen by a row of asterisks or by some other method (chapter 8).

Most parameters are associated with several values. There are four kinds of values: *prescribed* values, *preset* values, *actual* values, and *accumulated* values (see comments with Table 1.2).

Parameter values appear on the various subsystem displays.

In this manual, and also in messages and prompts that appear on the display, parameter values are sometimes called *settings*. Parameters are identified by name, while settings are numbers.

1.2.1 Prescribed parameter values

The program reads the *prescribed* value from the prescription file `prescr.dat` (or `exper.dat`). Parameters marked T in Table 1.2 have prescribed values in therapy mode, while parameters marked E have prescribed values in experiment mode.

The prescribed value of each parameter must lie within the range indicated in Table 1.1. If the prescription file contains a value outside this range, the control program indicates an error, and will not attempt to set up the subsystem that contains the parameter. It is not possible to overcome this problem by overriding the actual value.

There are two exceptions where the prescribed value is not read from the prescription file: FILTER and TIME. The program computes their prescribed values when the operator selects the field.

The program computes the prescribed flattening FILTER from the prescribed leaf settings. It selects the small field filter whenever the field shape determined by all the leaves fits inside a 12.5 cm square centered on the central axis, and the large field filter otherwise[1]. The program never selects none (in experiment mode only, the operator can select no flattening filter).

The program computes the prescribed treatment backup TIME from the preset DOSE and two dosimetry calibration factors TIME FACTOR and DOSE RATE (section 1.4.2) by the formula:

$$\text{TIME} = \begin{cases} \text{TIME FACTOR} \times \text{DOSE / DOSE RATE} \\ \\ 0.50 \text{ min} \end{cases} \quad \text{(whichever is greater)}$$

When the field is No field, the prescribed value of every parameter is blank in both modes.

[1] If any leaf is exactly on the border at 6.25 or -6.25 cm, the large field filter is selected.

Name	Description	Type	Units	Min.	Max.	Tol.⋆
GANTRY	Gantry rotation	Scale	deg	0.0	359.9	0.5
COLLIMATOR	Collimator rotation	Scale	deg	75.0	284.0	0.7
TURNTABLE	Couch turntable rotation	Scale	deg	62.0	298.0	0.7
LATERAL	Couch lateral position	Scale	cm	25.9	75.0	
LONGITUDINAL	Couch longitudinal position	Scale	cm	0.1	99.5	
HEIGHT	Couch height	Scale	cm	94.8	160.9	
TOP	Couch top rotation	Scale	deg	0.0	359.9	
WEDGE TYPE	Wedge selection	Indicator	deg	0, 30, 45, 60‡		
WEDGE ROT	Wedge rotation	Indicator	deg	0, 90, 180, 270		
FILTER	Flattening filter	Indicator		none, large, small		
LEAF 0	Collimator leaf 0	Scale	cm	-15.00	3.5	0.15†
⋮						⋮
LEAF 19	Collimator leaf 19	Scale	cm	-15.00	3.5	0.15
LEAF 20	Collimator leaf 20	Scale	cm	-3.5	15.00	0.15
⋮						⋮
LEAF 39	Collimator leaf 39	Scale	cm	-3.5	15.00	0.15
DOSE	Daily dose	Counter	MU	0.0	999.8	
TIME	Treatment time	Counter	min	0.0	99.99	
FRAC	Treatment days	Counter		0	99	
TOTAL MU	Total dose	Counter	MU	0.0	9999.9	

The Min. and Max. columns show the range permitted for prescribed and preset values. The actual values may exceed these ranges.

‡ The WEDGE TYPE, WEDGE ROT and FILTER actual values may take on the value displayed as ⋆⋆⋆ to indicate that the actual mechanism is between positions.

⋆ Tolerances are read from a file. The table shows the tolerances in use at this writing. See section 1.2.7.

† Indicated leaf tolerances are for open leaves. For closed leaves the tolerance is 0.20 cm.

Table 1.1: Therapy parameter names and descriptions

Name	Subsystem	Controller	Therapy Mode	Experiment Mode	Accum.	Motion Enable	Auto /Local
GANTRY	Gantry/Couch	TMC	T			M	
COLLIMATOR			T			M	
TURNTABLE			T			M	
LATERAL						M	
LONGITUDINAL						M	
HEIGHT						M	
TOP							
WEDGE TYPE	Filter/Wedge	PLC2	T	E		M	X
WEDGE ROT			T	E		M	X
FILTER			T⋆	E		M	X
LEAF 0 – 39	Leaf collimator	LCC	T	E		M‡	X
DOSE	Dosimetry	DMC	T†	P	A		
TIME			T⋆†	P			
FRAC			C		A		
TOTAL MU			C		A		

All parameters have actual values in both modes, except those marked C.
There are two actual values for DOSE, DOSE A and DOSE B

T — This parameter has prescribed and preset values in therapy mode.

T⋆ — The prescribed values of these parameters are not read from the prescription file, they are computed by the program from other prescribed parameters.

T† — In therapy mode the operator can edit the preset values for these parameters only.

E — This parameter has prescribed and preset values in experiment mode.

P — In experiment mode this parameter has no prescribed value, but it has a preset value.

C — There are prescribed values for these parameters in therapy mode only, but no preset values and no actual values.

A — The program records the accumulating total value for all runs for this parameter (therapy fields only)

M — This parameter has a motion enable relay.

X — This parameter has an auto/local control.

M‡ — There is a single motion enable relay and a single auto/local control for all 40 leaves.

Table 1.2: Therapy parameter characteristics

In experiment mode the prescribed values for the WEDGE TYPE, WEDGE ROT, and FILTER parameters are not the values read from (or derived from) the file `exper.dat`. Instead, they are the same as the actual values for those parameters (whatever the actual values happen to be). The only exception to this is the experiment field copied from the most recent therapy field (which is always study 1, field 1, see sections 5.4.2 and 5.4.4). For this field, the prescribed values from the therapy mode field are assigned to the prescribed values for the experiment mode field (see also section 5.4.5).

1.2.2 Preset parameter values

The program uses the *preset* parameter value to set up and monitor each run. Usually there is a preset value for every parameter that has a prescribed value (Table 1.2). In therapy mode, the preset value is the same as the prescribed value for all parameters except (possibly) DOSE and TIME. In experiment mode the operator may change the preset value of any parameter.

When the field is No field, the preset value of every parameter is blank in both modes.

1.2.3 Actual parameter values

The *actual* values are measured by sensors in the treatment equipment and are read from the controllers indicated in Table 1.2. There is an actual value for every parameter except TOTAL MU and FRAC. There are two actual values for DOSE, read from two independent dose monitoring channels, DOSE 1 (also called DOSE A) and DOSE 2 (DOSE B). The actual value of a counter parameter such as DOSE counts up during a run.

The program *polls* the controllers frequently to keep the actual values current[2]. The program polls the TMC for parameters in the Gantry/Couch and Filter/Wedge subsystems all the time it is running. It polls the LCC for Leaf collimator settings all the time, except when automatic leaf setup is in progress. It polls the DMC for actual (integrated) DOSE and actual (elapsed) treatment TIME only while a treatment run is in progress.

The actual value of a parameter is read from a sensor via a controller, so its value is not constrained by the control program and might exceed the range limits shown in table 1.1.

When the control program is not polling a controller or there is a controller error, the actual values of the scale and indicator parameters associated with that controller are blank.

[2] About once per second at this writing. The polling frequency is limited by the controllers provided by the cyclotron vendor.

Usually the DMC is not polled and the actual values of the counter parameters DOSE and TIME are initialized to blank when the field is selected. Each time the DMC is polled, the actual values are assigned. When the control program stops polling the DMC, the actual DOSE and TIME retain the values they held after the last poll until the next field is selected.

1.2.4 Accumulated parameter values

The control program also maintains the *accumulated* values for DOSE, TOTAL MU, and FRAC. Accumulated values are running totals that persist between runs and indicate the grand total that has accumulated during the day, or during the course of treatment. The accumulated daily DOSE for each field is reset to zero at midnight each night, while the accumulated FRAC and TOTAL MU continue to increase over the entire course of treatment. The control program writes the accumulated values to a checkpoint file after each run so they can always be restored if the program shuts down.

1.2.5 The official dose for the run

The *official dose* for the run is the DOSE value that is kept in the permanent record. It is stored in the the treatment record file and is used to calculate the accumulated DOSE and TOTAL MU. The accumulated DOSE for a field is the sum of the offical dose for every run with that field on the current day. The accumulated TOTAL MU is the sum of the official dose for every run with that field in the entire course of treatment.

During a treatment run the control program polls the DMC periodically to read the two actual DOSE values (section 3.4, fig. 3.5). The program considers the sequence of sampled DOSE values from both channels to determine the official dose. The rules for calculating the official dose recognize that the two dose channels usually differ by a small amount and there may be erroneous (noisy or otherwise corrupted) values in the sequence.

The program assigns an official dose to every run according to the following rules. The program uses the first rule that is applicable, and once the official dose for a run is assigned, it is never changed or revised (not even when subsequent occurences cause other rules to become applicable).

During a run, if the DMC detects an error it autonomously turns off the beam (via the dosimetry relays) and sends an error message to the therapy computer. In addition, if the control program detects a DMC communication error or if the sampled dose data is inconsistent, the control program turns off the beam (via the therapy sum interlock relay) and the official dose is the last apparently valid dose value preceding the error.

The dose increases on each sample by an amount determined by the dose rate and the interval since the previous sample (which may vary slightly). The dose should never decrease; if it does, the program indicates a dose data error. The program also indicates a dose data error if the dose increase exceeds a *jump tolerance*[3]. However the program ignores apparently erroneous readings that occur for only one sample on one channel (these are taken to be noise). In order to be considered an error and cause the beam to turn off, a jump or decrease must occur simultaneously on both channels, or must persist for two (or more) consecutive samples on one channel.

At the end of a normal run, the termination message from the DMC (`Dose reached` or `Time reached`) indicates that the DMC has turned off the beam. The program does not consider the first sample after the message. The program examines the second and third samples after the termination message in both channels. For each channel, the program determines whether a plateau has been reached. A plateau has been reached when the third sample is not less than, and not more than a small *drift tolerance* greater than, the second sample from that same channel[4]. If both channels reach a plateau, the third sample with the higher value is the official dose for the run. If only one channel reaches a plateau, the third sample from that channel is used. If the dose increases again (even if it jumps) after the plateau, the official dose does not change.

If for any reason the dose does not reach a plateau on either channel on the third sample after the termination message, and no error (jump or decrease) occurs, the official dose is not assigned until the operator presses **Confirm** to end the run (the program continues polling the DMC until this time). The **Confirm** box only appears when the beam plug has closed (or has timed out) and no further dose is physically possible. Then the official dose is the greater of the two actual DOSE values at this time.

If the beam is turned off by an interlock or some error condition unrelated to dosimetry, and no subsequent dosimetry-related errors (jumps or decreases) occur, it is usually possible to continue the run once the interlock has been cleared. However, if the operator chooses to terminate the run by pressing **Exit Run**, an official dose must be assigned. Then the official dose is the greater of the two actual DOSE values at this time (the program continues polling the DMC until this time).

This definition of the official dose was chosen for the following reasons: The termination message should indicate that the DMC has turned off the beam. The official dose is assigned as soon as possible because residual radiation present near the ion chambers will add erroneous dose counts in the time after the beam has turned off. We find that the first sample may not measure a stable value and may contain erroneous numbers (with a duplicated leading digit, for example). Normally the dose readings will then stableize when the second and third poll takes place. If the beam is off (the beam plug is closed) and one of the dose channels has reached a plateau, it is not possible for more dose to be delivered. Any increase in the other channel is then interpreted as a drift or readout problem, not a dose delivery error. If for some reason the beam fails to turn off when commanded

[3] At this writing the jump tolerance is 5 MU. It is coded into the program, not read from a file.

[4] At this writing the drift tolerance is 0.2 MU. It is coded in the program, not read from a file.

by the DMC, the dose does not reach a plateau and no official dose is recorded at this time.

An official dose is assigned for every run (possibly not until the end of the run). If an error condition is detected (dose decrease or jump, beam plug fails to close, DMC error message, etc.), the official dose is assigned but a warning message is displayed to the operator (chapter 6, especially section 6.5.5) and a message is logged (chapter 7, especially section 7.7.9). In some situations the DMC Error interlock is set (section 1.5.17). In some situations the *dose warning flag* is set (section 1.3) to indicate that the official dose may not be correct, and to advise the operator to consider other evidence (such as the LED display).

The DMC stores and displays the accumulated dose independently of the control program. The data in control program memory lag behind the data in the DMC until the dose stops changing at the end of the run. If the control program stops running or there is a communication problem between the control program and the DMC, only the data in the DMC are accurate. In these situations the operator should write down the accumulated dose displayed on the LEDs or the mechanical counters so it can be entered into the accumulated dose data file (see the operations manual [1], section 4.3.6).

1.2.6 Motions

Parameters marked M in Table 1.2 represent *motions* that have motion enable relays. For each of these motions there are three signals: the output *request*, and the inputs *drive* and *inconsistent*. The motion signals for all parameters are mediated through PLC2 (not the controller indicated in Table 1.2).

The program sets *request* to ENABLED (or DISABLED) to command the enable relay to enable (or disable) the motion.

The program senses *drive* to detect whether the enable relay has ENABLED (or DISABLED) the motion[5].

The program senses *inconsistent* to detect whether the PLC has determined that the enable relay signals are working properly (clear) or that there may be a problem (set).

Motions marked X in the table can be placed in an *automatic mode* where the operator can set them up by pressing a key at the control console (other motions must be set up in *local mode*, by the operator in the treatment room). For each of these motions there is a signal called *control*.

The program senses the input *control* to detect whether the motion is in AUTO mode or LOCAL

[5]The PLC uses these encodings: ENABLED = 1, DISABLED = 0, inconsistency OK (clear) = 1, not OK (set) = 0, AUTO = 1, LOCAL = 0.

mode. The value blank indicates that the PLC has failed and the signal is not available.

The motion enable status and automatic/local status appear on the subsystem displays.

1.2.7 Parameter status

The control program computes a parameter *status* that indicates when the parameter is ready for a run. The program assigns the status values READY and NOT READY. The operator can assign the status value OVERRIDE, to indicate that the run may proceed in any case.

The program assigns a status to each parameter that has a precribed value, except TIME. Therefore no status is assigned to external motions or dosimetry parameters in experiment mode.

The program computes the status of indicator and scale parameters by comparing the preset and actual values. For the discrete-valued indicator parameters it assigns READY when the actual and preset values are equal and NOT READY otherwise. For the continuous-valued scale parameters it assigns READY when the actual value is within tolerance of the preset value (Table 1.1). The tolerance for each parameter may be different (they are read from a file). The rule can be expressed as a formula. A parameter is READY when:

$$\mid \textit{actual value} - \textit{preset value} \mid \leq \textit{tolerance}$$

Moreover a different (larger) tolerance is used for closed leaves than open leaves (table 1.1).

To provide some immunity from transient noise, the control program does not consider scale parameters to be NOT READY unless actual values remain outside tolerance for at least two consecutive polling cycles. This one-sample noise filter is applied to all scale parameters that have preset values (GANTRY, COLLIMATOR, TURNTABLE and all 40 LEAF parameters).

GANTRY is a special case because its value wraps from 359.9 to 0.0. The tolerance is handled properly at the discontinuity (359.9 is considered to be 0.1 degree different from 0.0).

All forty LEAF parameters use a larger tolerance when their prescribed values indicate they should be closed (against the opposing leaves). At this writing the tolerance is 0.15 cm for open leaves and 0.20 cm for closed leaves.

The program assigns NOT READY when the preset value is blank. In this condition the operator cannot assign the status to OVERRIDE.

The status of the accumulating counter parameters are computed as follows:

DOSE is READY when the accumulated daily dose for the current day is less than the prescribed daily dose, and it has not been overridden[6].

DOSE is NOT READY when the accumulated daily dose equals or exceeds the prescribed daily dose, and it has not been overridden.

DOSE is OVERRIDE when the operator has entered or edited the preset dose value in therapy mode, or has selected a field despite a warning from the control program that the dose would differ from prescribed. There is no explicit override operation for DOSE; it is overridden implicitly when the operator enters or edits it, instead of just accepting the prescribed value (which is the default preset value).

TOTAL MU and FRAC are READY when their accumulated total values are less than their prescribed values, and they have not been overridden.

TOTAL MU and FRAC are NOT READY when their accumulated total values equal or exceed their prescribed values, and they have not been overridden.

TOTAL MU and FRAC are OVERRIDE whenever DOSE is overridden. There is no explicit override operation for these parameters, entering or editing DOSE implicitly overrides these parameters as well. This implicit override is only in effect for as long as the field is selected in one treatment session.

The program does not assign a status to TIME.

1.3 Field flags

For each field in the (therapy) prescription database, there are several *field flags* that indicate the status of the course of treatment using that field. For example the *completion flag* indicates when the course of treatment for that field is finished and the *dose warning flag* indicates when the accumulated dose value for that field may be incorrect. The values of these flags can affect how the field is displayed and may cause a warning message to appear when the field is selected (section 5.4.5). The values of the field flags are stored in `prescr.dat` and `accum.dat`. Table 1.3 shows the flags, their values and their meanings.

[6] The status of the DOSE parameter is not displayed anywhere. It is only used to compute the status of the Dosimetry subsystem.

Dose warning flag	Description
0	No warning
1	Accumulated dose may not be correct
2	Control program may have crashed during a treatment run

Completion flag	Description
T (Treatment)	Presently under treatment.
E (Exceeded)	The accumulated total dose exceeds the prescribed total by more than 2.4 MU.
C (Completed)	The accumulated total dose is at least the prescribed total minus 0.5 MU, but less than the prescribed total plus 2.4 MU
S (Superceded)	No further irradiations are expected, even if the prescribed total dose has not been delivered.
F (Film)	Not used for treatment, just for X-ray films.

Origin flag	Description
T (transferred)	Transferred from treatment planning system
X	Otherwise (more codes may be defined in the future)

Table 1.3: Field flags

1.4 Calibration constants and factors

Calibration constants and factors represent aspects of the treatment machinery (rather than the prescription or the course of treatment). *Calibration constants* are read from files and cannot normally be modified by the operator of the control program. *Calibration factors* are entered or edited by the operator or computed by the control program. There are two groups of constants and factors, one for the dosimetry system and another for the leaf collimator. There are also *temperature* and *pressure* values that contribute to the dosimetry factors.

1.4.1 Dosimetry calibration constants

The control program loads the pertinent dosimetry calibration constants into the DMC before every run (section 3.4, fig. 3.5). All the constants are displayed on the DOSIMETRY CALIBRATION screen (section 8.2.13, fig. A.12).

Dosimetry calibration constants are stored in the file `dosecal.dat`. The only way to change the dosimetry calibration constants is to use a separate **dosecal** utility on the department computer system[7] (or to edit the file with a text editor). Only certain users on the host computer are authorized to change this file.

Table 1.4 shows the dosimetry calibration constants. The values of the constants marked F in the table are used as the default or initial values of the corresponding dosimetry calibration factors (Table 1.5). The values of the remaining constants are used directly, without any subsequent modification by the operator or control program (there are no factors corresponding to these constants). The constants marked D in the table are loaded into the DMC; the rest are used to calculate other factors. The examples in the last column of the table are the values in use at this writing. The control program checks that the value of each constant lies between the Minimum and Maximum values shown in the table; if not, it sets the No Dosim. Cal. Available interlock (section 1.5.14).

The following paragraphs describe each constant.

[7] In particular HP cluster. See the operations manual [1].

Name	Fac.	DMC	Units	Minimum	Maximum	Example
DOSE RATE	F		MU/min	0.0	99.9	60.0
TIME FACTOR	F			1.00	2.00	1.49
CAL GAIN 1	F			600	800	711
CAL GAIN 2	F			600	800	721
DOSE RATE TIME WINDOW			SEC	0.0	300.0	10.0
LOW DOSE RATE FACTOR				0.00	1.00	0.10
XCFACT		D		10000	40000	32000
YCFACT		D		-40000.0	-10000.0	-20000
XRFACT		D		0	2000	1000
YRFACT		D		-2000	0	-1000
MAXRSET		D		2000	10000	9999
MINRSET		D		0	700	0
IONFAC		D		0	10000	5000
SERVMIN		D		0	0	0
SERVMAX		D		0	10	5
LOWFAC		D		-10	0	-1
HIGHFAC		D		0	50000	32000

F There is a calibration factor derived from this constant.

D This constant is loaded into the DMC before each run.

Table 1.4: Dosimetry calibration constants

DEFAULT DOSE RATE is the initial default value for the corresponding factor (section 1.4.2).

TIME FACTOR is the initial default value for the corresponding factor (section 1.4.2).

CAL GAIN 1 and 2 are the calibration constants used by the DMC to convert ion chamber charge signals to monitor units. They are modified by P/T FACTOR (section 1.4.3) to obtain the calibration factors that are loaded into the DMC before each run.

DOSE RATE TIME WINDOW and LOW DOSE RATE FACTOR are the *low dose rate time window* and *rate factor*, used to calculate the low dose rate warning (chapter 6). A warning is issued when the average dose rate over an interval of length DOSE RATE TIME WINDOW when the beam is on is less than LOW DOSE RATE FACTOR $\times$ DEFAULT DOSE RATE.

The remaining constants XRFACT through HIGHFAC are loaded into the DMC before each run (section 3.4, fig. 3.5). They are described in the cyclotron manufacturer's documentation for the DMC [10].

When the value of any of these constants is outside the range shown in Table 1.4, the No Dosim. Cal. Available interlock is set (section 1.5.14).

1.4.2 Dosimetry calibration factors

The control program loads several dosimetry calibration factors into the DMC before every run (section 3.4, fig. 3.5). The other factors are used to adjust these. All the factors are displayed on the DOSIMETRY CALIBRATION screen (section 8.2.13, fig. A.12). Procedures for entering and editing dosimetry calibration factors are described in section 5.7.1.

Table 1.5 shows the dosimetry calibration factors. The values of the factors marked C in the table are based on the values of the corresponding calibration constants (section 1.4.1). The factors marked D in the table are loaded into the DMC; the rest are used to calculate other factors.

There may be several values associated with each factor (Table 1.5). The *manual* value (indicated by M in the table) is entered by the operator (section 5.7.1). The *automatic* value (A) is computed by the program or derived from *actual* values (S) read from sensors.

P/T MODE The operator selects MANUAL (or AUTOMATIC) mode to use the manual (or automatic) values of the P/T FACTOR (section 1.4.3) and other factors. When the program starts up, P/T MODE is AUTOMATIC.

Name	DMC	Calib.	Man.	Auto.	Sens.	Units	Minimum	Maximum
P/T MODE							MANUAL, AUTOMATIC	
PRESSURE			M	A	S*	mbar	980.0	1040.0
TEMPERATURE			M	A	S	°C	19.0	28.0
P/T FACTOR			M	A			0.9400	1.0400
CAL GAIN 1	D	C	M	A			600	800
CAL GAIN 2	D	C	M	A			600	800
P/T STATUS							(several values)	
DEFAULT DOSE RATE		C	M			MU/min	0.0	99.9
TIME FACTOR		C	M				1.00	2.00

D This factor is loaded into the DMC before each run.

C This factor is derived from a calibration constant.

M This factor has a manual value.

A This factor has an automatic value.

S The automatic value of this factor is based on a sensor reading.

S* There are two pressure sensors.

P/T FACTOR can be out of range when both PRESSURE and TEMPERATURE are in range.

Table 1.5: Dosimetry calibration factors and pressure and temperature values

CAL GAIN 1 and 2 are the calibration factors used to convert the ion chamber charge signals to monitor units, obtained by dividing the corresponding calibration constants by the pressure/temperature correction factor:

$$\text{CAL GAIN 1 (factor)} = \text{CAL GAIN 1 (constant)} \;/\; \text{P/T FACTOR}$$

and likewise for CAL GAIN 2. If the pertinet (manual or automatic) P/T FACTOR or CAL GAIN constant is blank, then the CAL GAIN factor is blank also. In automatic mode the gains are computed each time the pressure or temperature sensors are polled. Both gains are loaded into the DMC before each run (but not the pressure, temperature, or correction factor, see section 3.4, fig. 3.5).

DEFAULT DOSE RATE is the requested dose rate from the cyclotron. It may be edited by the operator. The initial default value is the corresponding constant (above). The same value is used in automatic and manual modes (the entry in the automatic column on the display is left blank). The dose rate is loaded into the DMC before each run (section 3.4, fig. 3.5).

TIME FACTOR is used with DEFAULT DOSE RATE to calculate the preset treatment backup TIME setting from the preset DOSE setting (section 1.2.2) by the formula:

$$\text{TIME} = \begin{cases} \text{TIME FACTOR} \times \text{DOSE} \;/\; \text{DEFAULT DOSE RATE} \\ \\ 0.50 \text{ min} \end{cases} \quad \text{(whichever is greater)}$$

TIME FACTOR may be edited by the operator. The initial default value is the corresponding constant (above). The same value is used in automatic and manual modes (the entry in the automatic column on the display is left blank). The treatment backup TIME (not the time factor) is loaded into the DMC before each run (section 3.4, fig. 3.5).

1.4.3 Pressure and temperature correction factor

The control program adjusts the two CAL GAIN factors (section 1.4.2) by the pressure-temperature correction factor P/T FACTOR before every run (section 3.4, fig. 3.5). Several other values, constants and factors are used to compute P/T FACTOR. All of these are displayed on the DOSIMETRY CALIBRATION screen (section 8.2.13, fig. A.12).

These measured values contribute to the calculation of P/T FACTOR (see also Table 1.5):

PRESSURE is the barometric pressure in the treatment room. The manual value is entered by the operator (section 5.7.1). After startup until the operator enters a value, the manual value is blank.

There are two pressure sensors sensed through the PLC (section 3.5). The two sensor readings are displayed on the PLC STATUS screen (section 8.2.12, fig. A.10). The automatic value is computed from the two sensors each time the sensors are polled; it is this value which is displayed on the DOSIMETRY CALIBRATION SCREEN (section 8.2.13, fig. A.12). If the readings from both sensors are available (connected and working), the automatic value is the average of the two sensor values. If only one sensor reading is available, that sensor value is the automatic value. If both sensor readings are unavailable (disconnected or not working), the automatic value is blank.

TEMPERATURE is the temperature in the treatment head near the ion chamber. The manual value is entered by the operator. After startup until the operator enters a value, the manual value is blank. There is a single temperature sensor sensed through the PLC (section 3.5). The automatic value is updated each time the sensor is polled. If the sensor reading is unavailable the automatic value is blank. The sensor reading is displayed on both the PLC STATUS screen (section 8.2.12, fig. A.10) and in the automatic value cell DOSIMETRY CALIBRATION screen (section 8.2.13, fig. A.12).

These calibration constants contribute to the calculation of P/T FACTOR (see also Table 1.6):

PRESSURE DIFFERENCE TOL is the largest difference allowed between the two pressure sensors. If this difference is exceeded, P/T STATUS is assigned the value Pressure sensors differ (Table 1.7). This constant is read from the file `tol.dat`, not `dosecal.dat`.

P/T FACTOR TOL is the largest difference allowed between the manual and automatic P/T FACTOR. If this difference is exceeded, P/T STATUS is assigned the value P/T factor differs from manual (Table 1.7). This constant is read from the file `tol.dat`, not `dosecal.dat`.

P/T DEADLINE is the number of hours that the PRESSURE and TEMPERATURE values entered by the operator (below) can be used. After this deadline expires for either PRESSURE or TEMPERATURE, P/T STATUS is assigned the value Manual correction factor expired (Table 1.7). This constant is read from `dosecal.dat`. The program maintains separate timers for TEMPERATURE and PRESSURE, but the same P/T DEADLINE interval is used for both. When either deadline expires it is only necessary to enter a new value for the item that expired (PRESSURE or TEMPERATURE), but in practice operators always enter both because the DOSIMETRY CALIBRATION display does not indicate which of the two timers expired (section 8.2.13, fig. A.12). On that display P/T ENTERED shows the time when the manual PRESSURE or TEMPERATURE was entered, whichever was entered first.

Name	Fac.	Units	Minimum	Maximum	Example
PRESSURE DIFFERENCE TOL*		mbar	—	—	1.0
P/T FACTOR TOL*			—	—	0.01
P/T DEADLINE		HOURS	1	72	12

⋆ PRESSURE DIFFERENCE TOL and P/T FACTOR TOL only are read from the file `tol.dat`. No range checks are performed on these two constants.
The other constant is read from `dosecal.dat`.

Table 1.6: Pressure/temperature calibration constants

Here is the P/T FACTOR itself, and a related status value (see also Table 1.5):

P/T FACTOR is the pressure/temperature correction factor used to adjust CAL GAIN 1 and 2. It is calculated from PRESSURE and TEMPERATURE by the formula

$$\text{P/T FACTOR} = \frac{1013}{\text{PRESSURE (mbar)}} \times \frac{\text{TEMPERATURE (°C)} + 273}{295}$$

(where PRESSURE is in millibars and TEMPERATURE is in degrees centigrade)

In manual mode, the manual values of both factors are used; in automatic mode, the automatic values are used. The automatic value is computed each time the pressure or temperature sensors are polled. If the pertinent (manual or automatic) TEMPERATURE or PRESSURE is blank, then P/T FACTOR is blank also.

P/T STATUS is computed from the several pressure and temperature values each time the sensors are polled. Table 1.7 shows the rules for assigning the status. Conditions with higher priority appear in the columns on the left; when more than one condition occurs at the same time, the status will indicate the condition with the highest priority. Status values with higher priority appear in the rows nearer the top; when more than one status could be indicated, the status value with the highest priority is assigned.

P/T STATUS is displayed on the DOSIMETRY CALIBRATION screen (section 8.2.13, fig. A.12). Its text is diplayed in black when the Pressure/Temperature interlock (section 1.5.13) is clear and red when it is set.

P/T STATUS and P/T MODE determine when the Pressure/Temperature interlock is set (the logic is described in section 1.5.13). The interlock cannot be set while a run is in progress. It is only

used when the DMC is set up. If the interlock is set at the time the control program will not set up the DMC.

P/T Status message	PT exp	T rng	P1 bl	P2 bl	PT rng	PT dif	P dif	P1 rng	P2 rng
Manual correction factor expired	Y								
Temperature outside range	N	Y							
No pressure information available	N	N	Y	Y					
P/T factor outside range	N	N	N*	N*	Y				
P/T factor differs from manual	N	N	N*	N*	N	Y			
Pressure sensors differ	N	N	N	N	N	N	Y		
Pressures outside range	N	N	N*	N*	N	N	N	Y	Y
Pressure 2 outside range	N	N	N	N	N	N	N	N	Y
Pressure 1 outside range	N	N	N	N	N	N	N	Y	N
Pressure 2 unavailable	N	N	N	Y	N	N	–	N	–
Pressure 1 unavailable	N	N	Y	N	N	N	–	–	N
OK	N	N	N	N	N	N	N	N	N

Blank cell indicates *don't care*.

N No (condition is *false* in this cell)

Y Yes (condition is *true* in this cell)

– Condition not meaningful, not considered

N* N* This pair of cells may be N N, N Y, or Y N, anything but Y Y

Conditions appear in order from highest priority (left column) to lowest:

PT exp Manual TEMPERATURE or PRESSURE blank or out of range or P/T DEADLINE expired

T rng TEMPERATURE sensor blank (disconnected, not working) or out of range

P1 bl PRESSURE sensor 1 blank

P2 bl PRESSURE sensor 2 blank

PT rng P/T FACTOR out of range

PT dif Automatic P/T FACTOR differs from manual by more than P/T FACTOR TOL

P dif PRESSURE sensors 1 and 2 differ by more than PRESS DIFF TOL

P1 rng PRESSURE sensor 1 out of range

P2 rng PRESSURE sensor 2 out of range

Status values appear in order from highest priority (top row) to lowest.

When both pressure sensors are not blank, P/T FACTOR is computed from their average.
If one pressure sensor is blank, P/T FACTOR is computed from the other.
When both pressure sensors are blank, P/T FACTOR is blank.

Table 1.7: Pressure/temperature status

1.4.4 Leaf collimator calibration constants

The control program loads the leaf collimator calibration constants into the LCC each time a field is selected (section 3.3). All the constants are displayed on the LEAF COLLIMATOR CALIBRATION screen (section 8.2.14, fig. A.13). The are stored in the file `mlccal.dat`. The only way to set the values of these constants correctly is to perform the control program leaf collimator calibration procedure (section 1.4.4).

Table 1.8 shows the leaf collimator calibration constants. There are 120 constants, three for each leaf. They are stored in the file `mlccal.dat`. The constants are described in the cyclotron manufacturer's documentation [11].

When the value of any of these constants is outside the range shown in Table 1.8, the No Leaf Coll. Cal. Available interlock is set (section 1.5.8).

Constant	Minimum	Maximum
MINPOS for leaves 0 – 39	200.0	400.0
MAXPOS for leaves 0 – 39	0.0	200.0
SCAFAC for leaves 0 – 39	-3276.8	3276.8

There are MINPOS, MAXPOS and SCAFAC values for each leaf, 120 constants in all.

Table 1.8: Leaf collimator calibration constants

1.5 Interlocks

Interlocks are variables that indicate potentially hazardous conditions where certain operations must not proceed. Interlocks take on the two values *set* (potential hazard) and *clear* (safe). The therapy beam can only turn on or remain on when all interlocks are clear. When any interlock becomes set it prevents the beam from turning on, or causes the beam to turn off immediately. Moreover, if any interlocks are set (except the dosimetry relays) the control program will not send the START command to the DMC (this is a prerequisite for turning on the beam, see section 3.4). In addition, some interlocks prevent auto setup operations.

Not all binary indicators are interlocks. Other *status bits* are discussed in section 1.6.

All interlocks are continually displayed on the PLC STATUS screen (section 8.2.12, fig. A.10). Several are also displayed on the appropriate subsystem status displays (sections 8.2.8 through 8.2.11,

figs. A.6 through A.9). When an interlock becomes set during a run, causing the beam to turn off, the control program displays a message box (section 6.4.2) and logs a message (section 7.7.8). At other times, the program does not issue messages when interlocks become set.

Most interlocks described here are *software interlocks* that are computed by the control program. The effects of all the software interlocks are merged into the Therapy Sum interlock which is a program output to the PLC. Some interlocks are *hardware interlocks* that are sensed by the control program (through the PLC). Each hardware interlock is wired into the hardware safety trace (HSIS) and can turn off the beam directly, without any involvement by the control program. When a hardware interlock in the HSIS is set, the relay coil is deactivated and the relay contact is opened. Hardware interlocks do not contribute directly the Therapy sum interlock (it is possible for Therapy sum to be clear when hardware interlocks are set). Most interlocks are assigned to a subsystem (Table 1.10). Hardware interlocks do contribute to computing the status of their subsystem (READY or NOT READY, section 1.9).

Table 1.9 shows the name of each interlock as it appears on the PLC STATUS screen, and briefly describes the condition where the interlock is set, if this is not obvious from the name. For the hardware interlocks, it tells whether the relay coil is activated or deactivated and whether the relay contact is opened or closed when the interlock is set. All interlocks in the safety trace are deactivated with the contact opened when the interlock is set. Table 1.10 shows additional information about each interlock.

Some interlocks are *periodic*: their set/clear value is computed and assigned each time the pertinent controllers are polled (Table 1.10). Others are *event-driven*: their set/clear value is computed and assigned only when particular events occur. The event-driven interlocks are *latching*: once they become set, they remain set until a deliberate action clears them. The periodic interlocks are not latching; they become clear spontaneously as soon as the condition that set them goes away.

The following subsections describe each interlock and the conditions when each interlock is set and clear. Each periodic interlock is described this way: “This interlock is set whenever *condition*”. It is understood that the interlock is clear whenever *condition* is not true. Event-driven interlocks are described this way: “The control program sets this interlock when *event1* and clears it when *event2*.”

1.5.1 Gantry/Couch Check-and-Confirm

Gantry/Couch Check-and-Confirm is set whenever any parameter in the Gantry/Couch subsystem is NOT READY, or any motion in the subsystem is ENABLED, or its enable inconsistency indicator is set.

Name shown on PLC STATUS screen	Set condition	Status of Modicon Coil	Relay Contact	H
Gantry/Couch Check-and-Confirm	Check-and-Confirm not OK			
Collision				H†
TMC Error				
Filter/Wedge Check-and-Confirm	Check-and-Confirm not OK			
TMC Auto Setup	Setup in progress			
Filter/Wedge Fault				
Leaf Collimator Check-and-Confirm	Check-and-Confirm not OK			
No Leaf Coll. Cal Available				
LCC Error				
LCC Auto Setup	Setup in progress			
Dosimetry Check-and-Confirm	Check-and-Confirm not OK			
Dosimetry Relay 1		Deactivated		H
Dosimetry Relay 2		Deactivated		H
Pressure/Temperature				
No Dosim. Cal. Available				
DMC Setup Timeout				
DMC Start Timeout				
DMC Error				
DMC Auto Setup	Setup in progress			
PLC Error				
Relay Inconsistency		Deactivated	Open	H
Therapy Door	Door open	Deactivated	Open	H
Console Enabled	Not enabled	Deactivated	Open	H
Pedestal Key	Enabled	Deactivated	Open	H
Operator Logged In	Not logged in			
Beam Off At A		Deactivated	Open	H
Proton Beam Ready	Not ready	Deactivated	Open	H
Editing In Progress	(none)			
Auto Setup In Progress				
Therapy Sum	Sum not OK	Deactivated	Open	H
Watchdog A OK	Timed out (not OK)	Deactivated	Open	H

H Hardware interlock sensed by PLC
Interlocks not marked H are software interlocks.

† At this writing the collision sensor is not connected (always clear).

Table 1.9: Interlock names and descriptions

Name shown on PLC STATUS screen	Subsystem	Assign.	H
Gantry/Couch Check-and-Confirm	Gantry/Couch	Periodic	S
Collision	Gantry/Couch	Periodic	H†
TMC Error	Gantry/Couch⋆	Event-driven	S
Filter/Wedge Check-and-Confirm	Filter/Wedge	Periodic	S
TMC Auto Setup		Event-driven	S
Filter/Wedge Fault		Periodic	S
Leaf Collimator Check-and-Confirm	Leaf collimator	Periodic	S
No Leaf Coll. Cal Available		Event-driven	S
LCC Error		Event-driven	S
LCC Auto Setup		Event-driven	S
Dosimetry Check-and-Confirm	Dosimetry	Periodic	S
Dosimetry Relay 1		Periodic	H
Dosimetry Relay 2		Periodic	H
Pressure/Temperature		Periodic♢	S
No Dosim. Cal. Available		Event-driven	S
DMC Setup Timeout		Event-driven	S
DMC Start Timeout		Event-driven	S
DMC Error		Event-driven	S
DMC Auto Setup		Event-driven	S
PLC Error		Periodic	S
Relay Inconsistency		Event-driven	H
Therapy Door	Room interlocks	Periodic	H
Console Enabled		Periodic	H
Pedestal Key		Periodic	H
Operator Logged In		Event-driven	S
Beam Off At A		Periodic	H
Proton Beam Ready	Proton beam	Periodic	H
Editing In Progress	(none)	Event-driven	S
Auto Setup In Progress		Event-driven	S
Therapy Sum‡	(none)	Periodic	H
Watchdog A OK♡		Periodic	H

H Hardware interlock sensed by PLC (not included in Therapy Sum interlock)
S Software Interlock included in Therapy Sum interlock

† At this writing the collision sensor is not connected (always clear).
⋆ The TMC Error interlock is also considered part of the Filter/Wedge subsystem.
♢ The program never sets the Pressure/Temperature interlock during a run.
‡ The Therapy Sum interlock is an output to the PLC.
♡ The Watchdog A OK interlock is implemented by a toggle output to the PLC.

Table 1.10: Interlock characteristics

1.5.2 Collision

Collision is a hardware interlock that is sensed through the PLC. It is set whenever a sensor indicates that the therapy head is in contact with something[8].

1.5.3 TMC Error

At startup, the control program sets the TMC Error interlock if the operating system indicates it did not successfully open the port to the TMC. During operation, the program sets this interlock when the operating system indicates it did not successfully send a command to the TMC or did not successfully receive the response, or the TMC fails to respond to a command (times out), or responds with an error message or a message which is unintelligible or not in the expected format, or when the TMC sends an unsolicited or out-of-sequence message.

The control program clears the TMC Error interlock when the TMC responds correctly to the reset command that is sent when the operator invokes the **Select Field** operation.

When the TMC Error interlock is set, the control program does not poll the TMC and the actual values of all the parameters connected through the TMC are blank.

When this interlock is set the program will not attempt to auto setup the Filter/Wedge subsystem.

The TMC Error interlock belongs to both the Filter/Wedge and Gantry/Couch subsystems.

1.5.4 Filter/Wedge Check-and-Confirm

Filter/Wedge Check-and-Confirm is set when WEDGE TYPE, WEDGE ROT or FILTER is NOT READY, or its motion is ENABLED, or its enable inconsistency indicator (determined by the PLC) is set.

1.5.5 TMC Auto Setup

The control program sets the TMC Auto Setup interlock when the operator invokes the Filter/Wedge auto setup operation and the program determines that the operation is permitted. The program sets

[8] At this writing the collision sensor is not connected and this interlock is always clear.

this interlock before it commands the PLC to enable the motions or commands the TMC to begin the motions.

The control program clears the TMC Auto Setup interlock when it has determined that the Filter/Wedge auto setup operation is finished (whether or not it completed successfully). The program clears the interlock after it commands the TMC to stop the motions and commands the PLC to disable the motions. The program also clears this interlock when it sets the TMC Error interlock.

When the TMC Auto Setup interlock is set, the control program will not begin another Filter/Wedge auto setup operation. Each Filter/Wedge auto setup operation must complete (successfully or not) before the operator can begin another (with different preset values).

1.5.6 Filter/Wedge Fault

Filter/Wedge Fault is set whenever WEDGE TYPE, WEDGE ROT, or FILTER is at an in-between position indicated by $\star\star\star$ (Table 1.1), but its motion is not enabled and its enable inconsistency indicator (determined by the PLC) is clear.

1.5.7 Leaf Collimator Check-and-Confirm

Leaf Collimator Check-and-Confirm is set whenever any leaf is NOT READY, or leaf motion is ENABLED, or its enable inconsistency indicator (determined by the PLC) is set.

1.5.8 No Leaf Coll. Cal. Available

No Leaf Collimator Calibration Available indicates that the value of one or more of the leaf collimator calibration constants in control program memory are outside their permitted ranges (section 1.4.4). This could indicate that the leaf collimator calibration constants file is incorrect or corrupted, or that the calibration procedure was performed incorrectly.

When the control program starts up, this interlock is set. The program sets or clears this interlock each time it reads the leaf collimator calibration file. It reads the file at startup and each time the operator selects the leaf collimator calibration screen in experiment mode. If any constant is out of range it sets the interlock; if all constants are in range it clears the interlock. If the program is unable to read the file it does not change the in-memory calibration constants and does not change the interlock.

The program also sets or clears this interlock when the operator selects the **Write File** operation at the end of the leaf collimator calibration procedure. If any constant is out of range the program sets the interlock, displays a warning message, and does not write the leaf collimator calibration file. If all constants are within range the program clears the interlock, writes the file, and displays a message indicating success.

When this interlock is set, the control program will not attempt to auto setup the leaf collimator for a prescribed field or X-ray port.

1.5.9 LCC Error

At startup, the control program sets the LCC Error interlock if the operating system indicates it did not successfully open the port to the LCC. During operation, the program sets this interlock when the operating system indicates it did not successfully send a command to the LCC or did not successfully receive the response, or the LCC fails to respond to a command (times out), or responds with an error message or a message which is unintelligible or not in the expected format, or when the LCC sends an unsolicited or out-of-sequence message.

The program also sets the LCC Error interlock when the LCC fails to load and then write back the correct calibration constant values and tolerance window value at the **Select Field** operation.

The control program clears the LCC Error interlock when the operator invokes the Select Field operation, if the LCC responds correctly to the reset command and then loads and writes back the correct calibration constant values and tolerance window value.

When the LCC Error interlock is set, the control program does not poll the LCC, the actual values of all the leaves are blank, and the PLC is commanded to disable leaf motion. When this interlock is set, the control program will not attempt a leaf collimator auto setup, X-ray port setup, or calibration field setup.

1.5.10 LCC Auto Setup

The control program sets the LCC Auto Setup interlock when the operator invokes the leaf collimator auto setup operation from the keyboard or X-ray controller box, or presses one of the port field buttons on the X-ray controller box, or sets up a calibration field, and the program determines that the operation is permitted. The program sets this interlock before it commands the PLC to enable the motions and commands the LCC to begin the motions.

When the control program determines that the auto setup operation is finished (successfully or not) it command to the PLC to disable the motion and then clears the interock. The program also clears this interlock when it sets the LCC Error interlock.

When the LCC Auto Setup interlock is set, the control program will not begin another leaf collimator auto setup operation from the keyboard or X-ray controller box, and will not begin setup of an X-ray port or calibration field. Each of these operations must complete (successfully or not) before the operator can begin another. This is required by the LCC, which does not respond to new commands while it is setting up the leaves.

1.5.11 Dosimetry Check-and-Confirm

Dosimetry Check-and-Confirm is set whenever DOSE, FRAC, or TOTAL MU is not ready.

1.5.12 Dosimetry Relay 1 and 2

Dosimetry Relay 1 and 2 are two hardware interlocks that are sensed through the PLC. The relays are activated when the interlock is clear. They are controlled by the DMC. Both interlocks are set whenever the DMC determines that the beam is not allowed to be on for dosimetry reasons (for example because the the DMC has not yet been set up, or the preset dose has been delivered).

Both interlocks are supposed to indicate the same condition; they are duplicated for safety in the hardware trace. The control program checks that the two relays are consistent with the treatment phase and with each other; if not, it displays a warning message box and sets th DMC Error interlock (section 1.5.17).

1.5.13 Pressure/Temperature

Pressure/Temperature is set whenever the pressure/temperature calibration factor P/T FACTOR is not acceptable for a run (section 1.4.3). The interlock is set in different conditions, depending on whether the operator has selected MANUAL or AUTOMATIC for the P/T MODE. Table 1.11 shows the conditions where the interlock is set. The conditions are defined more fully in table 1.7. The status messages appear on the DOSIMETRY CALIBRATION screen (section 8.2.13, fig. A.12). They appear in red when the interlock is set.

The Pressure/Temperature interlock is periodic. While a run is in progress the status message may change but the interlock is never set. If the pressure/temperature factor is still unacceptable when

the run is finished, the interlock is set then.

When this interlock is set the program will not attempt to auto setup the dosimetry system.

P/T Status message	P/T MODE	
	AUTOMATIC	MANUAL
OK		
Pressure 1 unavailable		
Pressure 2 unavailable		
Pressure 1 outside range	A	
Pressure 2 outside range	A	
Pressures outside range	A	
Pressure sensors differ	A	
No pressure information available	A	
P/T factor differs from manual	A	
P/T factor outside range	A	M
Temperature outside range	A	
Manual correction factor expired	A	M

A Pressure/temperature interlock set in AUTOMATIC P/T MODE

M Pressure/temperature interlock set in MANUAL P/T MODE

Table 1.11: Pressure-temperature interlock conditions

1.5.14 No Dosimetry Calibration Available

No Dosim. Cal. Available indicates that the value of one or more of the dosimetry calibration constants in control program memory are outside their permitted ranges (section 1.4.1). This could indicate that the dosimetry calibration constants file is incorrect or corrupted.

When the control program starts up, this interlock is set. The program sets or clears this interlock each time it reads the dosimetry calibration file. It reads the file at startup and each time the operator selects the dosimetry calibration screen in experiment mode. If any constant is out of range it sets the interlock; if all constants are in range it clears the interlock. If the program is unable to read the file it does not change the in-memory calibration constants and does not change the interlock.

When this interlock is set, the control program will not attempt to auto setup the dosimetry subsystem.

1.5.15 DMC Setup Timeout

The control program sets the DMC Setup Timeout interlock when the maximum setup time has elapsed after the dosimetry system was set up but it has not been possible to begin a run because not all interlocks have been cleared[9]. The maximum setup time is read from a file; at this writing it is 15 minutes. The control program clears this interlock when a field is selected, or the dosimetry system is set up.

1.5.16 DMC Start Timeout

The control program sets the DMC Start Timeout interlock when the maximum start time has elapsed after the TREATMENT READY . . . Push START message was displayed but the operator has not pushed the START button[10]. The maximum start time is read from a file; at this writing it is 30 seconds. The control program clears this interlock when a field is selected, or the dosimetry system is set up.

[9] The Waiting phase was begun but the Ready phase has not begun (section 1.7).
[10] The Ready phase was begun but the Counting phase has not begun (section 1.7).

1.5.17 DMC Error

At startup, the control program always sets the DMC Error interlock and it remains set until the DMC responds correctly to a reset command. A reset command is sent to the DMC when the operator invokes the **Select Field** operation, and at some other times (section 3.4).

During operation, the program sets this interlock when the DMC fails to respond to a command (times out), or responds with an error message or a message which is unintelligible or not in the expected format, or when the DMC sends an unsolicited or out-of-sequence message. In particular, the program sets the interlock if the DMC responds erroneously to a self-test command.

The program also sets the interlock when the DMC fails to load and then write back the correct CAL GAIN 1 or CAL GAIN 2 calibration factor values or DOSE or TIME preset values at the dosimetry auto setup operation.

The program also sets this interlock if the control computer operating system indicates that it was unable to execute control program statements that communicate with the DMC. This could indicate problems with the communication hardware on the control computer.

The program also sets the DMC Error interlock if the operating system indicates it was unable to start or cancel the timers used to set the DMC Setup Timeout and DMC Start Timeout interlocks (the program must cancel the timer when the expected event occurs before the timeout expires).

The program also sets the interlock when an event occurs that causes one of the following messages to be logged. These events are described in section 6.5.5.

- `Dosimetry relay 1 closed, should be open` (or `relay 2` or `relays 1 and 2`)
- `Dose A` *`nnn.n`* `MU out of range` (or `Dose B`)
- `Elapsed time` *`nn.nn`* `out of range`
- `Delivered dose exceeds limits A` *`nnn.n`* `B` *`nnn.n`* `MU`
- `Excessive dose detected by therapy computer A` *`nnn.n`* `B` *`nnn.n`* `MU`
- `Inconsistent or corrupted dose A` *`nnn.n`* `MU` (or `Dose B`)
- `Simultaneous corrupted dose A` *`nnn.n`* `B` *`nnn.n`* `MU`
- `Elapsed time exceeds limit` *`nn.nn`* `minutes`

The control program clears the DMC Error interlock when the DMC responds correctly to a reset command.

When the DMC Error interlock is set, the control program does not poll the DMC, except in the last five conditions in the itemized list above (beginning with `Delivered dose exceeds limits`). In these five conditions, the communications with the DMC are apparently functioning normally.

If the DMC Error interlock becomes set during a run in a phase where the dosimetry relays are intended to be closed, the program sends the `CON STOP` command to the DMC. This should cause the DMC to open the dosimetry relays, turning the beam off.

If the DMC Error interlock is set at the end of a therapy run, the control program sets the dose warning flag for that field to a nonzero value (section 1.3).

Even when the DMC Error interlock is set, the program will still attempt to auto setup the dosimetry subsystem at the operator's request, because this is the recommended way to clear the interlock.

1.5.18 DMC Auto Setup

The program sets this interlock at the beginning of the dosimetry auto setup operation, before it resets the DMC or commands the DMC to begin its self-test. The program clears the interlock when it has determined that the dosimetry auto setup operation is finished (whether or not it completed successfully). This is required by the DMC, which does not respond to new commands while it is performing its self-test.

When the DMC Auto Setup interlock is set, the control program will not begin another dosimetry auto setup operation. Each dosimetry auto setup operation must be finished (successfully or not) before the operator can begin another.

1.5.19 PLC Error

The control program tests the PLC Error interlock condition on each PLC polling cycle. The program sets this interlock when the operating system indicates it did not successfully send the poll command to the PLC or did not successfully receive the response, or the PLC fails to respond (times out), or responds with a a message which is unintelligible or not in the expected format. The program clears the interlock when the command is sent successfully and a properly formatted response is received promptly.

If the PLC Error interlock is set on one or two successive polling cycles the program logs a message on each cycle. All the signals read through the PLC retain the values they held after the last successful polling cycle.

If the PLC Error interlock is set on three successive polling cycles the control program stops polling the PLC and logs a message. In this condition all the motion interlock inconsistency indicators are set, all the AUTO/LOCAL indicators and the actual temperature and pressure are set to blank, and all the other signals read through the PLC retain the values the held after the last successful polling cycle. There is no way to clear the PLC Error interlock in this condition. To resume normal operation it is necessary to shut down and restart the program.

The PLC Error interlock indicates that communications with the PLC have failed. If it is set at the end of a therapy run, this may indicate that information was lost during the run. In this situation the control program sets the dose warning flag for that field to 1 (sect 1.3).

1.5.20 Therapy Sum Relay Inconsistency

The program sets the Relay Inconsistency interlock when the therapy sum interlock relay input sensed by the program through the PLC is not the same as the therapy sum interlock output commanded by the program through the PLC (allowing for a time delay, five PLC polling cycles at this writing).

During each dosimetry auto setup operation, the control program peforms a test of the therapy sum interlock. The therapy sum interlock is always set during each DMC self-test (because the DMC Auto Setup interlock is set). At this time (allowing for the time delay) the control program checks that the therapy sum relay input indicates that the relay is deactivated. If it is in fact deactivated, the program clears the inconsistency interlock.

If the Relay Inconsistency interlock becomes set during a run after the program has commanded the PLC to deactivate the therapy sum relay, this may indicate that the relay has failed, allowing the beam to remain on when it should turn off. In this condition the control program sends the `CON STOP` command to the DMC. This should cause the DMC to deactivate the dosimetry relays, turning the beam off.

If the Relay Inconsistency interlock is set at the end of a therapy run, the control program sets the dose warning flag for that field to 1 (section 1.3).

1.5.21 Therapy Door

Therapy Door is a hardware interlock that is sensed through the PLC. It is set whenever a sensor indicates that the isocentric therapy room door is not closed.

1.5.22 Console Enabled

Console Enabled is a hardware interlock that is sensed through the PLC. It is set whenever the isocentric treatment console enable key is not turned on.

When this interlock is set the control program does not accept input from the X terminal keyboard (instead it beeps when any key is pressed).

When the operator turns off the console enable key after logging out, the control program sends the reset command to the DMC and the patient and field revert to No patient and No field.

1.5.23 Operator Logged In

The program sets the Operator Logged In interlock at startup and each time an operator logs out. The program clears this interlock each time an operator logs in.

1.5.24 Beam Off At A

Beam Off At A is a hardware interlock that is sensed through the PLC. It is set whenever the BEAM OFF button on the isocentric treatment console is being pressed or has just been pressed (the signal is extended to 1.5 seconds duration by a PLC one-shot).

1.5.25 Proton Beam Ready

Proton Beam Ready is a hardware interlock that is sensed through the PLC. It is set whenever the cyclotron control system indicates the proton beam interlock is not ready.

1.5.26 Editing In Progress

The program sets the Editing In Progress interlock when it begins an editing dialog by displaying any *dialog box*, *confirmation box*, *acknowledge box* or *menu* (sections 5.2.2 and 5.2.3). The program clears this interlock when the dialog is complete and the box or menu disappears. There is only one exception: this interlock remains clear while the operator edits a log message, so it is possible to log a message while the beam is on.

The program also sets this interlock when the operator selects a field, and clears this interlock after the DMC responds to the reset command at select field or dosimetry auto setup. This ensures that an interlock is set during the transition after a field is selected when preset settings are being reassigned and parameter and subsystem status is being recomputed. This can take an appreciable amount of time because high priority device control tasks can preempt and delay the task that reassigns preset setting values.

The program does not set this interlock when a *message box* is displayed (chapter 6).

1.5.27 Auto Setup In Progress

Auto Setup In Progress is the sum (logical *or*) of TMC Auto Setup, LCC Auto Setup, and DMC Auto Setup. It is set when any of these three are set, and clear when all three are clear.

When this interlock is set it is not possible to select a field.

1.5.28 Therapy Sum

Therapy Sum is the sum (logical *or*) of all the other software interlocks (but not the hardware interlocks). It is set whenever any other software interlock is set and is clear only when every one of the other other software interlocks are clear.

Therapy Sum is the only software interlock which is a program output (through the PLC). It drives a relay in the hardwired safety trace. There is an input (through the PLC) that senses the therapy sum relay; this input is used to compute the Relay Inconsistency interlock (section 1.5.20). Therapy Sum does not include the hardware interlocks.

The Therapy Sum interlock is not the same as the THERAPY I-LOCK indicated by a lamp on the treatment console. The THERAPY I-LOCK lamp is set when the Therapy Sum interlock is set as well as under the following conditions:

- Therapy room door open
- One or both dosimetry relays deactivated
- Line not selected in TREAT mode

The THERAPY I-LOCK lamp indicates interlocks which are the responsibility of the therapist but does not include momentary interlocks such as Beam Off At A. It does not include the proton beam interlock which is the responsibility of the cyclotron operator.

1.5.29 Watchdog A OK

Watchdog A OK is set whenever the control program has failed to poll the PLC before a deadline which is set in the PLC program[11]. This interlock indicates that the control program is not running or is running more slowly than it should.

This interlock is implemented differently than all the others. It is a two-state output whose value is changed (toggled) by the control program each time the PLC is polled[12]. If this output dwells at the same value past the deadline, the PLC program sets a hardware interlock.

The control program cannot clear this interlock. The only way to clear this interlock is to restore the control program PLC polling to the proper frequency (usually by restarting the program) and then press the reset button in the HSIS cabinet in the power supply room.

When this interlock is set the Proton Beam interlock is set and the Watchdog A OK status bit input is false (section 1.6).

1.6 Status bits

Status bits indicate binary conditions. They take on the two values *true* and *false*. Some are inputs sensed through the PLC, others are internal state variables (table 1.12). They are used to control sequencing and the display of information. All status bits are continually displayed on the PLC STATUS screen (section 8.2.12, fig. A.10).

Status bits are similar to interlocks (section 1.5) in that they take on two values. However status bits do not behave as interlocks. When a status bit becomes *true*, it does not cause the beam to turn

[11] At this writing the deadline expires 2.0 seconds after the previous poll.
[12] At this writing the polling interval is 1.5 sec.

off, and when a status bit is *true*, it does not cause any subsystem to be NOT READY and does not prevent the control program from sending the START command to the DMC.

Name	H
Start Pressed	H
DMC Timer Enabled	H
Plug Closed	H
DMC Setup Timer	
DMC Start Timer	
Plug Closed Timer	
Path Error	H
Safety Inconsistent	H
Watchdog A OK	H
X-ray Enable Key	H

H Hardware status bits sensed or computed by the PLC
Status bits not marked H are internal program variables.

Table 1.12: Status bits

1.6.1 Treatment sequence status bits

The following status bits are involved in the treatment sequence. When they make transitions from *false* to *true* or vice versa, they can trigger transitions in the treatment PHASE (chapter 2):

Start Pressed is *true* whenever the START button on the isocentric treatment console is being pressed or has just been pressed (the signal is extended to 1.5 seconds duration by a PLC one-shot). The operator presses the START button to command the PLC to start the beam on sequence (the control program does not participate in this). If this bit becomes *true* when the TREATMENT READY or TREATMENT INTERRUPTED message boxes are displayed, they are dismissed (sections 6.3.1 and 6.4.2).

DMC Timer Enabled is *true* whenever the signal that enables the DMC to count elapsed treatment time is asserted. At these times the DMC elapsed time indicator counts up. This signal indicates that Beam Plug A is open so it is possible for the beam to reach the isocentric treatment room.

When the DMC Timer Enabled bit becomes *true*, a Beam On treatment record is written, and if the TREATMENT READY or TREATMENT INTERRUPTED message boxes are displayed, they are dismissed. When this bit becomes *false*, a Beam Off treatment record is written, and if this occurs during a run when there is no `Dose reached` or `Backup time reached` message from the

DMC, the TREATMENT INTERRUPTED message box is displayed (section 6.4.2).

Plug Closed is *true* whenever sensors indicate Beam Plug A is closed. In this condition beam delivery is physically impossible. When this bit becomes *true* at the end of a run, the TREATMENT FINISHED message box appears (section 6.5.1).

DMC Setup Timer is *true* briefly when the 15 minute DMC setup timer expires. This sets the DMC Setup Timeout interlock (section 1.5.15) and causes the SETUP TIMEOUT message box to appear (section 6.2.2).

DMC Start Timer is *true* briefly when the 30 second DMC start timer expires. This sets the DMC Start Timeout interlock (section 1.5.16) and causes the START TIMEOUT message box to appear (section 6.3.2).

Plug Closed Timer is *true* briefly when the 10-second beam plug timer expires but the beam plug has not closed. When this bit becomes *true* at the end of a run, the BEAM PLUG NOT CLOSED message box appears (section 6.5.4).

X-ray Enable Key is *true* whenever the enable keyswitch on the X-ray unit is turned on. If this bit becomes *true* during any of the following treatment phases, the control program sends the reset command to the DMC: Tested Ok, Waiting, Ready, Paused, Term. Wait, Term. Test, Terminated, Stopped, Exited. This causes the dosimetry subsystem to become NOT READY and prevents the DMC from recording the X-ray dose as if it were neutron dose. However the control program does not reset the DMC when the X-ray enable key is turned on during the following phases, because that might cause accumulated dose information in the DMC to be erased: Counting, Resumed, Dose Delivered, Time Exceeded. The control program also does not reset the DMC when the X-ray enable key is turned on during the following phases, because that would be unnecessary: Reset, Self-Test.

TREATMENT FINISHED message box is displayed, the control program dismisses the box and ends the run (section 6.5.1). If this bit becomes *true* after the control program sends the START command to the DMC but the beam is not on, the control program resets the DMC and ends the run.

1.6.2 Indicator status bits

The following status bits (Table 1.12) indicate conditions that can cause message boxes to appear (section 6.6) and messages to be logged (section 7.8).

Path Error is *true* when one of these conditions is true:

1. The PLC has detected an inconsistency in one of the path elements (simultaneous indication of open and closed). In this case the **Beam Path Open** and **Beam Path Closed** lamps at the therapy console will flash in an alternating pattern. This fault creates an interlock in the hardwired trace (safety inconsistent) and can only be overcome after fixing the problem and pushing the **Inconsistency Reset** button in the HSIS cabinet.

2. One of the beam path elements has not reached the closed (or safe) position within 15 seconds of being commanded there. The **Path Closed** light will continue to flash in this case. Apart from the potentially increased background radiation, normal operation can continue in this case. No interlocks are set.

When Path Error becomes *true*, the control program displays the BEAM PATH message box (section 6.6.4).

Safety Inconsistent is *true* whenever the PLC indicates that an inconsistency exists among the signals that indicate relay closures in the hardware safety trace. This fault creates an interlock in the hardwired trace (safety inconsistent) and can only be overcome after fixing the problem and pushing the **Inconsistency Reset** button in the HSIS cabinet. However the control program does not treat the Safety Inconsistent bit by itself as an interlock: if this bit alone becomes set while other interlocks remain clear, it will not cause any control program subsystem to be NOT READY and will not prevent the control program from sending the START command to the DMC (in this hypothetical situation, the interlock in the hardwired trace would prevent the beam turning on).

When Safety Inconsistent becomes *true*, the control program displays the SAFETY TRACE message box (section 6.6.5).

Watchdog A OK is *true* whenever the PLC indicates the Watchdog A OK interlock is clear (section 1.5.29). When this bit is *false*, the proton interlock is set. However that is accomplished by mechanisms outside the control program. The control program does not treat this bit by itself as an interlock.

When Watchdog A OK is *false*, the control program displays the THERAPY WATCHDOG message box (section 6.6.1).

See also [12].

1.6.3 Port film status bits

The signals that sense and control X-ray port film setup through the PLC (Modicon 2) are also considered status bits. Each entry in Table 1.13 refers to a pair of status bits. For each portal

(including the prescribed field) there are two status bits, the input bit *requested* (or *commanded*) and the output bit *achieved* (or *obtained*).

All of these bits are displayed in the PLC STATUS screen.

Name
10 x 10 Field
16.5 x 16.5 Field
20.5 x 20.5 Field
24.5 x 24.5 Field
28.5 x 32.5 Field
Prescribed Field

Table 1.13: X-ray portal control signals

The PLC sets the *requested* bit *true* when the operator presses the button on the X-ray controller unit to request that portal. There is also a button in the treatment room that has the same effect as pressing the Prescribed field button on the X-ray controller. Pressing the Prescribed field button on the controller or in the therapy room is invokes the **Auto Setup** operation for the leaf collimator subsystem (section 5.4.6). Pressing one of the other buttons invokes an auto-setup-like operation for that portal (without changing the prescribed field). Therefore pressing one of these buttons clears the LEAF SETUP FAILED message box, if it is displayed.

The PLC sets the *requested* bit *false* when the *achieved* bit indicates the portal setup was achieved, or PLC program determines that the setup request has timed out.

The control program sets the *achieved* bit to *true* when the LCC indicates that the leaf settings for the requested portal have been reached. The control program sets the *achieved* bit to *false* when the next leaf auto setup operation begins (before the leaf motion is enabled or the LCC is commanded to move the leaves). If the requested portal is the prescribed field, the control program also sets the *achieved* bit to *false* when a new field is selected.

1.7 Treatment phases

Treatment phases are variables that indicate progress through the treatment sequence. They are also called *DMC phases*, as they are directly related to the status of the DMC. Events can cause transitions from one phase to another (chapter 2). The control program may respond differently to events, depending on the values of the phase variables.

The three treatment phase variables are PHASE, RUN and POLL (table 1.14)[13]. PHASE takes on ten different values during a normal treatment sequence and may take on five other values to indicate errors or other exceptional conditions. RUN has the value Running when PHASE indicates that a run is in progress and Setup at other times. POLL has the value Polling when the control program is polling the DMC and Idle at other times.

The PHASE and RUN variables appear on the PLC STATUS display (section 8.2.12, figure A.10). (These variables are not sensed or controlled by the PLC but there was nowhere else to put them.)

PHASE	RUN	POLL	DESCRIPTION
Reset			DMC reset, preparing for run
Self-Test			DMC self-test in progress
Tested OK			DMC self-test completed successfully
Waiting			DMC loaded with cal. factors, preset dose, time, etc. waiting for interlocks to become clear
Ready	R	P	Dosimetry relays energized, waiting for operator to press START button
Counting	R	P	Beam on
Dose delivered	R	P	Preset dose delivered, waiting for beam plug
Term. Wait	R	P	Waiting for operator to confirm end of run
Term. Test			DMC termination self-test in progress
Terminated			Idle after completing termination self-test
Paused	R	P	Beam turned off by interlock
Resumed	R	P	Beam on again after pause
Time exceeded	R	P	Preset time reached, waiting for beam plug
Stopped	R	P	Error condition, dosimetry relays de-energized
Exited			Idle after any exit except termination self-test

Phases above the line occur in this order during an uneventful run.

R RUN has value Running during this phase and Setup during other phases.
P POLL usually has value Polling during this phase and Idle during other phases

Table 1.14: Treatment phases

[13]The nomenclature and other contents of this table will be revised extensively in a forthcoming version of this manual.

1.8 Timers

A complete description of the state of the control program must include the *timers*. Timers are used to schedule periodic activities and timeouts. For each timer there is an interval or *deadline*, there are one or more *start events*, and there may be one or more *reset events*. When a start event occurs, the timer begins counting down toward the deadline. A reset event stops the timer so the deadline never expires (the timer does not resume counting). If no reset event occurs, eventually the deadline expires and the program performs some action.

For example there is a *setup timer* with a fifteen minute deadline. Successfully completing the DMC auto setup operation is the start event. Beginning a run is the reset event. If the deadline expires, the control program displays a message box and sets the DMC Start Timeout interlock.

The timers are described implicitly in other sections of this manual that describe timeouts and periodic activities (for example chapter 3, section 6.2.2, section 6.3.2).

The timers are not displayed anywhere, only their effects are visible.

1.9 Subsystems

There are six therapy subsystems. Each subsystem includes several parameters and interlocks (tables 1.15 and 1.16). For each subsystem the program computes a *status* that indicates whether the subsystem is ready for a run. The three status values are NOT READY, READY and OVERRIDE. The status of all six subsystems is continually displayed at the top of the screen (section 8.1.2, figs. A.1 through B.6).

The program computes subsystem status from the status of all the parameters (section 1.2.7) and interlocks in the subsystem, according to the following rules. When the program does not assign a status to a parameter (DOSE and external motions in experiment mode, TIME in both modes), that parameter does not contribute to the subsystem status.

A subsystem is NOT READY when one or more of these conditions is true:

- One or more of its interlocks is set.
- One or more of its motions is enabled, or a motion enable reading is inconsistent.
- One or more of its parameters is NOT READY.

- An editing dialog is in progress that might change the preset value of one of its parameters.

A subsystem is READY when all its interlocks are clear, all its motions are disabled, and all its parameters are READY.

A subsystem is OVERRIDE when all its interlocks are clear, all its motions are disabled, at least one of its parameters is OVERRIDE, and the rest are READY.

Tables 1.15 and 1.16 show the parameters and interlocks that are associated with each subsystem. Interlocks are identified by the names used in tables 1.10 and 1.9, see the tables for more information. The captions with the tables explain a few special cases.

SUBSYSTEM	GANTRY/COUCH	FILTER/WEDGE	LEAF COLLIMATOR
THERAPY PARAMETERS	GANTRY COLLIMATOR TURNTABLE LATERAL LONGITUDINAL HEIGHT TOP	WEDGE TYPE WEDGE ROT FILTER	LEAF 0 – 39
INTERLOCKS	Gantry/Couch C & C ‡ Collision TMC error⋆	Filter/Wedge C & C‡ TMC Auto Setup TMC error⋆ Filter/Wedge Fault	Leaf Collimator C & C‡ LCC Auto Setup LCC error No Leaf Coll. Cal.

‡ Each subsystem has its own check-and-confirm interlock.

⋆ The same TMC error interlock belongs to both Gantry/Couch and Filter/Wedge.

Table 1.15: Assignment of parameters and interlocks to subsystems (1)

SUBSYSTEM	DOSIMETRY	ROOM INTERLOCKS	PROTON BEAM
THERAPY PARAMETERS	DOSE TIME TOTAL MU FRAC		
INTERLOCKS	Dosimetry C & C Dosimetry Relay 1 Dosimetry Relay 2 Pressure/Temperature No Dosim. Cal. Available DMC Setup Timeout DMC Start Timeout DMC Error DMC Auto Setup PLC Error Relay Inconsistency	Therapy Door Console Enabled Pedestal Key Operator Logged In Beam Off at A	Proton Beam Ready

There are no therapy parameters in the ROOM INTERLOCKS subsystem.
It is READY when all interlocks are clear and NOT READY otherwise.
It is never OVERRIDE.

The PROTON BEAM subsystem is READY when the Proton Beam Ready interlock is clear and is NOT READY when the interlock is set. It is never OVERRIDE.

Table 1.16: Assignment of parameters and interlocks to subsystems (2)

Chapter 2

Treatment sequence

Each treatment run is a coordinated sequence of activities involving the operator, the control program, the attached controllers (especially the DMC), and the treatment equipment.

The treatment sequence is divided into *phases* (Table 2.1)[1]. The control program uses the phase to determine when a run is in progress, when to poll the DMC, when to display message boxes, and how to handle events. During certain phases the dosimetry relays should be energized (but the control program cannot enforce this, it can only command the DMC, which may respond after some delay). Some phases occur during every run, others only occur after interlocks or other exceptional conditions. Events cause transitions from one phase to another (Tables 2.2 and 2.3).

Note that there is no phase (or phases) called Beam on. The beam should only be on in the Counting and Resumed phases, but the program cannot control this directly. The PLC turns the beam on and relays in the HSIS or other components in the cyclotron control system turn the beam off.

There are many events that do not appear in tables 2.2 through 2.5 because they do not cause treatment sequence phase transitions. However these events can cause the control program to take other actions. For example, when the DMC Timer Enabled status bit (section 1.6 makes a transition from *false* to *true* the control program writes a beam-on treatment record. Many of these events and the actions they cause are described in chapter 4 on files and chapter 6 on messages.

Tables 2.4 and 2.5 show what happens during a particular treatment run. In this example the treatment is interrupted when the operator presses the **BEAM OFF** button on the therapy console, and is resumed when the operator presses **START** again. In other runs different events might occur.

[1]The nomenclature and contents of this chapter and its tables will be revised extensively in a forthcoming version of this manual.

Even when the same events occur, the exact ordering of events might be different than shown here because the time required for the operator to set up the equipment, and the time required for the beam path to open and close (etc.) may vary.

The columns in tables 2.4 and 2.5 show the activities of the operator, the phase, the control program, the X terminal display, the DMC and the treatment equipment. Time runs down the page, so chains of cause and effect appear as diagonals in the tables, sloping first from upper left to lower right for activities initiated by the operator, then down to lower left for activities responding to the treatment equipment.

The control program displays the current phase, whether a run is in progress, and whether the DMC relays are closed on the PLC STATUS screen in the cells labelled DMC PHASE, THERAPY RUN STATUS, Dosimetry Relay 1, and Dosimetry Relay 2, respectively (section 8)[2].

For more details about activities involving the controlled equipment during the treatment sequence see chapter 6 (especially section 6.5) in [7].

[2] At this writing the phases named Tested OK, Waiting and Ready in this manual appear as Tested, Loaded and Started on the PLC STATUS screen.

PHASE	RUN	POLL	DOSIM.	MSG	DESCRIPTION
Reset					DMC reset, preparing for run
Self-Test					DMC self-test in progress
Tested OK					DMC self-test completed successfully
Waiting					DMC loaded with cal. factors, preset dose, time, etc. waiting for interlocks to become clear
Ready	X	X	X	R	Dosimetry relays energized, waiting for operator to press START button
Counting	X	X	X		Beam on
Dose delivered	X	X			Preset dose delivered, waiting for beam plug
Term. Wait	X	X?		D,T,P,E	Waiting for operator to confirm end of run
Term. Test					DMC termination self-test in progress
Terminated					Idle after completing termination self-test
Paused	X	X	X	I	Beam turned off by interlock
Resumed	X	X	X		Beam on again after pause
Time exceeded	X	X?			Preset time reached, waiting for beam plug
Stopped	X	X?		S,E	Error condition, dosimetry relays de-energized
Exited					Idle after any exit except termination self-test

Phases above the line occur in this order during an uneventful run.

RUN A run is considered to be in progress during this phase.
POLL The control program polls the DMC during this phase.
(X? means poll unless a DMC communication error has been detected.)
DOSIM. The dosimetry relays should be energized during this phase.
MSG One of the indicated message boxes is always displayed during this phase.
(Other message boxes may appear during other phases.)

Message boxes:

R TREATMENT READY . . . Push START . . . or press EXIT RUN . . .
D TREATMENT FINISHED . . . Preset dose delivered . . . Press CONFIRM . . .
T TREATMENT FINISHED . . . Backup time reached . . . Press EXIT RUN . . .
P BEAM PLUG NOT CLOSED . . . Press EXIT RUN . . .
I TREATMENT INTERRUPTED . . . push START . . . or press EXIT RUN . . .
S TREATMENT STOPPED . . . Press EXIT RUN . . .
E (Other error or warning)

Table 2.1: Treatment sequence phases

Phase	Entered from	When one of these events occurs
Reset	(not running)	Operator presses SELECT FIELD (transition right before program sends RESET to DMC)
Self-Test	Reset	Operator presses AUTO SETUP (transition right before program sends CON SEL ISO to DMC)
Tested OK	Self-Test	DMC indicates successful completion of CON SEL ISO
Waiting	Tested OK	DMC indicates successful completion of OUT SETD . . . while PLC indicates interlocks are set (besides dosimetry)
Ready	Tested OK	DMC indicates successful completion of OUT SETD . . . while PLC indicates interlocks are clear (besides dosimetry) (transition right after completion of CON START)
	Waiting	PLC indicates interlocks are clear (besides dosimetry) (transition right after completion of CON START)
Counting	Ready	PLC indicates START button pressed PLC indicates DMC timer enable on PLC indicates beam plug open
Dose delivered	(polling)	DMC indicates preset dose reached
Term. Wait	(Dose delivered, Time exceeded)	PLC indicates beam plug closed Beam plug timer times out
Term. Test	Dose delivered	Operator presses CONFIRM at TREATMENT FINISHED . . . (transition before program sends CON TERM)
Terminated	Term. Test	DMC indicates successful completion of CON TERM DMC indicates error processing CON TERM

Phases usually occur in this order during an uneventful run, but
if interlocks are already clear after processing OUT SETD . . .
the system skips Waiting and proceeds directly from Tested OK to Ready.

The two columns on the right describe the transitions *into* the phase
named in the left column.

In the middle column, parentheses group sets of states where
each state responds to the event(s) in the right column in the same way.

In the right column, any one of the events in a group can cause the transition.

Table 2.2: Treatment sequence phase transitions during an uneventful run

Phase	Entered from	When one of these events occurs
Paused	(Ready,	PLC indicates any interlock set (except dosimetry)
	Counting,	PLC indicates DMC timer enable off
	Resumed)	
	(running)	PLC indicates BEAM OFF pressed at therapy console
Resumed	Paused	PLC indicates all interlocks clear and START pressed
Time exceeded	(polling)	DMC indicates preset time reached
Stopped	(running)	Control program detects DMC-related error during run
		Control program detects therapy sum relay error during run
		(transition right before program sends CON STOP to DMC)
Exited	Ready	Start timer times out
	(Ready,	Operator presses EXIT RUN
	Term. Wait,	
	Paused,	
	Stopped)	
Reset	Self-Test	DMC indicates error processing CON SEL ISO
		DMC times out (no response) after CON SEL ISO
	Tested OK	DMC indicates error processing INP CVOLT1 . . . etc.
		DMC times out (no response) after INP CVOLT1 . . . etc.

The two columns on the right describe the transitions *into* the phase named in the left column.

In the middle column, parentheses group sets of states where each state responds to the event(s) in the right column in the same way.

In the right column, any one of the events in a group can cause the transition.

Table 2.3: Treatment sequence phase transitions for exceptional conditions

OPERATOR	PHASE	CONTROL PROGRAM	DISPLAY	DMC	EQUIPME
Select Field	Reset or Exited or Termin-ated or Term.test	Assign prescribed values for new field to presets	Show presets, subsystem lamps turn red	LEDs dark	
Auto Setup	Reset	Send RESET command to controllers Send setup commands to TMC, LCC	Auto setup yellow lamp on	Execute reset LEDs dark	Leaves, we begin movi
Open door	Self-test	Send CON SEL ISO to DMC		Begin self-test LEDs show test	Door interl
Enter room			Room interlocks lamp turns red	(30 seconds) Respond	set
Set up ext. motions	Tested OK	Send INP CVOLT1 . . . to DMC		Execute INP . . . Respond	
Exit room	Waiting		Dosimetry lamp turns light green	LED's show preset dose, time	Leaves, we ext. motion reach pres
Close door			Subsystem lamps turn green Room interlocks lamp turns green		Door interl clear
		Send CON START to DMC		Execute START Respond	
Push START	Ready (Run begins)	Begin polling DMC	Dosimetry lamp turns dark green, "Push START" message appears	Respond to polling	Dosim. rela close
	Counting	Rewrite `run.dat` file, Write beam on log msg, treat. record	"Push START" message clears Dose, time count on screen	Time elapsed, Dose A, B count on LEDs	Path opens FC1 opens Beam on in room

Table 2.4: Treatment sequence example through beam on

OPERATOR	PHASE	CONTROL PROGRAM	DISPLAY	DMC	EQUIP
Push BEAM OFF	Counting		Time elapsed, Dose A, B count on screen	Time elapsed, Dose A, B count on LEDs	Beam o FC1 clo
Push START	Paused	Write beam off log msg, treat record	INTERRUPTED message appears, stop counting	Stop counting time elapsed	Path clo Path op FC1 op
	Resumed	Write beam on log msg, treat. record	INTERRUPTED message clears Count on screen	Count on LEDs Dose reaches preset Send dose reached message	Beam o in room Dosim. open
	Dose delivered				Beam o FC1 clo Path clo
Press CONFIRM	Term. Wait	Write beam off log msg, treat. record Compute dose for run	"FINISHED, press CONFIRM" message appears	Stop counting time elapsed. Dose, time remain on LEDs	
	Term. test (Run ends)	Stop polling DMC Increment accum. dose in memory Send CON TERM to DMC Write run finished log msg., treat. record Rewrite `accum.dat` file Rewrite `run.dat` file	FINISHED message clears Update accum. dose on screen	Execute term. test LED's show test: dose remains, time counts up Respond	
	Terminated		Dose, time remain on screen	LED's dark	

Table 2.5: Treatment sequence example through end of run

Chapter 3

Controllers

The program senses and controls the treatment equipment through five controllers (Table 3.1).

The two PLCs handle input and output of all single-bit data items including all interlocks and status bits and most motion controls. The TMC, LCC and DMC set preset values and read actual values for particular subsystems. They also use calibration constants and factors.

The TMC, LCC, and DMC are connected through RS232 serial communication ports and the two PLCs are connected through Ethernet. The operations manual [1] describes how to connect and configure the serial port hardware, and how to assign IP addresses on the Ethernet.

Ctlr	Description	Subsystems	Variables
PLC1	Programmable logic controller	(various)	Interlocks, status bits
PLC2	Programmable logic controller	Filter/Wedge (all motions) (X-ray unit)	Preset, actual values motion enables, auto/local Enable, port selection
TMC LCC DMC	Treatment motion controller Leaf collimator controller Dose monitor controller	Gantry/Couch, Leaf collimator Dosimetry	Preset setting values, actual setting values, calibration constants, factors

Table 3.1: Controllers

The control program keeps a record in memory of recent communication with the TMC, LCC and DMC (in both directions) for troubleshooting purposes. At this writing these records go back for hours to weeks, depending on the controller and the amount of activity (Table 3.2, the DMC logs go back much further because the program only polls the DMC during runs). This record can be displayed on the screen or written out to a file on demand. The examples in this chapter (fig. 3.1

etc.) were recorded by this method.

Ctlr	Length, lines	Duration (approx.)
TMC	64600	6 hours
LCC	154600	5.5 hours
DMC	75000	1 to 2 weeks

Table 3.2: Controller logs

3.1 Communication protocol for TMC, LCC and DMC

The TMC, LCC and DMC were provided by the cyclotron manufacturer and all three use the same command-oriented communication protocol and similar command sets. The protocol and commands are described in detail in the manufacturer's documentation [10, 11, 13]. Here is a summary.

3.1.1 Serial port settings

The TMC, LCC and DMC are each connected to one of the therapy computer RS232 serial lines. Communication uses these settings:

baud rate 1200 (except LCC uses 9600)
7 bits per character
even parity
one stop bit

All these settings are set by the control program when it starts up (none are set by hardware switches or jumpers).

3.1.2 Commands and responses

The TMC, LCC and DMC use a command-oriented communication protocol. Most communications are initiated by the therapy control computer: it sends a command to a controller, and the controller responds by sending back some messages. First, the controller responds immediately

(within a fraction of a second) with an *acknowledgement* message to indicate that it has received the message. Then the controller performs the commanded action. When the controller has completed the action, it sends a *completion* message.

In most cases the completion message arrives about a second after the command is received. The control program will usually wait for the completion message for up to 4 seconds. After that, the control program indicates a timeout error. For a few operations, processing the command takes much longer, and in those special cases a much longer timeout is used. For example, there is an 80 second timeout for setting up the collimator leaves (usually leaf setup takes less than 25 seconds). All those special cases are noted below.

A controller ignores any commands sent while it is executing a command; a controller can only process a command after it has issued a completion message.

In a few cases a controller cannot process commands for an interval after it has issued a completion message. In those special cases the control program must wait for an interval before sending the next command. All those special cases are noted below[1].

Not all communications are initiated by the therapy control computer. A controller can send unsolicited messages to the control computer; the therapy control program must be able to handle this. Each controller sends a message when it is reset at power up and when its hardware reset button is pressed. In addition, the DMC can send unsolicited messages to indicate it has detected various fault conditions.

3.1.3 Message format

Messages are strings of ASCII characters.

Every command to a controller is terminated by a carriage return *but no line feed*.

Every message from a controller is terminated by a line feed and a carriage return *in that order*.

Controllers respond to every command with the *acknowledgement sequence*, a space character followed by a line feed and carriage return.

Controllers indicate they have finished performing a command by sending the *completion sequence*, a dollar sign (and then the line feed and carriage return).

When a controller sends data it terminates each string of data values with a pound sign, then a line

[1] We discovered these by trial and error.

Controller	Interval (seconds)	Frequency (minutes^{-1})
PLC1	0.20	300
PLC2	0.20	300
TMC	1.02	59
LCC	1.50	40
DMC	2.40	25

Table 3.3: Controller polling intervals and frequencies

feed and carriage return. This is called the *continuation sequence* because it is always followed by another line of message text, with more data or the completion sequence.

3.1.4 Polling

Much of the time the control program *polls* the controllers repeatedly. To initiate each polling cycle, the control computer sends a command to a controller, requesting some data. After a brief delay, the controller responds with the acknowledgement sequence. Then, after an appreciable delay, the controller responds with the data, terminated by the completion sequence. The delay accounts for most of the polling interval, so the polling rate is limited by the controller and cannot be increased by speeding up the program. After receiving the completion sequence, the control program waits briefly (about 1/20 second at this writing) before polling again. Polling is not strictly periodic (it is not synchronized to a regular clock tick). The controller may take a variable amount of time to respond to the command, and the control computer may take a variable amount of time to initiate the next cycle, depending on their work loads. However, the polling interval is usually quite regular. The typical interval (and corresponding frequency) for each controller appears in table 3.3 (during each LCC polling cycle, the program sends four separate commands to the LCC to read all 40 leaves, section 3.3).

3.1.5 Reset

Reset commands reinitialize the controller. A reset command sets certain of the controller's settings and other internal parameters to default values set in the controller's program in ROM.

The control program sends a reset command to the TMC, LCC, and DMC each time the operator selects a field and each time the operator presses the **Refresh** key (except when a run is in progress).

The reset command is a single ASCII *escape* character (1B hex) followed by a carriage return.

The controller responds to the reset command with a text string or *banner* that identifies the controller, then line feed and carriage return, then the completion sequence (but no separate acknowledgement sequence, in effect the banner string takes the place of the space character in the usual acknowledgment sequence).

3.1.6 Error messages

Error messages can be issued by controllers in response to commands. The DMC can also issue unsolicited error messages when it detects various fault conditions.

The format of an error message is `ERROR` n `;` *`message`* (n is the error number), then a line feed and carriage return. When a command evokes an error message, first the controller responds with the acknowledgement sequence, then the error message itself, and finally the completion sequence.

3.2 TMC (Treatment Motion Controller)

The TMC (Treatment Motion Controller) [13] reads actual parameter values for the Gantry/Couch subsystem[2]. This controller does not use any calibration constants or factors[3].

3.2.1 TMC activity during a typical treatment sequence

Communication with the TMC is quite simple. Almost always, the control program merely polls the TMC periodically the read the actual values of the parameters in the Gantry/Couch subsystem. Each time the operator selects a new field or presses the refresh key (except while a run is in progress), the program resets the TMC.

Figure 3.1 shows communication with the TMC before and after selecting a treatment field. The following commentary refers to the step numbers in the figures (the step numbers and ellipses are not part of the communication). This section describes normal successful operations only. Errors and exceptions are described in the following section (3.2.2).

1. The control computer sends the `OUT ALL` command to poll the TMC. The TMC responds with the acknowledgement sequence.

[2]Before April 2002 the TMC also set and read Filter/Wedge parameters. This is now handled by one of the PLCs.
[3]The TMC has facilities to calibrate the readout signals but this is presently not used.

```
   ⋮
1  OUT ALL
2  1 269.9 108.0 048.6 075.6 180.0 180.3 3701 00 0090 000.0 000.0 #
3  $
4  <ESC>
   ^[
5  "TMC Vers 1.1 841206 .  PHa."
6  $
7  CON DIS COL WEDT WEDR VER LAT LON FLO GAN FIL
8  $
9  OUT ALL
   1 269.9 108.0 048.6 075.6 180.0 180.3 3701 00 0090 000.0 000.0 #
   $
   OUT ALL
   1 269.9 108.0 048.6 075.6 180.0 180.3 3701 00 0090 000.0 000.0 #
   $
   OUT ALL
   1 269.9 108.0 048.6 075.6 180.0 180.2 3701 00 0090 000.0 000.0 #
   $
   OUT ALL
   1 269.9 108.0 048.6 075.6 180.0 180.2 3701 00 0090 000.0 000.0 #
   $
   ⋮
```

Figure 3.1: TMC communication during field selection and polling

2. About one second later, the TMC responds with the actual values of all the parameters in the Gantry/Couch and Filter/Wedge subsystems, followed by the continuation sequence. The ordering and encoding of the values is shown in table 3.4.

3. The TMC sends the completion sequence. This completes one polling cycle.

   The polling rate is 59 samples/minute (1.02 second sampling interval), determined by the TMC response time.

   The control program repeats polling at all times when it has no other commands to process and the TMC Error interlock is clear.

4. When the operator selects a field (section 5.4.5)[4], the control program sends the reset command to the TMC (here the escape character is indicated by `<ESC>`, then `^[`, just as it appears on the communication display (section 8.2.17, A.15) and in the controller log file (section 4.2).

5. The TMC responds with the banner string.

6. The TMC sends the completion sequence.

7. The control program sends the `CON DIS` command to ensure that all motions are disabled at the TMC (the parameter name abbreviations are shown in table 3.4). The TMC responds with the acknowledgment sequence.

8. The TMC sends the completion sequence.

   If the TMC Error interlock was set, the program clears it now.

9. The control program resumes polling the TMC.

   No other commands (besides `OUT ALL`) are sent until the operator selects another field.

3.2.2 TMC errors and exceptional situations

When the operator presses **Select** to begin the dialog to enter a TMC command using the pass-through facility (section 5.8.3), the program stops polling the TMC (this is only possible in experiment mode). The program does not resume polling the TMC until the operator selects another display.

If the TMC does not respond to a command (including a poll) as expected, responds with an error message, or sends an unsolicited message, the control program sets the TMC Error interlock, clears the TMC Auto Setup interlock if it is set, and stops polling the TMC.

[4] Presses **Select** when the selected field is highlighted on the field list display.

Therapy Parameter Name	Description	Abbreviation used by TMC	Units
FILTER	Flattening filter	`FIL`	(none, large, small)*
COLLIMATOR	Collimator rotation	`COL`	deg
HEIGHT	Couch height	`VER`	cm
LATERAL	Couch lateral position	`LAT`	cm
LONGITUDINAL	Couch longitudinal position	`LON`	cm
TURNTABLE	Couch turntable rotation	`FLO`	deg
TOP	Couch top rotation	`TOP`	deg
GANTRY	Gantry rotation	`GAN`	$1/20$ deg$^\diamond$
WEDGE TYPE	Wedge selection	`WEDTYP, WEDT`	deg (0, 30, 45, 60)†
WEDGE ROT	Wedge rotation	`WEDROT, WEDR`	deg (0, 90, 180, 270)‡

The order of settings in this table (from top) is the same as the order of actual setting values that appear in the response to the `OUT ALL` command (from left), for example:

```
OUT ALL
1 269.9 108.0 048.6 075.6 180.0 180.3 3701 00 0090 000.0 000.0 #
$
```

The last two entries in the response (both 000.0) are not used.

$\star$ FILTER coding: `0` none, `1` large, `2` small, `9` (in transition)

$\diamond$ Encoded gantry rotation e is a 4 digit integer, each unit is $1/20$ degree.
Top (zero) is 3701 (not 3700), decoded values range from 0.0 to 359.9.
Decoded gantry rotation d is

$$d = (e - 3701)/20.0$$

GANTRY = d if $d \geq 0.0$ and $360.0 + d$ otherwise.

$\dagger$ WEDGE TYPE coding: `00` none, `30` 30 deg, `45` 45 deg, `60` 60 deg, `99` (in transition)

$\ddagger$ WEDGE ROT coding: `0000` 0 deg, `0090` 90 deg, `0180` 180 deg, `0270` 270 deg, `0099` (in transition)

Table 3.4: TMC parameter ordering, abbreviations, and encodings

The only way to recover from this condition is to select a field again (step 4 above), or press the Refresh key. If the TMC responds correctly (after steps 5, 6) the program clears the TMC Error interlock and resumes polling again (at step 9).

3.3 LCC (Leaf Collimator Controller)

The LCC (Leaf Collimator Controller) [11] sets preset leaf settings and reads actual leaf settings. This controller uses the calibration constants described in section 1.4.4. The calibration procedure is described in sections 3.3.4 and 5.7.2.

3.3.1 LCC activity during during a typical treatment sequence

Figures 3.2 and 3.3 show communication with the LCC while selecting and setting up one treatment field. The same pattern of commands and responses is used for every field; only the parameter values differ. The following commentary refers to the step numbers in the figures (the step numbers and ellipses are not part of the communication). This section describes normal successful operations only. Errors and exceptions are described in the following section (3.3.2).

1. The control computer sends the `OUT ACT 30 to 39` command to poll the LCC for the actual positions of leaves 30 through 39. The LCC responds with the acknowledgement sequence.
2. About 0.4 second later, the LCC responds with the actual values of leaves 30 through 39, followed by the continuation sequence.

   The LCC reports actual leaf positions in mm. The control program displays and logs them in cm.
3. The LCC sends the completion sequence. This completes the polling cycle. During each polling cycle, the program sends four separate `OUT ACT` commands, for ten leaves at a time.

   The polling rate is 40 samples/minute (1.5 second sampling interval), determined by the LCC response time (the program sends all four commands to read the entire 40 leaf settings in each 1.5 second interval).

   The control program repeats polling at all times when it has no other commands to process and the LCC Error interlock is clear.
4. When the operator selects a field (section 5.4.5)[5], the control program sends the reset command to the LCC (here the escape character is indicated by <ESC>, then ^[).

[5] Presses **Select** when the selected field is highlighted on the field list display.

```
    ⋮
 1  OUT ACT 30 TO 39
 2  +001.4 +084.9 +084.8 +075.0 +070.1 +058.6 +057.6 +046.8 +000.2 +000.0 #
 3  $
 4  <ESC>
    ^[
 5  >
 6  $
 7  INP MAXPOS 00 294.5 293.9 292.0 290.6 294.0 296.2 293.2 297.0
 8  $
 9  ⋮
10  INP MINPOS 00 105.0 104.9 103.4 101.2 106.0 105.5 102.8 108.8
    $
    ⋮
11  INP SCAFAC 00 -3095.3 -3086.1 -3078.8 -3093.5 -3067.7 -3117.0 -3111.6 -3071
    $
    ⋮
12  OUT MAXPOS 00 TO 07
13  +294.5 +293.9 +292.0 +290.6 +294.0 +296.2 +293.2 +297.0 #
    $
14  ⋮
    OUT MINPOS 00 TO 07
    +105.0 +104.9 +103.4 +101.2 +106.0 +105.5 +102.8 +108.8 #
    $
    ⋮
    OUT SCAFAC 00 TO 07
    -3095.3 -3086.1 -3078.8 -3093.5 -3067.7 -3117.0 -3111.6 -3071.4 #
    $
    ⋮
15  IN WIN 1.5
    $
16  OUT WIN
17  +001.5 #
    $
18  OUT ACT 00 TO 09
    +000.5 +000.6 +000.6 +000.4 +000.4 +000.0 +000.9 +000.1 +000.2 +000.0 #
    $
    ⋮
```

Figure 3.2: LCC communication during field selection

```
    ⋮
19  OUT ACT 00 TO 09
    +000.5 +000.6 +000.6 +000.4 +000.4 +000.0 +000.9 +000.1 +000.2 +000.0 #
    $
    OUT ACT 10 TO 19
    +000.0 +000.5 +000.3 +000.1 +001.0 +000.4 +000.5 +000.4 +000.1 +000.2 #
    $
    OUT ACT 20 TO 29
    +000.8 +085.0 +080.4 +079.8 +074.9 +069.9 +067.7 +057.8 -000.1 +000.1 #
    $
    OUT ACT 30 TO 39
    +001.4 +084.9 +084.8 +075.0 +070.1 +058.6 +057.6 +046.8 +000.2 +000.0 #
    $
20  INP SET 00 -39.0 -39.0 -32.0 -28.0 -18.0 -11.0 0.0 0.0 0.0 0.0
    $
    INP SET 10 -45.0 -50.0 -60.0 -70.0 -80.0 -86.0 0.0 0.0 0.0 0.0
    $
    INP SET 20 83.0 83.0 73.0 73.0 73.0 75.0 0.0 0.0 0.0 0.0
    $
    INP SET 30 87.0 87.0 87.0 48.0 48.0 47.0 0.0 0.0 0.0 0.0
    $
21  CON RUN
22  $
23  OUT ACT 00 TO 09
    -039.1 -039.3 -031.8 -028.2 -018.3 -011.1 -000.6 -000.3 -000.6 +000.0 #
    $
    OUT ACT 10 TO 19
    -045.4 -050.3 -060.2 -070.6 -080.2 -086.5 -000.3 -000.6 -000.3 +000.0 #
    $
    OUT ACT 20 TO 29
    +083.6 +082.4 +073.1 +073.4 +073.4 +075.2 +000.1 +000.6 -000.1 +000.1 #
    $
    OUT ACT 30 TO 39
    +087.6 +087.7 +087.5 +048.1 +048.1 +047.4 +000.2 +000.5 +000.0 +000.0 #
    $
    ⋮
```

Figure 3.3: LCC communication during field setup

5. The LCC responds with the banner string, which is simply `>`.

6. The LCC sends the completion sequence.

7. The program sends the `INP MAXPOS 00 ...` command to load the LCC with the MAXPOS calibration constants for the first eight leaves, starting with leaf 0. The LCC responds with the acknowledgement sequence.

8. The LCC sends the completion sequence.

9. The program loads the remaining 32 MAXPOS constants in four more commands: `INPUT MAXPOS 08` etc. (not shown).

10. The program loads the 40 MINPOS constants in five commands (the last four commands are not shown).

11. The program loads the 40 SCAFAC constants in five commands (the last four commands are not shown).

12. The program sends the `OUT MAXPOS 00 TO 07` command to read back the MAXPOS calibration constants for the first eight leaves, starting with leaf 0. The LCC responds with the acknowledgment sequence.

13. The LCC sends the MAXPOS calibration constants for the first eight leaves, starting with leaf 0. Then it sends the continuation sequence and the completion sequence.

14. The program sends 14 more commands to read back the remaining 112 calibration constants. The LCC responds (most commands and responses are not shown).

    The program checks that the values read back agree with the values that were sent.

15. The program sends the `IN WIN 1.5` command to load the LCC with the tolerance window (expressed in millimeters).

16. The program sends the `OUT WIN` command to read back the tolerance window.

17. The LCC responds with the tolerance window.

    The program checks that this tolerance agrees with the value that was sent.

    If the LCC Error interlock is set, the control program clears it now.

18. The control program resumes polling the LCC.

19. The control program polls the LCC for the actual values of all 40 leaves in four commands. The LCC responds.

20. When the operator invokes the **Auto Setup** operation, the control program checks that the LCC Error, LCC Auto Setup, and No Leaf Coll. Cal Available interlocks are clear, leaf motion control is in automatic mode, and the preset leaf settings are within range and do not collide. If all these conditions are satisfied, setup proceeds. Moreover, setup proceeds even if the leaf collimator is already set up (the status of all the leaves is already READY). This makes is possible to improve the setup when one or more leaves are just marginally inside tolerance.

    The control program sets the LCC Auto Setup interlock.

    The program sets the actual values of all the leaves to blank because the positions of the leaves cannot be determined until setup completes.

    The program commands PLC2 to enable leaf motions.

    The program waits at least two PLC polling cycles (0.4 sec at this writing). During this interval the program does not poll the LCC.

    The program tests the motion enable drive bit to confirm that the leaf motion has been enabled. If the motion is enabled at this time, setup proceeds.

    The program sends four `INP SET ...` commands to load the LCC with the preset values for all forty leaves (expressed in mm, not cm).

21. The program sends the `CON RUN` command. This causes the LCC to begin moving the leaves.

    Up to 80 seconds may pass while the leaves are moving.

22. When the leaves have reached their preset positions, the LCC sends the completion sequence.

    The program clears the leaf motion enable request bit. Each time the program polls the PLC, it monitors the motion enable sensor. If the sensor does not indicate that leaf motions are disabled, the control program sets the Leaf Collimator subsystem status NOT READY. Moreover, if leaf motion is enabled a hardwired interlock is set. This prevents the beam turning on when leaf motion is enabled.

    The program clears the LCC Auto Setup interlock.

23. The program resumes polling the LCC. If polling is successful the actual leaf setting values are no longer blank.

    No other commands (besides `OUT ACT ...`) are sent until the operator selects another therapy or experiment field, or sets up an X-ray port, or sets up a calibration field.

    The SET values in LCC memory remain unchanged and motions remain disabled until the operator sets up another field (for therapy, experiment, X-ray port, or calibration).

3.3.2 LCC errors and exceptional situations

At the **Auto Setup** command (step 20 above), if the control program determines that the leaves cannot be set up because of an interlock condition, or because the leaves are in local mode, it just continues polling. It also displays an acknowledge box to the operator (section 5.4.6) and logs a message (section 7.7.5).

If the leaf motion enable drive bit is not set after 2.5 seconds (step 20 above) the program abandons the setup attempt. It clears the leaf motion enable request bit, clears the LCC Auto Setup interlock, and logs a message.

There is an 80 second deadline for leaf setup[6]. If the setup does not complete within the deadline (step 21 above), program abandons the setup attempt. It clears the leaf motion enable request bit, and clears the LCC Auto Setup interlock. The program also sets (and displays) the LCC Error interlock, sets all the actual leaf setting values to blank, logs a message, and stops polling the LCC.

It is possible that the LCC may respond within the deadline with the message `ERROR 4 ; LEAF NO-MOTION ERROR!` This occurs when at least one leaf is outside an (internal LCC) tolerance window and cannot be moved into the window (because it is already touching another leaf, for example). When this occurs the setup may still be acceptable. The control program uses a more sophisticated tolerance window rule to assess the setup: the tolerance is read from a file, moreover a different (larger) tolerance is used for closed leaves than open leaves (section 1.2.7, also table 1.1).

If the LCC sends the `LEAF NO-MOTION ERROR` message, the control program waits 5 seconds and then polls the LCC once. If the actual settings match the preset settings (within the control program's tolerance) the program merely logs a message, `Recoverable leaf no motion error`, and continues as in the successful setup (above). If the settings do not match, the program logs a message `Unrecoverable leaf no motion error` and displays a message box for the operator `Leaves not positioned properly, try setup again` (section 6.2.1). Then the program exits the setup operation: it clears the motion enable request bit, clears the LCC Auto Setup interlock, and resumes polling. This is not considered an error condition, the error interlock is not set and the program is ready to handle another setup request.

It is possible that the leaves may be placed in local mode after the control program begins the setup attempt. The LCC can respond to this in two different ways, apparently depending on when the leaves are switched into local mode. The LCC may respond to the `CON RUN` command with the message `ERROR 2; LOCAL MODE`. When this happens the control program logs a message and and also displays a message box for the operator `Collimator in local mode` (section 6.2.1). Then the program exits the setup operation without setting the error interlock, and is ready to handle another setup request after the operator places the leaves back in automatic mode.

[6] At this writing the deadline is hard-coded in the program, it is not read from a file.

Alternatively, the LCC may respond with a `LEAF NO-MOTION ERROR` message. The control program handles this as described above.

When the operator presses **Select** to begin the dialog to enter an LCC command using the pass-through facility (section 5.8.3), the program stops polling the LCC (this is only possible in experiment mode). The program does not resume polling the LCC until the operator selects another display.

If the LCC does not respond to a command (including a poll) as expected, responds with an error message, or sends an unsolicited message, the control program sets the LCC Error interlock, clears the LCC Auto Setup interlock if it is set, sets all the actual leaf setting values to blank, logs a message, and stops polling the LCC.

The only way to recover from this condition is to select a field again (step 4 above), or press the Refresh key. If the LCC loads and sends back the calibration constants and tolerance correctly (through step 17) the program clears the LCC Error interlock and resumes polling again (at step 18).

3.3.3 Setting up X-ray port fields and calibration fields

The control program sets up calibration fields and X-ray port fields in the same way as prescribed fields, except it performs fewer checks at step 20.

Before setting up calibration fields the program only checks that the LCC Error and LCC Setup interlocks are clear.

Before setting up X-ray port fields (commanded by pressing buttons on the X-ray control box) the program checks that the LCC Error and LCC Setup interlocks are clear, the leaf calibration factors are valid, and the leaves are in automatic mode.

3.3.4 Recalculating calibration constants

The LCC calibration procedure is described from the operator's point of view in section 5.7.2. The underlying controller operations and message traffic are described here, because they refer to the numbered items in section 3.3.1.

When the operator indicates the leaves have been set to their correct positions for the large calibration field, the program sends `CON CALIB MAX` to command the LCC to compute new values for

all 40 MAXPOS calibration constants (one for each leaf) and store them in LCC memory. When the operator indicates the leaves have been set to their correct midline positions, the program sends `CON CALIB MIN` to command the LCC to compute new values for all 80 MINPOS and SCAFAC constants.

After each `CON CALIB ...` command, the LCC responds with the acknowledgement sequence and then the completion sequence. The control program waits up to 5 seconds for the completion sequence.

The `CON CALIB ...` commands only change the constants in LCC memory, not the control program memory. If, at the end of the calibration procedure, the operator indicates the new constants should be saved, the control program sends a sequence of `OUT ...` commands to read the new calibration constants from LCC memory into control program memory, as in steps 12 – 14 above. If the operator does not request the program to save the new constants, but instead decides to discard the new calibration data, the program sends a sequence of `INP ...` commands to load the old calibration constants from control program memory back into LCC memory, as in steps 7 – 11 above.

The control program offers the option of changing calibration constants for just one pair of leaves. The program accomplishes this by sending `CON CALIB ...` commands to change all the calibration constants in LCC memory, sending `OUT ...` commands to read them all into a temporary buffer in memory (as in steps 12 – 14 above), assigning the new values from the temporary buffer to only one leaf pair in the in-memory calibration contants, and then sending `INP ...` commands to copy the calibration constants from control program memory back into LCC memory (the old constants except for new constants in one pair of leaves, as in steps 7 – 11 above).

3.4 DMC (Dose Monitor Controller)

The DMC (Dose Monitor Controller) [10] sets the preset DOSE and TIME, determines the actual DOSE and TIME while the beam is on, and turns off the beam when the preset DOSE or TIME is reached, whichever comes first. (The DMC also generates signals used to steer the beam and control the dose rate from the cyclotron, but the therapy control program is only minimally involved in these functions). This controller uses the calibration constants and factors described in sections 1.4.1 and 1.4.2.

There are two DMCs. DMC-1 is usually in use, DMC-2 is a spare. The timing requirements of the two DMCs are different; DMC-2 requires some additional delays. The control program works with both DMCs.

3.4.1 DMC activity during a typical treatment sequence

Figures 3.4 and 3.5 show communication with the DMC while setting up and performing a typical (uneventful) treatment with a single field. The same pattern of commands and responses is used for every typical treatment; only the parameter values differ. The following commentary refers to the step numbers in the figures (the step numbers and ellipses are not part of the communication). This section describes normal successful operations only. Errors and exceptions are described in the following section (3.4.2).

1. Between runs, the control program does not poll the DMC.

2. When the operator selects a field in therapy mode (section 5.4.5)[7], the control program assigns the prescribed DOSE value to the preset DOSE value and computes the preset TIME value from calibration factors by the formula given in section 1.4.2. In experiment mode the preset DOSE and TIME are not changed. In both modes, the program sets the actual values of DOSE and TIME to blank.

   The program clears the DMC Auto Setup interlock if it is not already clear.

   The program sends the reset command to the DMC (here the escape character is indicated by <ESC>, then ^[).

3. The DMC responds with the banner string.

4. The DMC sends the completion sequence.

   If the DMC Error interlock was set, the control program clears it now.

   The control program waits for the operator to invoke **Auto Setup**. Any time after selecting a field and before Auto Setup, the operator may enter a different value for the preset DOSE, and the program will calculate the new preset TIME. The operator may also enter a different value for the preset TIME.

5. When the operator invokes the **Auto Setup** operation, the control program checks that the DMC Auto Setup, Pressure/Temperature and No Dosim Cal. Available interlocks are clear and that the preset DOSE and TIME are not blank and are within range. If these conditions are satisfied, setup proceeds. (If the DMC Error interlock is set, setup proceeds; the setup procedure may clear the interlock.)

   The program sets the actual values of DOSE and TIME to blank if they are not already blank.

   The program sets the DMC Auto Setup interlock.

   The program resets the DMC and it responds.

   If the DMC Error interlock was set, the control program clears it now.

[7] Presses **Select** when the selected field is highlighted on the field list display.

```
1  ⋮
2  <ESC>
   ^[
3  "SCANDITRONIX DMC VER 1.2"
4  $
   <ESC>
5  ^[
   "SCANDITRONIX DMC VER 1.2"
   $
6  CON SEL ISO
7  $
8  INP CVOLT1 712 CVOLT2 722 IONFAC 5000
   $
9  OUT CVOLT1 CVOLT2
10 0712 0722 #
   $
11 INP XCFACT 32000 YCFACT -20000 XRFACT 1000 YRFACT -1000
   $
   INP LOWFAC -1 HIGHFAC 32000 SERVMIN 0 SERVMAX 5
   $
12 CON SERV OUT ON
   $
13 CON SERV CURR ON
   $
14 CON SERV IONS ON
   $
15 INP SETD 560 TIME 162 RATES 600 MAXR 9999 MINR 0
   $
16 OUT SETD TIME
17 056.0 01.62 #
18 $
19 CON START
   $
20 OUT RATE1 RATE2 DOSE1 DOSE2 ELATIME CURTARG INTTARG
   000.2 000.2 000.0 000.0 00.00 00.00 000.0 #
   $
   OUT RATE1 RATE2 DOSE1 DOSE2 ELATIME CURTARG INTTARG
   000.1 000.0 000.0 000.0 00.00 00.00 000.0 #
   $
   ⋮
```

Figure 3.4: DMC communication during field selection and setup

```
    ⋮
    OUT RATE1 RATE2 DOSE1 DOSE2 ELATIME CURTARG INTTARG
    000.1 000.1 000.0 000.0 00.00 00.00 000.0 #
    $
21  OUT RATE1 RATE2 DOSE1 DOSE2 ELATIME CURTARG INTTARG
    013.0 012.9 000.4 000.4 00.03 19.23 000.2 #
    $
    OUT RATE1 RATE2 DOSE1 DOSE2 ELATIME CURTARG INTTARG
    027.7 027.6 001.3 001.4 00.07 35.49 001.7 #
    $
    OUT RATE1 RATE2 DOSE1 DOSE2 ELATIME CURTARG INTTARG
    038.7 038.5 002.8 002.8 00.11 49.80 003.4 #
    $
    ⋮
    OUT RATE1 RATE2 DOSE1 DOSE2 ELATIME CURTARG INTTARG
    052.2 052.0 052.3 052.1 01.05 60.64 060.0 #
    $
    OUT RATE1 RATE2 DOSE1 DOSE2 ELATIME CURTARG INTTARG
    052.3 052.0 054.4 054.2 01.09 59.86 062.5 #
    $
    OUT RATE1 RATE2 DOSE1 DOSE2 ELATIME CURTARG INTTARG
22  END 00 ;Dose reached!  *
    $
23  051.1 051.0 056.2 056.0 01.14 00.00 064.8 #
    $
    OUT RATE1 RATE2 DOSE1 DOSE2 ELATIME CURTARG INTTARG
    000.1 000.2 056.2 056.0 01.15 00.00 064.8 #
    $
24  OUT RATE1 RATE2 DOSE1 DOSE2 ELATIME CURTARG INTTARG
    000.1 000.2 056.2 056.0 01.15 00.00 064.8 #
    $
    ⋮
    OUT RATE1 RATE2 DOSE1 DOSE2 ELATIME CURTARG INTTARG
    000.2 000.1 056.2 056.0 01.15 00.00 064.8 #
    $
    OUT RATE1 RATE2 DOSE1 DOSE2 ELATIME CURTARG INTTARG
    000.0 000.0 056.2 056.0 01.15 00.00 064.8 #
    $
25  CON TERM
26  $
27  ⋮
```

Figure 3.5: DMC communication during a treatment run

6. As soon as the DMC sends the completion string after responding to the reset command, the control program sends `CON SEL ISO` to command the DMC to perform its self-test.

7. The DMC performs its self-test. This takes about 25 seconds.

   During the self-test the DMC relays may close briefly. The control program does not interpret this as a DMC error.

   During the self-test the therapy sum interlock should be set. If it remains clear, the program sets the Relay Inconsistency interlock. If it becomes set, the program clears the Relay Inconsistency interlock.

   When the DMC successfully completes its self-test, it sends the completion sequence.

   The program waits two seconds. Then it checks that both DMC relays are open and the Relay Inconsistency interlock is clear[8].

8. The program sends `INP CVOLT1 ...` to load the DMC with the CAL GAIN 1 and CAL GAIN 2 (`CVOLT1` and `CVOLT2`) calibration factors and the IONFAC calibration constant.

   The program calculates the CAL GAIN 1 and CAL GAIN 2 factors from the corresponding CAL GAIN constants and the P/T FACTOR computed from PRESSURE and TEMPERATURE, according to the formulas in sections 1.4.2 and 1.4.3. The program calculates the CAL GAIN factors each time the pressure or temperature is sampled (each time the PLC is polled). The program updates its in-memory values for the CAL GAIN constants each time it rereads the dosimetry calibration file: when the program starts up and each time the operator selects the DOSIMETRY CALIBRATION display in experiment mode (section 4.1).

9. The program sends the `OUT CVOLT1 CVOLT2` command to read back the CAL GAIN calibration factors.

10. The DMC sends the values of the CAL GAIN factors.

    The program checks that the values read back agree with the values that were sent.

11. The program sends two `INP ...` commands to load the DMC with the XCFACT, YCFACT, XRFACT, YRFACT, LOWFAC, HIGHFAC, SERVMIN and SERVMAX calibration constants.

    After the DMC responds, the control program waits two seconds before sending the next command[9].

12. The program sends `CON SERV OUT ON` to turn on one of the DMC servo functions.

    Ater the DMC responds, the program waits one second.

13. The program sends `CON SERV CURR ON` and then waits one second.

[8] DMC-2 requires the two-second wait to open both relays and clear the Relay Inconsistency interlock after the DMC self-test. DMC-1 does not, but the program waits so it will work with both DMCs.

[9] DMC-2 requires this wait and the next three waits. DMC-1 does not. The program waits so it will work with boths DMCs.

14. The program sends `CON SERV IONS ON` and waits one second.

15. The program sends `INP SETD ...` to load the DMC with the preset DOSE and TIME for this run. It also loads the DMC with the DOSE RATE (RATES) calibration factor and the MAXRSET and MINRSET calibration constants.

    Here preset DOSE and TIME are expressed in units of MU/10 and min/100, respectively.

16. The program sends the `OUT SETD TIME` command to read back the preset DOSE and TIME

17. The DMC sends the values of the preset DOSE and TIME.

    Here preset DOSE and TIME are expressed in units of MU and min, respectively.

    The program checks that the values read back agree with the values that were sent.

    The program clears the DMC Auto Setup interlock.

18. Now DMC setup is complete. The program waits for all the interlocks (except the dosimetry relays) to clear so it can begin the run. If all the interlocks are already clear, the program waits two seconds.

    The DMC will accumulate dose now and the panel LED displays will usually count up slowly because of residual radiation in the treatment head. The `CON START` command will set the dose counters to zero.

19. When all interlocks (except the dosimetry relays) are clear, and at least two seconds have passed since the response to the `OUT SETD TIME` command, the control program sends `CON START` to command the DMC to close the dosimetry relays[10].

20. As soon as the DMC responds to `CON START`, a run is considered to be in progress.

    The control program waits one second and then begins polling the DMC[11]. The data items are described in table 3.5. The control program only uses the actual accumulated DOSE (both channels) and elapsed TIME.

    The polling rate is approximately 25 samples/min (2.4 second sampling interval), largely determined by the DMC response time. The control program waits for each completion sequence from the DMC, then sends the next command.

    Polling shows that the actual values of the accumulated DOSE and elapsed treatment time TIME are both zero because the beam has not yet reached the treatment room.

    When the control program senses that the dosimetry relays have closed, it displays the message box `TREATMENT READY ...Push START ...` advising the operator to turn on the beam.

[10] DMC-1 requires the two-second delay, presumably DMC-2 does as well.
[11] DMC-2 requires the one-second delay.

After the operator pushes the **START** button, the beam turns on (cyclotron RF on), the beam path opens, Faraday Cup 1 opens, and the beam can reach the treatment room. When Beam Plug A opens, the DMC begins counting elapsed time. When the beam reaches the treatment room, the DMC begins measuring accumulating dose.

21. Polling shows that the beam is on in the treatment room: the actual DOSE and TIME have begun to exceed zero.

    Successive samples show the accumulating DOSE and TIME.

22. The DMC sends the message `END 00 ;Dose reached! *` to indicate that the actual DOSE equals or exceeds the preset DOSE.

    At this time the DMC opens the dosimetry relays, which causes the beam to turn off and the Faraday Cup to close.

    The `Dose reached` message is not synchronized with polling. The control program is prepared to handle this message at any time.

23. The DMC responds to the poll that preceded the `Dose reached` message. Occasionally the contents of this message are corrupted (there are extra digits or incorrect numbers). Therefore the control program does not apply the usual checks (range checks etc.) to the contents of this message.

    The program continues polling the DMC.

24. This is the third data message received after the `Dose reached` message (even though it is the response to the second polling command after `Dose reached`).

    The actual value of the accumulated DOSE has reached a plateau. This indicates the beam is off in the treatment room. The elapsed TIME is no longer counting up. This indicates that Faraday Cup 1 is closed and the beam cannot reach the treatment room.

    The control program usually computes the official dose for the run from the contents of this message.

    The program continues polling the DMC.

    When the control program senses that the beam plug has closed (usually a few seconds after this message), it displays a message box `TREATMENT FINISHED ...Press CONFIRM ...` advising the operator to finish the run.

25. When the operator presses **Confirm**, the run is considered to be finished.

    The control program stops polling the DMC.

    The control program sends `CON TERM` to command the DMC to begin its termination self-test.

    The termination self-test can take 30 seconds or more.

26. The DMC finishes the termination self-test and sends the completion sequence.

27. The program does not send any more commands to the DMC until the operator selects the next field.

    The program does not poll the DMC between runs.

Abbreviation	Description	Units
RATE1	Dose rate, dosimetry channel 1	MU/minute
RATE2	Dose rate, dosimetry channel 2	MU/minute
DOSE1	Accumulated dose, dosimetry channel 1	MU
DOSE2	Accumulated dose, dosimetry channel 2	MU
ELATIME	Elapsed treatment time	minutes (and minutes/100)
CURTARG	Target current	uA
INTTARG	Integrated target charge	uA · minutes

The order of settings in this table (from top) is the same as the order of settings and values that appear in DMC polling command and response, for example:

```
OUT RATE1 RATE2 DOSE1 DOSE2 ELATIME CURTARG INTTARG
038.7 038.5 002.8 002.8 00.11 49.80 003.4
$
```

The control program only uses DOSE1, DOSE2 and ELATIME.

Table 3.5: DMC polling

3.4.2 DMC errors and exceptional situations

At the **Auto Setup** command (step 5 above), if the control program determines the DMC cannot be set up, it sends no commands to the DMC. It also displays the NO DOSIMETRY SETUP acknowledge box (section 5.4.6) and logs a message (section 7.7.5).

At **Auto Setup**, if the DMC does not respond properly to the reset command (step 5), the program clears the DMC Auto Setup interlock.

At **Auto Setup**, if the DMC does not pass its self-test (step 7) but returns an error message or times out instead, the control program clears the DMC Auto Setup interlock, sets the DMC Error interlock, and logs a message.

Whenever the the DMC Error interlock is set, the DOSIMETRY subsystem is NOT READY and its subsystem lamp is red.

Two seconds after the self-test, if the Relay Inconsistency interlock is set, the control program displays the THERAPY SUM RELAY ERROR message box (section 6.6.2) but does not set the DMC Error interlock. The Relay Inconsistency interlock remains set until the next sucessful DMC **Auto Setup** operation.

Two seconds after the self-test, if either dosimetry relay is clear, the control program displays the DOSIMETRY RELAY ERROR message box (section 6.6.3) and sets the DMC Error interlock. This interlock remains set until the next succesful Select Field or DMC **Auto Setup** operation.

When the control program checks the values returned by the DMC for the CAL GAIN calibration factors (step 10) and the preset DOSE and TIME (step 17), if the returned values do not agree with the values that were sent, the control program clears the DMC Auto Setup interlock, sets the DMC Error interlock, and logs a message.

If 15 minutes pass after **Auto Setup** but a run has not started, the program sets the DMC Setup Timeout interlock but does not send any commands to the DMC. The only way to clear this interlock is to select a field or invoke **Auto Setup** again.

When the program sends CON START (step 19), if the DMC does not respond properly the program sets the DMC Error interlock and logs a message that shows the erroneous response. The control program remains in the Waiting phase and the dosimetry subsystem lamp reverts from lime green to red (section 8.1.2). It does not consider a run to be in progress and does not start polling.

After the program sends CON START and the TREATMENT READY ...Push START ... message box is displayed (step 20), if the operator presses **Exit Run** instead, the control program stops polling the DMC, sends CON STOP to command the DMC to open the dosimetry relays, and the run is considered to be finished.

After the program sends CON START and the TREATMENT READY ...Push START ... message box is displayed (step 20), if 30 seconds pass and the operator does not push **START** or **Exit Run**, the control program sets the DMC Start Timeout interlock, stops polling the DMC, sends CON STOP to command the DMC to open the dosimetry relays, and the run is considered to be finished. The only way to clear the interlock is to select a field or invoke **Auto Setup** again.

If, during a run (step 21 etc.), the beam is turned off by an interlock, the program continues polling the DMC as usual. At times when the beam is off, polling shows that the actual values of the accumulated DOSE and elapsed TIME remain the same. After the beam plug has closed, the TREATMENT INTERRUPTED message box appears (section 6.4.2). If the interlock is cleared and the beam is turned on once more, polling shows DOSE and TIME increasing again. If instead the operator invokes **Exit Run**, the control program stops polling the DMC, sends CON STOP to command the DMC to open the dosimetry relays, and the run is considered to be finished.

If the beam remains on until the actual elapsed TIME equals or exceeds the preset TIME, the DMC sends the message `END 02 ;Time reached!  *`. The control program handles this the same way as the `Dose reached` message (step 22), except a different message box is shown (at step 24). The control program continues polling the DMC and usually calculates the dose for the run on the third sample after the message (step 24).

While the termination self-test is still in progress (step 25), the operator may select a field (or invoke **Auto Setup**). In that case the control program interrupts the termination self-test by sending a reset command, and the sequence resumes at step 2 (or step 5).

It is possible that the DMC may not respond to a command (including a poll) as expected, or responds with an error message, or with some other unsolicited message such as the reset banner. In this situation the control program sets the DMC Error interlock, clears the DMC Auto Setup interlock if it is set, and logs a message. If the error occurs during a run, the program does not stop polling the DMC. If the error occurs during a treatment phase when the dosimetry relays are closed the program sends `CON STOP` to command the DMC to open the relays.

If the DMC responds properly to commands but polling shows that the measured dose is out of range or appears corrupted or inconsistent in both channels simultaneous or in two successive samples in one channel (but not one sample in one channel, section 1.2.5) the program sets the DMC Error interlock and sends `CON STOP` to command the DMC to open the dosimetry relays, but does not stop polling the DMC.

If the Relay Inconsistency interlock becomes set during a run, this may indicate the therapy sum relay has failed, allowing the beam to remain on when it should be off. In this condition the control program sends CON STOP to command the DMC to open the dosimetry relays. This should cause the beam to turn off. The program continues polling the DMC and does not set the DMC Error interlock.

3.4.3 Resetting the DMC

The control program never resets the DMC when a run is still in progress, because this would interrupt the run and blank the displays. Resetting the DMC also re-initializes internal DMC program and sets certain calibration factors (such as the calibration gains) to their default values (however it does not reset the dose counters).

The control program only resets the DMC when a run is finished, after the operator has indicated that it may proceed (after the operator has been given the opportunity to write down the displayed data). In particular, the control program sends the reset command to the DMC at these times:

1. When the operator selects a field (section 5.4.5).
2. When the operator presses the Refresh key, except during a run.
3. When the operator invokes the auto setup operation for the dosimetry subsystem (section 5.4.6). After that the control program commands the DMC to perform its self-test and load the treatment parameters.
4. When the operator finishes the editing dialog for pressure, temperature, or a dosimetry calibration factor at the DOSIMETRY CALIBRATION screen (section 5.7.1) in experiment mode in these treatment phases: Tested OK, Waiting. Then the operator must command an auto setup operation to load the new values into the DMC.
5. When the operator finishes the editing dialog for the preset dose or time at the DOSIMETRY display (section 5.5.5) in these treatment phases: Tested OK, Waiting. Here again, the operator must command an auto setup opreation to load the new values.
6. When the operator turns on the X-ray Enable key (section 1.6.1) in any of these treatment phases: Tested Ok, Waiting, Ready, Paused, Term. Wait, Term. Test, Terminated, Stopped, Exited. In this case, it is expected that the operator will take an X-ray picture. If the DMC is not reset, it would sense the dose pulse from the X-rays and send an error message to the control computer.
7. When the operator turns off the Console Enabled key (section 1.5.22) after logging out. This blanks the DMC displays.
8. When the operator types RESET to the DMC command pass-through utility, which is active when the DMC message log screen is displayed in experiment mode and a run is not in progress (section 5.8.3).

3.5 PLC (Programmable Logic Controller)

The two PLCs (Programmable Logic Controllers) [14] handle input and output of all single-bit data items including interlocks, status bits, motion enable controls, motion auto/local controls, and X-ray portal controls. All of these items appear on the PLC STATUS screen (chapter 8), and many appear on other subsystem screens as well.

Both PLCs are connected to the same Ethernet network that connects the control computer to the host and X terminal. For more details about configuring the Ethernet, assigning IP addresses etc., see the operations manual [1]. Communication uses a protocol that runs on top of TCP/IP which is (rather scantly) described in the manufacturer's manuals [15][12].

[12] The commands and responses will be described in more detail in a forthcoming version of this manual.

Communication with the PLCs is unlike communication with the other three controllers. Instead of sending different commands at different phases of the treatment sequence, the program simply polls both PLCs periodically the entire time the control program is running. On each polling cycle the program sends the same commands, to set every one of the output bits and read every one of the input bits (the program repeats the commands to set all the output bits to their current values on every polling cycle, even though the values of most output bits do not change on any given cycle).

The polling rate is usually about 5 samples/second (usually about 200 msec sampling interval). This includes a 100 msec delay in the control program; the rest of the delay is composed of control program computation, data transmission, and the PLC response time. The control program is not strictly periodic because this portion of the period may take a variable amount of time.

One of the output bits is toggled (between 0 and 1 and back) on every polling cycle. This bit is the input to the PLC1 program (called a *network*) that computes the Watchdog A OK interlock. If the control program does not poll PLC1 for 500 msec, the PLC1 program sets this interlock. The only way to clear this interlock is to restart the control program and press the watchdog reset button.

If either PLC does not respond correctly to a poll, the control program sets the PLC Error interlock and logs a message. If the PLC responds correctly to the next poll, the program clears the interlock. If the PLC Error interlock is set on three consecutive polling cycles, the program stops polling both PLCs (this will cause Watchdog A OK to set also) and logs a message. There is no way to recover from this, except to restart the control program.

Chapter 4

Files

Data files store the values of some of the state variables described in chapter 1. Some data files store prescriptions and treatment summaries including accumulating fractions and doses for each patient under treatment. Other data files store calibration constants and factors and other machine parameters such as timeouts. *Treatment records* and *log files* store a chronological record of machine activity which is more detailed than the treatment summaries in the data files. They are used for patient quality assurance and archival purposes, and also also for engineering diagnostic and troubleshooting purposes.

This chapter describes the general contents of the files and explains when each file is read and written. A separate operations manual [1] describes the location (directory), ownership, protection and format of all files[1]. It also describes how and where (which directories) the files are archived. That manual also describes some additional configuration files that are not pertinent here.

4.1 Data files

Table 4.1 describes the data files, their contents, and their access modes. Most files are read-only (mode `r`), their contents are updated by utilities (often just a text editor) outside the control program. A few files are also written by the control program (mode `w`).

In addition to the control program itself, there is also a *treatment planning program* that adds patients and fields to the prescription file `prescr.dat`. There is also a *prescription utility* that removes (archives) patients and fields from `prescr.dat` and the accumulations file `accum.dat`.

[1] The location of the files is configurable in the control program startup file (see section 3.3 in [1]).

The prescription utility also sets some of the field flags (section 1.3) in `prescr.dat`. The control program itself never writes `prescr.dat`. See the therapist's guide [5] for more about both programs.

When a data file is written, no new file is created; the old file is rewritten in place. Therefore the collection of data files is small and fixed.

Tables 4.2 and 4.3 explain when each data file is read and written (tables 4.5 and 4.6 describe treatment records and log files). The program reads all data files (except `exper.dat`) when the program starts up. The program reads the pertinent file again each time the operator invokes the operation where new data from that file might be needed (for example the program reads the prescription file `prescr.dat` each time the operator selects the patient list display in therapy mode). The program writes a file when new data becomes available, at the end of each treatment run (`accum.dat`) or at the end of the leaf collimator calibration procedure (`mlccal.dat`).

If the file server becomes inaccessible, the control program will time out when it attempts to read or write a file. It logs a message and displays a message box warning the operator that files are inaccessible. After this occurs the program does not attempt to read or write any files (except one, see below) but it continues running normally, using (or retaining) the data in memory. When the operator selects the patient list display again the program attempts to read `prescr.dat` once more. If that succeeds, the program logs a message, displays a message box, and resumes reading and writing all files again. Selecting the patient list display is therefore the only way to start reading and writing files again after a file access problem.

Table 4.4 shows the names used to identify data files in log messages (section 7.4).

4.2 Treatment records and log files

Table 4.5 describes the treatment record files and log files. They contain a chronological record of machine activity which is useful for troubleshooting purposes and to reconstruct the sequence of events if needed.

Treatment record files record the therapy system status each time the beam turns on or off and at the completion of each run. Each treatment record in the file contains all the prescribed, preset, actual and accumulated setting values, and the dose calibration factor values, at the time the record was written. The treatment record files are not read back by the control program (the control program does not use these files keep track of accumulated fractions and dose for each patient).

Message log files record events that occur as the control program runs, including the beam turning

File	Mode	Contents
accum.dat	r,w‡	Accumulated doses and fractions, dose warning flag
calfields.dat	r	LCC calibration field sizes
dosecal.dat	r	Dose calibration constants
exper.dat	r	Experiment studies, fields, prescribed settings
message.dat	r	Help screen text (message of the day)
mlccal.dat	r,w	Leaf collimator calibration constants
oper.dat	r	Operator identification, password, authorization
ports.dat	r	X-ray portal field shapes
prescr.dat	r,w†	Patients, fields, prescribed settings, field flags
run.dat	r,w	Run in progress/Run completed indicator
timeouts.dat	r	Setup timeout, start timeout, other timeouts
tol.dat	r	Tolerance windows for leaves and other settings

r Read by control program and prescription utility program
w Written by control program only
w‡ Written by control program and prescription utility
w† Written by treatment planning program and prescription utility

Table 4.1: Data file names and contents

File	Mode	Read when . . .
accum.dat	r,w‡	Startup only
calfields.dat	r	LCC calibration screen selected in experiment mode, startup
dosecal.dat	r	Dosimetry calibration screen selected in experiment mode, startup
exper.dat	r	Patient (actually study) list selected in experiment mode only
message.dat	r	Help screen selected, startup
mlccal.dat	r,w	LCC calibration screen selected in experiment mode, startup
oper.dat	r	Logout, startup
ports.dat	r	LCC calibration screen selected in experiment mode, startup
prescr.dat	r,w†	Patient list selected in therapy mode, startup
run.dat	r,w	Startup only
timeouts.dat	r	Startup only
tol.dat	r	LCC calibration screen selected in experiment mode, startup

r Read by control program and prescription utility program
w Written by control program only
w‡ Written by control program and prescription utility
w† Written by treatment planning program and prescription utility

Table 4.2: Reading data files

File	Mode	Written when . . .
`accum.dat`	r,w‡	Run finishes in therapy mode
		Write File at Fields screen in therapy mode
		Patient is archived
`mlccal.dat`	r,w	Write File when LCC calibration complete
`prescr.dat`	r,w†	Fields transferred from treatment planning system
		Patient is archived
		Some field flags are changed
`run.dat`	r,w	Beam turns on or run finishes in therapy mode

r Read by control program and prescription utility program
w Written by control program only
w‡ Written by control program and prescription utility
w† Written by treatment planning program and prescription utility

Table 4.3: Writing data files

File	Name in log messages
`accum.dat`	`Accumulated dose`
`calfields.dat`	`Collimator cal fields`
`dosecal.dat`	`Dose cal`
`exper.dat`	`Experiment`
`message.dat`	`Daily message`
`mlccal.dat`	`Collimator cal`
`oper.dat`	`Operator`
`ports.dat`	`Ports`
`prescr.dat`	`Prescription`
`run.dat`	`Run`
`timeouts.dat`	`Timeout file`
`tol.dat`	`Tolerances`

Table 4.4: Data file names in log messages

on and off and the completion of runs, operator logins, controller setups, error messages from controllers etc. Chapter 7 describes the message log file contents in detail.

Controller log files record the message traffic between the control program and the attached controllers (DMC, LCC, TMC and PLC). The program writes a controller log file whenever the operator commands it (section 5.8.3). Each controller log file stores the contents of a buffer in control program memory that contains the most recent 4500 lines of messages between the program and controller (in both directions), similar to figures 3.1 through 3.5 but also including time stamps at one minute intervals.

Stored field files contain actual machine settings recorded at the operator's demand, in a form that can be used to set up the machine again later. (These files are obsolete. The **Store Field** operation was removed from recent control program versions.)

Table 4.6 shows when each file is created. A new file of each type is created at the operator's command. In addition a new treatment record file and a new message log file is created each time the program starts up and at midnight each night. Each new file is given a unique name incorporating the date and time at the time of its creation. There is a large and ever-growing collection of these files.

The entire contents of the stored field files and controller log files are written when the files are created, then the files are closed permanently. Treatment record files and message log files remain open from their creation until the following midnight. The control program appends a new record to the treatment record file each time the beam turns on or off and at the end of each run. The program frequently appends new messages to the message log file.

Table 4.7 shows the names used to identify treatment record files and log files in log messages (section 7.4).

File	Description
dmc*yyyy-mmdd-hhmmss*.dat	DMC logs
iso-d*yyyy-mmdd-hhmmss*.log	Message logs written on demand
iso*yyyy-mmdd-hhmmss*.log	Message logs written automatically
isotr-d*yyyy-mmdd-hhmmss*.log	Treatment records written on demand
isotr*yyyy-mmdd-hhmmss*.log	Treatment records written automatically
lcc*yyyy-mmdd-hhmmss*.dat	LCC logs
pat*iiiii*fld*jj*.dat	Stored therapy fields
plc*yyyy-mmdd-hhmmss*.dat	PLC logs
study*iiiii*fld*jj*.dat	Stored experiment fields
tmc*yyyy-mmdd-hhmmss*.dat	TMC logs

An example of study*iiiii*fld*jj*.dat is study00001fld12.dat.
An example of isotr*yyyy-mmdd-hhmmss*.log is isotr1999-0907-064734.log.

Table 4.5: Treatment records and log files

File	New file when . . .
dmc*yyyy-mmdd-hhmmss*.dat	Write File at DMC screen
iso-d*yyyy-mmdd-hhmmss*.log	Write File at message log screen
iso*yyyy-mmdd-hhmmss*.log	Startup, then midnight every night
isotr-d*yyyy-mmdd-hhmmss*.log	Write File at message log screen
isotr*yyyy-mmdd-hhmmss*.log	Startup, then midnight every night
lcc*yyyy-mmdd-hhmmss*.dat	Write File at LCC screen
pat*iiiii*fld*jj*.dat	Store Field in therapy mode
plc*yyyy-mmdd-hhmmss*.dat	Write File at PLC screen
study*iiiii*fld*jj*.dat	Store Field in expriment mode
tmc*yyyy-mmdd-hhmmss*.dat	Write File at TMC screen

Table 4.6: Creating treatment records and log files

File	Nname in log messages
dmc*yyyy-mmdd-hhmmss*.dat	DMC message
iso-d*yyyy-mmdd-hhmmss*.log	Log message
iso*yyyy-mmdd-hhmmss*.log	Log message
isotr-d*yyyy-mmdd-hhmmss*.log	Treatment record
isotr*yyyy-mmdd-hhmmss*.log	Treatment record
lcc*yyyy-mmdd-hhmmss*.dat	LCC message
pat*iiiii*fld*jj*.dat	stored field
plc*yyyy-mmdd-hhmmss*.dat	PLC message
study*iiiii*fld*jj*.dat	stored field
tmc*yyyy-mmdd-hhmmss*.dat	TMC message

Table 4.7: Treatment record file and log file names in log messages

Chapter 5

Operator commands

The operator runs the machine by issuing *commands*. Most commands are issued by pressing keys on the X terminal; others are issued by pressing buttons on control panels[1].

This chapter describes all the commands that the operator can invoke. It describes when each command can be invoked (and when each command is disabled). When an command involves a dialog involving one or more dialog boxes or menus, this chapter shows each dialog box (or menu) and describes the effects of entering any data or choosing any option.

5.1 Keyboard

You usually operate the control program by pressing keys on the X terminal keyboard (a few commands can be invoked by pressing buttons on the control console panels, the mobile pedestal, and the X-ray control box). The mouse is never used (we use arrow keys and the keypad instead).

To use the keyboard, the console enable key on the treatment control panel must be turned on. When the console enable key is turned off, pressing keys on the terminal has no effect, except the terminal beeps. In this condition the terminal screen displays a yellow strip near the bottom with the message `CONSOLE ENABLE KEY OFF. TURN CONSOLE KEY TO ENABLE SYSTEM`.

When the console enable key is on, usually all commands are enabled and commands can be invoked in any order. There are exceptions when certain commands are not enabled (while a therapy run is

[1]The control program can also read sequences of commands from the console terminal or from a script (file), but this capability is not enabled in the present configuration. See [2].

in progress, for example).

If you press a key for a command that is not enabled at that time, nothing will happen, except the terminal will beep. If you press an enabled key to select a command that might have appreciable consequences (such as overriding a parameter) the program will ask you to confirm the command and you may cancel it.

When the program is busy reading or writing files it does not respond immediately to keystrokes (it does not even beep). Usually these delays are barely noticeable but if there is a problem with the network or host computer (file server) there can be an appreciable delay. In the worst case the program will wait up to 15 seconds attempting to access a file before processing keyboard input. During this interval the program does not respond to the keyboard and does not update the display, but it continues to communicate with the attached controllers normally and continues to monitor and set interlocks promptly.

5.1.1 Keypad and function keys

You begin most commands by pressing a key on the keypad or the row of function keys at the top of the keyboard. Each key invokes a different command (pressing a keypad key or function key is similar to selecting a menu item in some programs). All commands needed by therapists are on the keypad. The function keys are for the commands used by engineers, technicians and physicists.

Fig. 5.1 shows the keypad and function keys (on the actual terminal, the function keys are in a single row above the alphabetic keys). Each key is labelled with the command it invokes (on the actual keys, not just in the figure).

5.1.2 Control keys

There are only a limited number of keypad keys and function keys, so a few rarely-used commands are bound to control keys. You invoke these commands by pressing down the control key at the same time you press another key. For example `ctrl-8` indicates you press the control key and the 8 key. For some commands you must press the shift key also, for example `ctrl-shift-Q` indicates you press the control key, the shift key and the Q key all at the same time. Table 5.1 shows all the control keys.

Expt Mode	Dosim Cal	LCC Cal	Lg Cal Field	Midline Field

Write file	TMC	LCC	DMC	PLC	PLC Motions	Room Display

Re-fresh	Help	Mess-ages	Log Msg
Patient List	Field List	Field Summ-ary	
Gantry Couch	Filter Wedge	Leaf Collim	Dosi-metry
Over-ride	Auto Setup	Exit Run	Select Confirm
Cancel Acknowledge		Log out	

Figure 5.1: Keypad and function keys

Keys	Mode	Command
`ctrl-1`	T	Set up 10 x 10 port‡
`ctrl-2`	T	Set up 16.5 x 16.5 port†
`ctrl-3`	T	Set up 20.5 x 20.5 port†
`ctrl-4`	T	Set up 24.5 x 24.5 port†
`ctrl-5`	T	Set up 28.5 x 28.5 port†
`ctrl-7`	T	Show TREATMENT RECORDS screen
`ctrl-8`	T	Show PROGRAMMABLE LOGIC CONTROLLER (PLC) messages screen
`ctrl-9`	T	Show DOSE MONITOR CONTROLLER (DMC) messages screen*
`ctrl-0`	T	Show PLC STATUS screen*
`ctrl-shift-C`	E	Set time
`ctrl-shift-Q`	E	Shutdown
`ctrl-shift-A`	E	Halt, assertion failure
`ctrl-shift-K`	E	Crash, access fault/bus error
`ctrl-shift-L`	E	Crash, illegal instruction
`ctrl-shift-W`	E	Deadlock, wait for semaphore
`ctrl-shift-M`	E	TMC task crash, access fault/bus error
`ctrl-shift-H`	E	TMC task deadlock, wait for semaphore

E Commands enabled in experiment mode only
T Commands enabled in therapy mode and experiment mode

∗ Commands also bound to function keys
† Commands also bound to X-ray controller buttons

‡ (The `ctrl-1` key is disabled at this writing)

Table 5.1: Control keys

5.1.3 Arrow keys

Press the arrow keys to move the display cursor (pressing these keys is similar to moving the mouse in some programs). For example, you press these keys to move the cursor on a menu, or to move the cursor to a patient on the patient display to prepare to treat him or her, or to move the cursor to a leaf on the leaf collimator display if you must override it, or to move the cursor to the preset dose on the dosimetry display if you must edit it. Then to select the item at the cursor, use the **Select/Confirm** key (pressing that key is similar to clicking the mouse in some programs).

Press the arrow keys also to page through multipage displays, such as the patient list and the field list. Press the down arrow key when the cursor is at the bottom of the page to display the next page. The entire next page appears (not just the next line). Press the up arrow key when the cursor is at the top of the page to display the previous page.

Pressing an arrow key once causes the cursor to move to the next item in that direction (holding down an arrow key causes the cursor to jump across several items, this is usually not helpful). Usually only the up and down arrow keys are effective because items appear in a list with a single column. The leaf collimator display has two columns so there the right and left arrow keys are effective also. If you press an arrow key which is not effective (because there are no items in that direction, or you have reached the end of the list) the terminal beeps.

5.1.4 Alphabetic keys

Use the alphabetic keys to type your username and password at the login screen, and to type text into dialog boxes, such as log message text or commands to controllers.

5.1.5 Numeric keys

Use the numeric keys (on the top row above the alphabetic keys) to type numbers into dialog boxes, such as preset dose or the pressure and temperature used to calculate the manual pressure/temperature correction factors.

You cannot use the keypad keys to type in numbers.

5.2 Interaction methods

5.2.1 Dialogs versus messages

The operator can press certain keys to begin a *dialog*. A box appears in the upper half of the display area, requesting some response from the operator. The box remains until the operator responds. While the box is displayed most other commands are disabled, so pressing other keys just causes the terminal to beep.

Some events cause a *message box* to appear in the lower half of the display area. Message boxes also remain until the operator responds, but other keys are not disabled when a message box is displayed.

5.2.2 Dialogs

There are three kinds of dialogs: dialog boxes, confirmation boxes, and acknowledge boxes.

Dialog boxes (Fig. B.1) show a message prompting you to type in some text. There is a white cell where text appears when you type. If you make a mistake, press the **backspace** key to delete the last character. When you are finished, press **Return** or **Confirm** (Marked **Select/Confirm**) to cause the control program to read the text you typed. If the text is valid (is a number which is within range, etc.) the program accepts the data and the dialog box disappears. If the text is not valid, the control program beeps and the dialog box remains. Press **Cancel** (marked **Cancel/Acknowledge**) to discard the text and make the dialog box disappear, leaving the program in the same condition it was before the box appeared. The alphanumeric keys and punctuation keys are enabled while the box is displayed, but function keys and keypad keys except **Confirm** and **Cancel** are disabled.

Confirmation boxes (Fig. B.2) show a message that offers to perform some action, and always end with a line that says `CONFIRM or CANCEL`. Press **Confirm** to to perform the action and make the box disappear. Press **Cancel** to make the box disappear without performing the action, leaving the program in the same condition it was before the box appeared. All keys except **Confirm** and **Cancel** are disabled while the box is displayed.

Acknowledge boxes (Fig. B.3) show an informative message, and always end with a line that says `ACKNOWLEDGE`. Press the **Acknowledge** key (marked **Cancel/Acknowledge**) to make the box disappear. No other action is performed. All keys except **Acknowledge** are disabled while the box is displayed.

5.2.3 Menus

Pressing certain keys can display a *menu* (Fig. B.4). Use the up and down arrow keys to move the cursor to the item you want (the right and left arrow keys are disabled when a menu is displayed, and the cursor cannot reach the caption at the top of the menu). Press **Select** to select the item at the cursor and make the menu disappear. Press **Cancel** to make the menu disappear without selecting any item, leaving the program in the condition it was before the menu appeared. All keys except the up and down arrow keys, **Select** and **Cancel** are disabled while the menu is displayed.

5.2.4 Message boxes

Certain events can cause a *message box* to appear in the bottom half of the screen display area (Figs. B.5, B.6). Unlike dialog boxes and menus, message boxes do not appear when the operator issues a command. Instead, they appear spontaneously (without operator action) when the control program detects certain events or conditions (chapter 6). However message boxes do not disappear spontaneously; they remain on the display until the operator presses **Acknowledge**, **Confirm**, **Exit Run**, or whatever the box requests.

Other keys are not disabled when a message box is displayed[2]. However, the message box will always appear on top of other display contents.

It is possible for a message box to be displayed at the same time as a a dialog box or menu. In this situation most keyboard input goes to the dialog box so the operator can complete the dialog before dealing with the message. **Cancel**, **Acknowledge**, **Confirm**, **Select**, and **Return** go to the dialog box. When the dialog is finished, the dialog box disappears and the message box remains. After that, keyboard input goes to the message box. However **Exit Run** always goes to the message box, even when a dialog box is displayed, because this key is never handled by a dialog box.

5.2.5 Complex procedures

Usually commands can be issued in any order, and most commands are always available (except when a dialog is in progress). The only exception is the leaf collimator calibration procedure, where a particular sequence of commands must be issued. While this procedure is in progress, the command sequence is enforced and most other commands are disabled. See section 5.7.2.

[2] At this writing it is even possible to begin a dialog while a message box is displayed. We may change this.

5.2.6 Summary of interactions

Most operations are disabled when the console enable key is turned off. Most operations are disabled when a dialog box, confirmation box, acknowledge box or menu is displayed. Most operations are disabled during the leaf collimator calibration procedure. This goes without saying in the following sections: “always enabled” means “always enabled, except when a dialog box is displayed or . . . ”, unless explicitly noted otherwise.

5.3 Interaction commands

Use the **Select/Confirm** and **Cancel/Acknowledge** commands to select items from lists and to respond to dialogs, menus, and messages.

5.3.1 Select/Confirm

The **Select/Confirm** key is the large key at the lower right corner of the keypad (Fig. 5.1).

Press this key to select the item at the display cursor (pressing this key is similar to clicking the mouse button in some programs). For example, you press this key to select a patient on the patient display to prepare to treat him or her, or to select a leaf on the leaf collimator display if you must override it, or to select the preset dose on the dosimetry display if you must edit it. To move the cursor to the item you want, use the arrow keys (pressing those keys is similar to moving the mouse in some programs).

Press this key also to confirm actions offered by confirmation boxes. Pressing this key causes the program to perform the action and makes the box disappear.

Press this key also when you are finished entering text into a dialog box. If the text is valid (is a number which is within range, etc.) the program accepts the data and the dialog box disappears. If the text is not valid, the control program beeps and the dialog box remains. (Alternatively, you can use the **Return** key to indicate you are finished entering data into a dialog box; in this context it behaves the same as **Select/Confirm**.)

5.3.2 Cancel/Acknowledge

The **Cancel/Acknowledge** key is the large key at the lower left corner of the keypad (Fig. 5.1).

Press this key to dismiss acknowledge boxes, confirmation boxes, and dialog boxes. Pressing **Cancel/Acknowledge** usually causes any box displayed on the screen to disappear, without causing any other action. If you press a key by mistake and a box appears, you can usually get rid of it (without causing anything else to happen) just by pressing this key. In the few cases where this key cannot dismiss the box, the terminal will beep when you press the key.

5.4 Session commands

Use **Log out** to change operators. Use **Patient List**, **Select Patient**, **Field List**, **Select Field**, **Auto Setup**, and (sometimes) **Exit Run** to step through the treatment sequence for each patient and field.

5.4.1 Logout and Login

Press the **Logout** key to log out and enable another operator to log in.

The **Logout** command is disabled when a run is in progress.

Pressing this key displays a confirmation box with this message:

```
LOGOUT
Are you SURE you want to log out?
CONFIRM or CANCEL
```

Press **Confirm** to log out.

The Operator Logged In interlock sets. No operator appears in the lower left corner of the screen. The LOGIN display appears (Fig. A.1). The `Operator NAME logged out` message is logged. The program reads the operator authorization file (to ensure the most recent version is in memory).

Logging out does not change the current patient and field (so it is convenient to change operators at any time except during a run).

Turning off the console enable keyswitch when the console is logged out causes the current patient (or study) to revert to No patient (or No study) and No field.

When the LOGIN display is visible, the next operator can log in by entering a username and password. All other commands are disabled.

When the LOGIN display appears, the border around the Username: box is wide, to indicate that this is where typed input will appear.

Type your username, as you type it appears in the Username: box.

If you make a typing mistake, use the backspace key to remove the last character. To start over, press the keypad **Cancel** key.

We always assign usernames and passwords made of uppercase letters. If your username does not appear in uppercase as you type, press the shift lock key and start over.

When you are done typing your username, Press **Return**. The wide border moves to the Password: box.

Type your password, asterisks appear in the Password: box. Press **Return** again.

If you typed the correct username and password, you are now logged in.

If the username or password are incorrect, the program beeps and clears the password. If you type again, your input is interpreted as another attempt at a password. To start over with the username, press **Cancel**. The wide border moves back the Username: box.

When you successfully log in, the Operator Logged In interlock clears. Your username appears in the lower left corner of the screen. The `Operator` *`xxxxx`* `logged in` message and the Memory Alloc: *nnnnnnn* Free: *nnnnnn* message are logged. The patients display appears (fig. A.2) (in experiment mode the list of studies appears).

Logging in does not normally change the current patient and field, except in the case where the program was in experiment mode and the new operator is a therapist. In that case, the program reverts to therapy mode with no patient and no field selected.

The control program records the username of the logged-in therapist in every treatment record. When you go off duty you should log out so the next therapist can log in.

When the control program starts up, the LOGIN display is shown. An operator must log in before any other commands can be performed.

5.4.2 Patient List

In therapy mode, the **Patient List** command displays the list of patients which can be treated (fig. A.2)[3].

In experiment mode this command displays the list of experimental studies (fig. A.3). The first study is based on the patient who was most recently selected in therapy mode, before switching to experiment mode. This makes it possible to set up therapy fields in experiment mode[4]. The name of this first study is composed of the patient number followed the patient's name (as much as will fit).

Patient List is always enabled.

Press the up and down arrow keys to move the cursor and to page through the list. The right and left arrow keys are disabled.

Usually **Patient List** causes the control program to read the most recent version of the prescription file `prescr.dat` (or `exper.dat`). This ensures that the control program's in-memory prescription database, including all patients and fields and all their prescribed settings, are up-to-date. When the program reads the file, it calculates the prescribed value of the flattening filter for every field from the prescribed values of that field's leaf settings.

You may notice a few seconds delay before the list appears, as the control program attempts to read the file. During this interval the control program does not respond to keystrokes and does not update the display. If the control program is unable to read the file after several seconds (at this writing it is 15 seconds), it abandons the attempt, logs a message and displays this acknowledge box:

```
FILE ACCESS TIMEOUT
Delay caused by treatment planning access problem
Recent field additions may be missing
ACKNOWLEDGE
```

Press the **Acknowledge** key to dismiss the message. The control program uses the list of patients which it read on the last successful attempt. You may select a patient and continue treating in this situation but the most recently transferred patients and fields may not be available in the control program[5].

[3] At this writing, the **Patient List** command is bound to the keypad key labelled Select Patient (Fig. 5.1). We plan to change the keycap label.

[4] Actually, they are *copies* of therapy fields.

[5] If the program is switched to experiment mode and a study selection is attempted when the file server is not accessible, patients and therapy fields remain in memory and the experiment studies are not loaded.

The control program attempts to read the prescription file each time you invoke the **Select Patient** command. If it succeeds again after a failure, it logs a message and displays this acknowledge box:

```
FILE ACCESS SUCCESS
File server responding, reading and writing files again
ACKNOWLEDGE
```

Press the **Acknowledge** key to dismiss the message. Now the lists of patients and fields in the control program should be up-to-date.

5.4.3 Select Patient

When the patient list is displayed, press the **Select** key to select the patient (or study) at the cursor.

The selected patient becomes the current patient. The `Selected patient` *nnnn* `(index` *nn*`)` message is logged. The selected patient's entry in the list is highlighted. The selected patient's number and name appear in the patient cell at the top of the screen[6]. When a patient is first selected, no field is selected.

Selecting a patient is disabled when a run is in progress.

5.4.4 Field List

In therapy mode, the **Field List** command displays the list of fields for the currently selected patient (fig. A.4)[7].

In experiment mode, the **Field List** command displays the list of fields for the currently selected study (fig. A.3).

If the current study is the first one, which is based on the most recently selected patient, there is only one field: a copy of the field which was most recently selected for that patient before switching to experiment mode. To select a copy of a therapy field in experiment mode, select the patient and the field, then switch to experiment mode, then select the first study and the first (and only) field for that study. That field is a copy of the therapy field. To select a different therapy field in experiment

[6]The patient number is the one assigned by the Prism treatment planning system, not the UW hospital ID number.

[7]At this writing, the **Field List** command is bound to the keypad key labelled Select Field (Fig. 5.1). We plan to change the keycap label.

mode, you must return to therapy mode and select that patient and field, then switch to experiment mode again. At any time, there is only a copy of one therapy field available in experiment mode.

Field List is disabled when no patient (or study) is selected.

Press the up and down arrow keys to move the cursor and to page through the list. The right and left arrow keys are disabled.

5.4.5 Select Field

When the field list is displayed, press the **Select** key to select the field at the cursor.

In the usual case the program first sets the Editing In Progress interlock. The selected field becomes the current field. The prescribed and accumulated settings for the new field are copied from the in-memory prescription database into the appropriate parameters. The status of each parameter and subsystem is assigned to READY or NOT READY as the case may be. All overrides are cancelled; no parameter or subsystem has status OVERRIDE after a field is selected. The program computes the preset dose from the difference of the prescribed dose and the accumulated dose for the current day. The program computes the preset treatment time from the preset dose and certain dose calibration factors. The `Selected field` *`Field Name`* message is logged. The selected field's entry in the list is highlighted. The selected field's name appears in the field cell at the top of the screen. The program sends the reset command to the TMC, LCC and DMC. At this time the dosimetry LED displays turn dark any information displayed there disappears. If a controller fails to respond correctly, its error interlock is set, otherwise it is cleared. After the DMC responds (correctly or not) the transition to the new field is considered complete and the program clears the Editing In Progress interlock.

The control program also commands the LCC to read and send back all its calibration constants. This takes about ten seconds. During this interval the LCC BUSY lamp appears on the LEAF COLLIMATOR display (section 8.2.10). If the LCC does not respond or sends back incorrect values, the program sets the LCC Error interlock.

In therapy mode, all the prescribed settings from the prescription file are assigned to the preset settings.

In experiment mode, only the prescribed leaf settings are assigned. The preset dose and time are not assigned, they just retain their previous values (which may be blank). If the current actual values of WEDGE, WEDGE ROT and FILTER are within range, they are assigned to the preset values. If the value of any of these settings is not within range (perhaps because it is at an in-between position) that value is not assigned and the setting retains its previous preset value.

There is one exception to the preceding rule about preset values in experiment mode. For the one experiment field which is a copy of the most recently selected therapy field, the prescribed values for WEDGE, WEDGE ROT and FILTER from the therapy mode field are assigned to the preset values in the experiment mode field.

Selecting a field is disabled when a run is in progress. In that case the terminal just beeps. Selecting a field is also disabled when the Auto Setup in Progress interlock is set. In that case the program displays an acknowledge box:

```
AUTO SETUP IN PROGRESS
Cannot select field while auto setup in progress
Wait for auto setup to finish, then select field
ACKNOWLEDGE
```

There are several cases where pressing **Select** does not select the field immediately, but instead begins a dialog.

Three messages concern prescribed values. These three conditions are checked in both therapy and experiment mode. If the prescribed value of any parameter is out of range the program displays a confirmation box:

```
Field name INVALID PRESCRIPTION
PARAMETER NAME value nn.n out of range
CONFIRM or CANCEL
```

(the actual field name, parameter name and the offending parameter value appear). If the prescribed values of any leaves overlap (the treatment planning system should prevent this) the program displays a confirmation box:

```
Field name INVALID PRESCRIPTION
LEAF nn value nn.n causes collision
CONFIRM or CANCEL
```

In addition to the confirmation box, the program also writes a log message. It is possible that one or more of these three conditions might be true for more than one parameter at the same time (in fact the collision condition, if true, is true for at least two leaves). In that case, there is a log message written for every offending parameter and condition, but the program only displays a single confirmation box with one of the messages.

Despite these conditions, the operator can press **Confirm** to select the field. In that case the field with the offending prescribed settings becomes the current field, but it will not be possible to auto setup the field (section 5.4.6).

The remaining condition is checked in therapy mode only.

If the prescribed value of the flattening filter is not consistent with the field shape defined by the leaf settings the program displays a confirmation box:

```
Field name INVALID PRESCRIPTION
FILTER value n.n inconsistent
CONFIRM or CANCEL
```

(This box shows the code, not the name, of the filter: 0.0 for none, 1.0 for large, and 2.0 for small.)

5.4.6 Auto Setup

Begins the auto setup operation for the subsystems indicated by the currently selected display.

The auto setup command is disabled when a run is in progress or when no field is selected.

Pressing **Auto Setup** when the FILTER/WEDGE screen is displayed begins the auto setup operation for the filter/wedge subsystem. Likewise for the LEAF COLLIMATOR and DOSIMETRY displays and the corresponding subsystems. Pressing **Auto Setup** when the FIELD SUMMARY screen is displayed begins the auto setup operation for all three subsystems. If none of these four screens are displayed, the auto setup command is disabled.

Auto Setup can also be invoked for the leaf collimator subsystem by pushing one of the buttons on the X-ray controller box, or the button in the treatment room (section 1.6.3). This works while any screen is displayed.

Invoking the auto setup operation for the TMC or the LCC causes the control program to load the controller with the preset setting values for the run, and then command the controller to set up the treatment equipment to those values (sections 3.2 and 3.3). Invoking the auto setup operation for the DMC causes the control program to send the reset command and then the self-test command to the DMC. If the DMC completes these operations successfully, the control program then loads the DMC with several calibration factors and with the preset dose and time for the run (section 3.4).

The program will not attempt to auto setup a subsystem when the Auto Setup interlock for that

subsystem is already set. If the **Auto setup** key is pressed in that condition, the program merely logs a message: `TMC setup already in progress` etc. In this situation the program does not display a message box (we found that such message boxes would often appear when they should not, apparently due to key bounce).

Many conditions can prevent the auto setup operation from proceeding. If a pertinent condition occurs, the program displays an acknowledge box, for example:

```
NO DOSIMETRY SETUP FOR Field name
P/T factor differs from manual, auto 0.9908 manual 1.0023 Dosime-
try system adjustment necessary
ACKNOWLEDGE
```

The conditions that are checked are:

- *PARAMETER NAME* overridden
- *PARAMETER NAME* value *nn.n* out of range
- *PARAMETER NAME* in local mode
- TMC error interlock set
- Filter, wedge already set up
- LCC error interlock set
- LEAF *nn* value *nn.n* causes collision
- Leaf calibration factors not valid
- Leaves in local mode
- DMC error interlock set
- Dose calibration factors not valid
- *Pressure/temperature status, P/T values*
  Dosimetry system adjustment necessary
- No preset dose
- Preset dose *nnnn.n* out of range
- Preset time *nnn.nn* out of range

Here *nnnn.n* represents the largest possible number of digits; there may be fewer.

The *Pressure/temperature status* is one of the messages in table 1.7, and *P/T Values* are the values of the calibration factors relevant to the message, in one of these forms for pressures, temperatures, P/T factors, and other combinations, respectively:

- p1 *nnnn.n* p2 *nnnn.n* manual *nnnn.n*
- auto *nn.n* manual *nn.n*
- auto *n.nnnn* manual *n.nnnn*
- *auto/manual pressure temperature p/t factor*

This condition is checked in therapy mode only:

- FILTER value *n.n* inconsistent

Most of these conditions apply to only one subsystem. The conditions that are checked and reported depend on which subsystem display is selected.

More than one of these conditions can occur at the same time. The program logs a separate message for each pertinent condition, but only shows one acknowledge box.

The program will not attempt to set up any filter/wedge parameters if they are already set up or are overridden, or if the subsystem error interlock is set. However the program will attempt to set up the leaves or the dosimetry system again, even if it is already set up, and will attempt to set up the dosimetry system even if its error interlock is set.

There are several cases where pressing **Auto Setup** does not set up the dosimetry system immediately, but instead begins a dialog.

If the accumulated daily DOSE is greater than zero and the warning flag is clear (zero), this dialog box appears (Fig. B.1):

Field name PARTIAL FRACTION
DAILY DOSE: *xx.x* prescribed, *yy.y* already delivered, difference *zz.z*
Press CONFIRM or CANCEL, or edit dose for this run: *zz.z*

The default dose (*zz.z* in the example above) is the difference dose. If the operator presses **Confirm**, the field is selected with the default dose. The operator may also edit in a different dose than the default dose, then press **Confirm** or **Return** to select the field with that dose. If the operator presses **Cancel** the current field is not changed.

It may happen that the accumulated daily DOSE is greater than zero, but the warning flag is set (nonzero, in this case asterisks appear in place of this field's accumulated daily dose and total dose in the field list). This dialog box appears:

```
Field name PARTIAL FRACTION
Dose from earlier run not recorded in computer
You must determine the remaining dose for this run
Press CANCEL, or enter dose for this run:
```

No default dose is offered. If the operator wishes to select the field, he (or she) must enter a dose.

If the accumulated daily DOSE is zero, indicating no dose has been delivered on the current day, but the warning flag is set, this dialog box appears:

```
Field name TREATMENT RECORD INCOMPLETE
Total dose not recorded in computer, must be updated from pa-
per records
Press CONFIRM or CANCEL, or edit dose for this run:  zz.z
```

Here the default dose *zz.z* is just the usual prescribed daily DOSE.

If the accumulated daily dose is greater than 0.5 MU less than the prescribed daily dose and less than 1.0 more than the prescribed daily dose, this dialog box appears:

```
Field name DAILY DOSE DELIVERED
DAILY DOSE: xx.x prescribed, yy.y already delivered
Press CANCEL, or enter MU for this run:
```

No default dose is offered. If the operator wishes to select the field, he (or she) must enter a dose.

If the accumulated total dose is less than 1.0 MU less than the prescribed total dose and the accumulated total dose plus prescribed daily dose would exceed the prescribed total dose by more than 2.0 MU, this dialog box appears:

```
Field name FINAL FRACTION
FRACTIONS: nn prescribed, mm delivered
DAILY MU FOR dd-mmm-yyyy:  xx.x prescribed, yy.y delivered
TOTAL MU: ww.w prescribed, zz.z delivered
Press CANCEL, or edit dose for this run:  nn.n
```

Here the default dose (*nn.n* in the example above) is the difference between the prescribed total dose and the accumulated total dose.

If the accumulated total dose is greater than 1.0 MU less than the prescribed total dose and less than 2.0 more than the prescribed total dose, this dialog box appears:

```
Field name TOTAL DOSE DELIVERED
TOTAL DOSE: xxx.x prescribed, yyy.y already delivered
Press CANCEL, or enter MU for this run:
```

No default dose is offered. If the operator wishes to select the field, he (or she) must enter a dose.

If the accumulated daily DOSE exceeds the prescribed daily DOSE by 0.5 MU, or the accumulated TOTAL MU exceeds the prescribed TOTAL MU by 2.0 MU, or the accumulated number of treatment days FRAC exceeds the prescribed number of treatment days, this dialog box appears:

```
Field name PRESCRIPTION EXCEEDED
FRACTIONS: nn prescribed, mm delivered
DAILY MU FOR dd-mmm-yyyy:  xx.x prescribed, yy.y delivered
TOTAL MU: ww.w prescribed, zz.z delivered
Press CANCEL, or enter MU for this run:
```

No default dose is offered. If the operator wishes to select the field, he (or she) must enter a dose.

If the completion flag is set to S (superceded), this dialog box appears:

```
Field name SUPERCEDED FIELD
SUPERCEDED FIELD, FRACTIONS: nn prescribed, mm delivered
DAILY MU FOR dd-mmm-yyyy:  xx.x prescribed, yy.y delivered
TOTAL MU: ww.w prescribed, zz.z delivered
Press CANCEL, or enter MU for this run:
```

No default dose is offered. If the operator wishes to select the field, he (or she) must enter a dose. It is possible to enter zero dose (see table 1.1).

If the completion flag is set to S (superceded), this dialog box appears:

```
Field name FILM FIELD
Film field, xx.x prescribed
Press CONFIRM or CANCEL, or edit dose for this run:  zz.z
```

The default dose is the preset dose for this field (which might be zero).

At the **Select Field** operation control program commands the LCC to read and send back all its calibration constants. This takes about ten seconds. During this interval the LCC BUSY lamp appears on the LEAF COLLIMATOR display (section 8.2.10). The operator can select **Auto Setup** during this interval, but the control program does not command the leaf collimator to set up until the calibration check is completed.

Successfully invoking **Auto Setup** for the leaf collimator subsystem when the LEAF SETUP FAILED message box is displayed causes the message box to disappear (section 6.2.1).

If the auto setup of any parameters can proceed, the program writes a log message indicating which, for example:

```
Setting up wedge wedge rot.  flat.  filter.
```

Then the program sends the setup commands to the controllers. Setting up the leaves or dosimetry system can take more than half a minute. Setting up the filter/wedge subsystem can take a minute and a half.

5.4.7 Starting a run

You may begin the treatment run when all parameters are at their prescribed values and all interlocks are clear. Usually this occurs when the door closes after you leave the treatment room. In this condition the status lamps at the top of the display are all green. The lamp in the **START** button on the therapy control panel turns on, and a message box appears:

```
TREATMENT READY
Push START button to begin treatment
or press EXIT RUN key to exit
```

As soon as the **START** button lights up, you may press it to begin the treatment run. It is not necessary to wait for the message box on the display, which may lag behind the lamp by a second or two. After you press **START** the message box disappears and several actions begin which should result in turning on the beam in the treatment room. See section 6.3.1 for more details on starting a run.

5.4.8 Ending a run

When the preset dose is delivered the dosimetry system turns off the beam. The control program waits until the beam plug is closed and it is physically impossible to deliver more dose. A message appears (fig. B.5):

```
TREATMENT FINISHED
Preset dose delivered
Press CONFIRM (or turn X-ray keyswitch) to end this run
Then you may select another operation
```

While this message is displayed the dose and time for the run remain on the dosimetry panel LED displays. They remain there until the operator takes the deliberate action of ending the run by pressing **Confirm**.

Confirm ends the run. The message disappears. The DMC begins its termination self-test so the dose and time for the run disappear from the LED displays.

When this message is displayed, turning on the X-ray controller keyswitch has exactly the same effect as pressing **Confirm**.

When the beam is turned off for any other reason, the program displays another message box instead, offering the `EXIT RUN` option (fig. B.6). For example:

```
TREATMENT INTERRUPTED
Proton interlock
To continue, push START button when interlocks are clear
or press EXIT RUN key to terminate treatment
```

Press **Exit Run** to end the run. In this situation the DMC termination self-test is not performed. The dose and time for the run remain on the LED's until the DMC is set up again or a field is selected.

Exit Run is disabled at all other times.

See sections 6.4.2 through 6.5.5 for more details on ending a run.

5.4.9 Experiment Mode

Experiment Mode toggles between experiment mode and therapy mode. The program must be in experiment mode to change calibration factors, to access the database of experiment fields, to send commands to the controllers for diagnostic or troubleshooting purposes, and to shut down the control program.

This command is disabled when the operator is not identified as a physicist in the operator authorization file, so therapists cannot place the program in experiment mode (if a therapist logs in when the program is in experiment mode, the program reverts to therapy mode).

This command is disabled when a run is in progress. This command is also disabled when an LCC calibration is in progress (so you cannot toggle back to therapy mode until the calibration is completed or abandoned).

When this key is pressed, the program toggles from therapy to experiment mode (or vice versa). The program reverts to No patient (No study) and No field.

If the program is in therapy mode when this command is invoked, the program copies the currently selected patient and therapy field into the in-memory database of studies. The name of the first experimental study is constructed from the patient number and patient name. The first and only field for this study is a copy of the therapy field. This makes it possible to set up and deliver (a copy of) a therapy field in experiment mode (sections 5.4.2 and 5.4.4 above).

If the patient (study) list screen is displayed when this command is invoked, the program reads the experimental study file (or the prescription file) and displays the list of studies (or patients) so the display and its contents are consistent with the selected mode. If the field list screen is displayed when this command is invoked, the the screen is redisplayed, consistent with the selected mode and No studies (or No patient).

5.5 Subsystem commands

Use **Field Summary**, **Gantry/Couch**, **Filter/Wedge**, **Leaf Collim** and **Dosimetry** to select the subsystem display screens, and also to prepare for editing or overriding certain parameters. Use **Override** to begin the dialog to override a parameter.

5.5.1 Field Summary

This command shows the FIELD SUMMARY display (Fig. A.5).

It is not possible to edit or override any parameters on this display. The arrow keys, the **Select** key, and the **Override** key are disabled when this display is shown.

Pressing **Auto Setup** at this display causes the control program to attempt to set up all three subsystems (subject to the conditions in section 5.4.6).

5.5.2 Gantry/Couch

This command shows the GANTRY/COUCH display (Fig. A.6). When the display appears, the cursor is at the bottom of the PRESCRIBED column, on the *parking place* cell marked OVERRIDE.

It is possible to override the GANTRY, COLLIMATOR and TURNTABLE parameters. Use the up and down arrow keys to move the cursor over the setting you wish to override, then press **Override** (fig. B.2). The right and left arrow keys are disabled. **Override** is disabled when no field is selected.

It is not possible to edit any settings on this display. The **Select** key is disabled when this display is shown.

It is not possible to auto setup any parameters on this display. The **Auto Setup** command is disabled when this display is shown.

5.5.3 Filter/Wedge

This command shows the FILTER/WEDGE display (Fig. A.7). When the display appears, the cursor is at the bottom of the PRESCRIBED column, on the parking place cell marked OVERRIDE.

It is possible to override the WEDGE TYPE, WEDGE ROT and FILTER parameters. Use the up and down arrow keys to move the cursor over the setting you wish to override, then press **Override**. The right and left arrow keys are disabled. **Override** is disabled when no field is selected.

It is not possible to edit settings in therapy mode. In this mode the **Select** key is disabled.

In experiment mode only when a field is selected, it is possible to edit the preset WEDGE TYPE, WEDGE ROT and FILTER settings (the column is still labelled PRESCRIBED in experiment mode). Use the up and down arrow keys to move the cursor over the setting you wish to edit, then press **Select**. This causes the menu of possible setting values to appear (Fig. B.4). Here is the menu for WEDGE TYPE (the cursor cannot reach the caption line at the top of the menu).

```
WEDGE TYPE
NONE
30 deg
45 deg
60 deg
```

For WEDGE ROT the menu is

```
WEDGE ROT
0 deg
90 deg
180 deg
270 deg
```

For FILTER the menu is

```
FILTER
NONE
LARGE
SMALL
```

Select is disabled when no field is selected.

Pressing **Auto Setup** causes the control program to attempt to set up the Filter/Wedge subsystem (subject to the conditions in section 5.4.6).

5.5.4 Leaf Collimator

This command shows the LEAF COLLIMATOR display (Fig. A.8). When the display appears, the cursor is at the bottom of the PRESCR column on the left side, on the "parking place" cell marked OVERRIDE.

It is possible to override any leaf setting. Use the up and down arrow keys to move the cursor in one column, and use the right and left arrow keys to move the cursor to the opposite column. Position the cursor over the leaef you wish to override, then press **Override**. You can override more than one leaf, but you must override each leaf individually. It is not possible to override all the leaves at once.

It is not possible to edit settings in therapy mode. In this mode the **Select** key is disabled.

In experiment mode only, it is possible to edit the preset value of any leaf (the column is still labelled PRESCR in experiment mode). Use the up and down arrow keys to move the cursor over the leaf you wish to edit, then press **Select**. This causes the dialog box to appear, for example:

```
EDIT SETTING
Enter value for LEAF 35 between -3.5 and 15.0 cm:
```

(For leaves 0 – 19 the range is -15.0 to 3.5 cm, for leaves 20 – 39 it is -3.5 to 15.0 cm).

Pressing **Auto Setup** causes the control program to attempt to set up the leaf collimator (subject to the conditions in section 5.4.6).

5.5.5 Dosimetry

This command shows the DOSIMETRY display (Fig. A.9). When the display appears, the cursor is at the bottom of the PRESET column, on the "parking place" cell marked MODIFY.

It is possible to edit the preset value of DOSE or TIME. To edit preset dose, use the up arrow key to move the cursor over DOSE A, then press **Select**. This dialog box appears:

```
EDIT SETTING
Enter value for DOSE between 0.0 and 999.8 MU:
```

When you enter a dose, the PRESET values displayed for both DOSE A and DOSE B change to the value you entered. The program calculates a new treatment TIME from this dose value and the relevant dosimetry calibration factors. The new TIME value appears in both the PRESCRIBED and PRESET columns.

To edit treatment time, use the up and down arrow keys to move the cursor over TIME, then press **Select**. This dialog box appears:

```
EDIT SETTING
Enter value for TIME between 0.0 and 99.99 min:
```

When you enter a time, the time displayed in the PRESET column only changes.

Pressing **Auto Setup** causes the control program to attempt to set up the dosimetry subsystem. The program performs all the usual checks (section 5.4.6). Therefore, if the preset dose or time is blank (as they are after an experiment field is first selected) the program will not set up the dosimetry system, but will display a message in an acknowledge box.

You may edit preset DOSE or TIME after the dosimetry system is set up, but before the run begins (in the Self-test OK or Waiting treatment phases). When you complete the editing dialog (by pressing RETURN or CONFIRM at the dialog box), the control program resets the DMC to clear the values that were set up previously. This causes the dosimetry system to become NOT READY, and you must auto setup the dosimetry system again to load the new values.

5.5.6 Override

Press the **Override** key to display the confirmation box for overriding the setting. The box (fig. B.2) says

```
OVERRIDE
Override PARAMETER NAME?
CONFIRM or CANCEL
```

The override command is enabled when the display cursor is positioned over the preset value of parameter that can be overridden (these parameters only appear on certain subsystem displays, see above).

The override command is disabled when no field is selected or a run is in progress.

Pressing **Confirm** when the status of the parameter is READY or NOT READY changes the parameter status to OVERRIDE (this may also have the effect of changing the subsystem status to OVERRIDE).

You can also use **Override** to un-override an overridden parameter. If the parameter status is already OVERRIDE, pressing **Confirm**, changes the status back to NOT READY or READY as appropriate. In other words, This command acts as a toggle (however the confirmation box prompt text is always the same).

You can override a parameter even if its status is READY or if its actual value is out of range. When you override a parameter, it remains overridden until you toggle off the override, even if its actual value changes. This makes it possible to override a parameter when when its actual value is varying rapidly in and out of tolerance (perhaps due to noise on its sensor), or when its actual value is at some extreme value (perhaps due to a faulty sensor)[8].

Selecting a new field cancels all the overrides. After a field is selected, no parameter has status OVERRIDE.

If you press **Override** when the cursor is not positioned over a setting (it is still parked), the program displays this acknowledge box:

```
OVERRIDE
Use arrow keys to position cursor over setting
then press OVERRIDE
ACKNOWLEDGE
```

5.6 X-ray port commands

There are commands to set up the five X-ray ports, and one more command to restore the prescribed field shape:

- 10 x 10
- 16.5 x 16.5
- 20.5 x 20.5

[8] It is possible to override filter and wedge settings when they are at the in-between positions indicated by asterisks, but the FILTER/WEDGE subsystem is NOT READY in this condition because the Filter/Wedge Fault interlock is set (section 1.5.6)

- 24.5 x 24.5
- 28.5 x 28.5
- Prescribed field

Unlike most commands they are not usually invoked by pressing keys. Instead they are bound to buttons on the X-ray controller box. There is one button for each port, including the prescribed field. There is also a button for setting up the prescribed field on the mobile pedestal in the treatment room.

The buttons on the X-ray controller box are connected to the control computer through the PLC, not the X terminal. These buttons are enabled by the PLC program, not the control program. The PLC enables the buttons when the X-ray generator is enabled for an exposure in the isocentric room (this requires that the same key used to enable the mobile pedestal in the therapy room be placed in the X-ray controller in the control room).

Even when the buttons are enabled by the PLC, the control program may not execute the commands. When a button is pressed, the control program checks to see if the command is allowed. First it checks that a run is not in progress and that no other request to set up a field or port is pending. If either condition is true, the program simply ignores the command and issues no message. Then the program checks for additional conditions. If any of these conditions is true, the program displays a message box (not an acknowledge dialog box), for example:

```
NO LEAF SETUP FROM PUSHBUTTON
LCC error interlock set
Press ACKNOWLEDGE key to dismiss message
```

The program checks for these conditions:

- `LCC error interlock set`
- `Leaf calibration factors not valid`
- `Leaves in local mode`
- `LCC setup already in progress`

And, when the prescribed field button is pressed, it also checks

- `No prescribed field`

Setting up the prescribed field is subject to the same conditions as the **Auto Setup** command for the leaf collimator subsystem (section 5.4.6).

These commands are also bound to control keys (Table 5.1).

5.7 Calibration commands

5.7.1 Dosimetry Calibration

Dosimetry Calibration displays the DOSIMETRY CALIBRATION screen (Fig. A.12). This command is enabled in both therapy mode and experiment mode.

In experiment mode only, this command causes the control program to read the dosimetry calibration file `dosecal.dat`. This updates the in-memory dosimetry calibration constants with the values in the file. Use this command after updating the file contents with an editor or utility program.

In both therapy and experiment mode, it is possible for operators authorized as physicists to edit the MANUAL values for the dose calibration factors PRESSURE, TEMPERATURE, and TIME FACTOR. This makes it possible for a physicist to log in, edit the factors, and log out without losing the patient and field selected by a therapist. It is always possible for any operator to edit DOSE RATE. This makes it easy to enter a lower dose rate when the cyclotron is temporarily unable to provide the usual high dose rate.

To edit a calibration factor, use the up and down arrow keys to position the cursor over the calibration factor you wish to edit. Press **Select** to cause a dialog box to appear:

```
EDIT SETTING
Enter value for PRESSURE between 980.0 and 1040.0 mbar:
```

Here are the prompts for all the dosimetry calibration factors that can be edited:

- `Enter value for PRESSURE between 980.0 and 1040.0 mbar`
- `Enter value for TEMPERATURE between 20.0 and 28.0 C`
- `Enter value for DOSE RATE between 0.0 and 99.9 MU/min`
- `Enter value for TIME FACTOR between 1.00 and 2.00`

When the PRESSURE or TEMPERATURE is changed, the program recomputes the MANUAL P/T FACTOR. The control program also updates P/T ENTERED to the time that the other factor was last changed (this time is used with the P/T DEADLINE to calculate when the MANUAL P/T FACTOR expires).

When the DOSE RATE or TIME FACTOR is changed, the control program recomputes the preset treatment TIME.

You may edit these calibration factors after the dosimetry system is set up, but before the run begins (in the Self-test OK or Waiting treatment phases). When you complete the editing dialog (by pressing RETURN or CONFIRM at the dialog box), the control program resets the DMC to clear the calibration factors that were set up previously. This causes the dosimetry system to become NOT READY, and you must auto setup the dosimetry system again to load the new calibration factors.

5.7.2 Leaf collimator calibration

The leaf collimator is calibrated by setting up two calibration fields (20×32.5 cm and leaves closed on midline) determined by mechanical jigs and reading the readout potentiometers to calculate calibration constants. The procedure is described in detail in the *Standard Operating Procedures* book. This section just describes the calibration as far as the control program is concerned.

LCC Calibration displays the LEAF COLLIMATOR CALIBRATION screen (Fig. A.13). This command is enabled in both therapy mode or experiment mode.

In experiment mode only, this command causes the control program to read several calibration constant files:

- `calfields.dat`, leaf collimator calibration field sizes
- `mlccal.dat`, leaf colimator calibration constants
- `ports.dat`, X-ray port field shapes
- `tol.dat`, tolerance windows for leaves and other parameters

Reading these files causes the control program to update its in-memory constants with their contents. Use this command after updating the file contents with an editor or utility program (the file `mlccal.dat` is usually only updated by the control program itself, see below).

This screen must be displayed to enable the LCC calibration commands described below.

5.7.3 Large Calibration Field

Large Calibration Field begins the LCC calibration procedure. The calibration procedure involves several steps. Once you begin you must either complete the procedure or explicitly abandon the procedure before you can select any other display. The procedure is designed to ensure that, when you exit the procedure by either method, the calibration factor data are consistent in the LCC, in control program memory, and in the file.

This command is enabled in experiment mode when the LEAF COLLIMATOR CALIBRATION screen is displayed and a run is not in progress.

First, the program sets the field to No field (so prescribed settings become blank and subsystems are NOT READY). It will be necessary to select a field again after the calibration procedure, which will ensure that the control program will load its latest in-memory calibration factors into the LCC.

The program displays a dialog box:

```
CALIBRATE LARGE FIELD
You may calibrate just one pair of leaves, or all of them
Enter leaf pair number 0 - 19, or SELECT for all
```

If you just press **Select** the program displays a confirmation box:

```
ADJUST LARGE CALIBRATION FIELD
Wait for setup, manually adjust leaves to large field posi-
tion
Press CONFIRM when large field achieved
CONFIRM OR CANCEL
```

If you enter a leaf pair number the confirmation box appears, except one line says

```
Wait for setup, manually adjust leaves ii and jj to large field
position
```

While this confirmation box is visible, the large calibration field sets up (using the presently valid LCC calibration). First the central region of the screen says

```
SETTING UP
LARGE CAL. FIELD
```

then it shows the leaves. They should be opened to the large calibration field. Do not press **Confirm** yet.

Then go into the treatment room and adjust the leaves against the large field calibration jig. When the leaves are adjusted, press **Confirm**.

At this time the new MAXPOS calibration factors are computed and stored in the LCC, but they are not yet copied into control program memory. An acknowledge box appears:

```
STORE LCC CALIBRATION FACTORS
MAXPOS have been updated in LCC
Next select MIDLINE FIELD to calibrate MINPOS and SCAFAC
or select another display to restore old calibration
ACKNOWLEDGE
```

Press **Acknowledge** to dismiss the box. Now you are ready for **Midline Field**.

5.7.4 Midline Field

Midline Field continues the LCC calibration procedure.

This command is enabled in experiment mode when the LEAF COLLIMATOR CALIBRATION screen is displayed, the large calibration field adjustment is completed, and a run is not in progress. (It is not possible to begin a run after beginning the LCC calibration procedure because the during the procedure the leaf collimator subsystem is NOT READY).

The program displays a confirmation box:

```
CALIBRATE MIDLINE FIELD
Calibrate all the leaves
Pressing CONFIRM will close the leaves -- remove the jig first
CONFIRM OR CANCEL
```

Remove the jig. Press **Confirm**. A confirmation box appears:

```
ADJUST MIDLINE FIELD
Wait for setup, manually adjust leaves to midline position
Press CONFIRM when midline achieved
CONFIRM OR CANCEL
```

(or `Wait for setup, manually adjust leaves` *`ii`* `and` *`jj`* `...`)

Do not press **Confirm** yet.

While this box is visible, the midline field sets up. First the central region of the screen says

```
SETTING UP
MIDLINE CAL. FIELD
```

then it shows the leaves. They should be opened to the midline calibration field. Do not press **Confirm** yet.

Go into treatment room and adjust leaves to midline using the midline jig. Then press **Confirm**.

At this time the new MINPOS and SCAFAC are computed and stored in the LCC, but they are not yet copied into control program memory. An acknowledge box appears:

```
STORE LCC CALIBRATION FACTORS
MINPOS and SCAFAC have been updated in LCC
Next select WRITE FILE to save calibration factors
or select another display to restore old calibration
ACKNOWLEDGE
```

Press **Acknowledge** to dismiss the message box.

The program prevents you from performing calibration commands out of sequence. If you select **Midline Field** before **Large Calibration Field** this acknowledge box appears:

```
CALIBRATE MIDLINE FIELD
You must calibrate the large field first
Press ACKNOWLEDGE, then select LARGE CAL FIELD
ACKNOWLEDGE
```

5.7.5 Completing or abandoning the LCC calibration

There are two ways to exit the calibration procedure, depending on whether you wish to save the new calibration factors, or discard them and revert to the previous factors.

To save the new calibration factors, press **Write File**. This confirmation box appears:

```
SAVE LCC CALIBRATION FACTORS
Save new MAXPOS, MINPOS and SCAFAC
in control program memory and save in LCC calibration file
CONFIRM OR CANCEL
```

Until this time the new calibration factors have only been stored in the LCC, not control program memory. Press **Confirm** here to cause the control program to read the new calibration factors from the LCC and store them into control program memory. The calibration factors shown on the screen update, showing the new values for the first time.

The control program checks whether the communication with LCC proceeded without error and whether the new calibration factors are within range. If there were no LCC errors and the new factors are within range, the program writes the new calibration factors to the LCC calibration file, replacing the old factors (the old factors are lost). If the file is written successfully, this acknowledge box appears (fig. B.3):

```
LEAF COLLIMATOR CALIBRATION FILE
MAXPOS, MINPOS and SCAFAC saved in collimator cal.  file
and stored in control program memory
ACKNOWLEDGE
```

Press **Acknowledge** to dismiss this message box.

The calibration procedure is finished. The new calibration values are stored in the LCC, in the control program memory, and in the calibration file. From now on, each time a new field is selected the new calibration factors will be loaded from control program memory into the LCC. The new factors will be read from the file and loaded into control program memory each time the LEAF COLLIMATOR CALIBRATION display is selected in experiment mode (and each time the program is restarted).

You must **Write File** after each calibration procedure where you wish to save the data. If, after calibrating all the leaves, you decide you want to recalibrate one or more pairs of leaves again, you

must **Write File** after calibrating all the leaves, before you recalibrate the first pair. Then you must **Write File** again after recalibrating each pair of leaves, before recalibrating the next pair.

It is possible that the calibration procedure might fail at the **Write File** command. If the new calibration factors are not within range, the program sets the No Leaf Coll Cal. Available interlock, which appears as a red lamp on the LEAF COLLIMATOR CALIBRATION display and also the regular LEAF COLLIMATOR display. In this case the program does not write out the new (bad) factors so the old factors remain in the file but the new factors remain in control program memory. It is not possible to set up the LCC in this condition because the No Leaf Coll Cal. Available is set. You must discard the new calibration factors from memory (as described below). In this situation the control program displays this acknowledge box:

```
LEAF COLLIMATOR CALIBRATION FILE
MAXPOS, MINPOS and SCAFAC not saved, range error
Select another display to restore old calibration
ACKNOWLEDGE
```

If there was an LCC communication error, the program sets the LCC Error interlock and the acknowledge box says `read error` or `timed out` instead of `range error`. In this situation also there may be new calibration factors (or some new factors) in memory but the old factors remain in the file. If the LCC communication succeeded and the new factors are in range but there was an error writing the file, no interlocks are set but the acknowledge box says `open error` or `write error` or `timed out`. In this situation there are valid new calibration factors in memory but the file still contains the old factors.

If any of these failures occurs, you can try **Write File** again.

If any step in the calibration procedure fails, or you decide to abandon the calibration procedure for any reason, you can exit the procedure and discard the new calibration factors at any time when a dialog box is not displayed (it is not necessary to calibrate both fields before doing this). Just select any other display (such as the patient list or the help screen). This confirmation box appears:

```
DISCARD LCC CALIBRATION FACTORS
WARNING: Unsaved MAXPOS, MINPOS and SCAFAC
Press CONFIRM to discard data, CANCEL to continue calibra-
tion
CONFIRM or CANCEL
```

Press **Cancel** to dismiss the message box and continue with the calibration procedure.

Press **Confirm** to exit the calibration procedure and discard the new calibration factors. The control program rereads the leaf collimator calibration file, restoring the old calibration factors in control program memory. Then the control program loads the old calibration factors back into the LCC.

There are only two ways out of the calibration procedure. After a successful **Write File** command, the new factors are in the LCC, control program memory, and the file. After a discard command, the old factors are in the file, control program memory, and the LCC. In both cases the data are consistent everywhere. Moreover, during the calibration procedure the field is No field so it will be necessary to select another field before setting up the LCC again. At that time the control program will once again load the calibration factors into the LCC[9].

The program checks to make sure you do not select commands in the wrong order.

If you try to toggle back to therapy mode (by pressing **Experiment Mode** before completing the calibration procedure, the terminal beeps.

If you select **Midline Field** before **Lg Cal Field** an acknowledge box appears (see above, with **Midline Field**).

If you press **Write File** before calibrating either field, the terminal beeps.

If you press **Write File** after calibrating just the large field, this message appears

```
SAVE LCC CALIBRATION FACTORS
You must also calibrate the midline field
Press ACKNOWLEDGE, then select MIDLINE FIELD
ACKNOWLEDGE
```

5.8 Troubleshooting and maintenance commands

5.8.1 PLC Status

Press the **PLC** key to show the PLC STATUS screen (Fig. A.10)[10]. This display is continually updated to show the current values of most of the input and output signals handled by the PLC. The remaining signals handled by the PLC are displayed on the PLC MOTIONS screen. (section 5.8.2).

[9] The only potential problem occurs if, at the discard command, an open error or read error or timeout occurs when the control program tries to read the old calibration file. In that case the new factors remain in control program memory and will be reloaded into the LCC when a new field is selected.

[10] Pressing `ctrl-0` will also display this screen, to accommodate terminals that do not provide ten function keys.

This command is always enabled.

5.8.2 PLC Motions

Press the **PLC MOTIONS** key to show the PLC MOTIONS screen (Fig. A.11).This display is continually updated to show the current values of the motion control signals handled by the PLC.

This command is always enabled.

5.8.3 Controller message displays and pass-through utilities

Press the **TMC**, **LCC** and **DMC** keys to display the TREATMENT MOTION CONTROLLER (TMC), LEAF COLLIMATOR CONTROLLER (LCC) and DOSE MONITOR CONTROLLER (DMC) message screens, respectively (for example, fig. A.15). Press `ctrl-9` to display the PROGRAMMABLE LOGIC CONTROLLER (PLC) message screen (the **PLC** key shows the PLC STATUS screen (section 5.8.1).

These commands are always enabled.

These screens show a log of recent message traffic (in both directions) between the control program and the controller, with date and time stamps at one minute intervals. When you select a message display, it shows the most recent messages on the screen. This is a “snapshot” made at the time you pressed the key: normally the screen does not update, even though message traffic continues (otherwise messages would quickly scroll away). Press the up-arrow key to scroll back through the older messages, press down-arrow to scroll forward again to the recent messages. To refresh the screen with a new snapshot of the most recent messages, press the key (**DMC** or whatever) again.

Several thousand lines of messages and time stamps are stored for each controller (fewer messages are stored after the control program starts up, of course). This message buffer holds several hours to several weeks of messages, depending on the controller and its activities (table 3.2).

Press **Write File** to write the entire contents of the message buffer (including the timestamps) out to a file (up to 4500 lines). The control program assigns a unique filename created from the controller name and the current date and time (section 4.2). It is usually easier to examine this file than to scroll back through the messages.

Write File is enabled whenever a controller message log screen is displayed.

There is a *pass-through* utility that you can use to type commands directly to the controller. To start the pass-through utility, press **Select** while a controller message screen is displayed. The pass-through utility is only enabled in experiment mode when a run is not in progress.

The control program stops polling the TMC, LCC, or PLC when you start the pass-through utility for that controller (it continues polling the other controllers). However the control program does not stop polling the DMC, if it was polling the DMC already (during some phases the control program does not poll the DMC, see chapter 2). The control program also enables scrolling on the message display, so you can see the effect of the commands you type.

When you start the pass-through utility, a dialog box appears where you can type a command to the controller:

```
CONTROLLER COMMAND
Enter command string
```

Type the command, then press **RETURN** or **Select**. The dialog box disappears and the control program sends the command to the controller. The command appears on the display, then the controller's response appears. Make sure you type the command in uppercase, otherwise the controller will respond with an error message (we usually leave the caps lock engaged).

To reset a controller, type the command `RESET`. The pass-through utility detects this and sends the escape character (the reset command) to the controller. This is the only special case where the utility does not send exactly what you type.

When you type `CON RUN` to the LCC pass through utility, the control program also commands PLC2 to enable the motion.

The pass-through utility remains in effect as long as the controller screen is displayed: the control program does not poll the controller and scrolls the controller message display. You must press **Select** again to invoke the dialog box for each command.

To turn off the pass-through utility, select another screen (or just select the same controller screen again). The control program resumes polling the controller and stops scrolling the controller message display.

5.8.4 Messages

Press the **Messages** key to show the MESSAGE LOG display (fig. A.14).

This command is always enabled.

Press the up and down arrow keys to page through the log.

Press **Write File** to write the entire contents of the message log buffer and the treatment record buffer out to two separate files (each up to 4500 lines). The control program assigns unique filenames created from the current date and time (section 4.2). This provides a way to write out log messages and treatment records after contact with the file server has been interrupted and then resumed. Otherwise, some of the log messages and treatment records would not be recorded in the file system.

Write File is enabled whenever the message log screen is displayed (except during dialogs).

5.8.5 Log Message

Displays a dialog box where the operator may type a message for the message log:

```
LOG MESSAGE
Enter message:
```

The message that the operator types is time-stamped and appended to the message log.

This command is always enabled, even during runs.

5.8.6 Treatment records

Press `ctrl-7` to show the TREATMENT RECORDS display. These are the same records as appear in the treatment record file.

This command is always enabled.

Press **Write File** while this screen is displayed to write out the contents of the in-memory treatment record buffer (up to 4500 lines).

5.8.7 Write File

Press **Write File** to write out a file of data related to the current display. This command is enabled when the following screens are displayed (when no dialog or LCC calibration is in progress), and writes out the indicated files. There is no confirmation box or other dialog for this command.

- THERAPY FIELDS (therapy mode only), writes accumulated dose file `accum.dat`
- LEAF COLLIMATOR CALIBRATION (end of LCC calibration procedure only), writes `ml-ccal.dat`
- MESSAGE LOG, writes on-demand message log file `iso-d`*yyyy-mmdd-hhmmss*`.log` and on-demand treatment record file `isotr-d`*yyyy-mmdd-hhmmss*`.log`
- TREATMENT RECORDS, writes on-demand treatment record file only.
- TREAMENT MOTION CONTROLLER (TMC), writes TMC message file `tmc`*yyyy-mmdd-hhmmss*`.dat`
- LEAF COLLIMATOR CONTROLLER (LCC), writes LCC message file `lcc`*yyyy-mmdd-hhmmss*`.dat`
- DOSE MONITOR CONTROLLER (DMC), writes DMC message file `dmc`*yyyy-mmdd-hhmmss*`.dat`
- PROGRAMMABLE CONTROLLER (PLC), writes PLC message file `plc`*yyyy-mmdd-hhmmss*`.dat`

See also chapter 4.

5.8.8 Set date and time

When the control program starts up, it sets its own clock to the current date and time indicated by the host [1]. After that, the control program clock usually counts on its own, but it is possible to reset the control program clock from the host again without restarting the control program. This may be useful if the control program clock drifts or if the host clock was wrong to begin with (however the control program does its own daylight savings time adjustment, independent of the host clock, see [1]).

This command is enabled in experiment mode when a run is not in progress.

Press `ctrl-shift-C`. This confirmation box appears:

```
RESET TIME
Are you SURE you want to reset the time from the host?
CONFIRM or CANCEL
```

Press **Confirm** to reset the clock time. There are no other effects. Pending timeouts are not affected. The clock time is only used to update the on-screen clock and create time stamps for log messages, file names etc.

5.8.9 Control program shutdown

This command is enabled in experiment mode when a run is not in progress.

To shut down the program, press `ctrl-shift-Q` (for *quit*). The program displays this confirmation box:

```
SHUTDOWN
Are you SURE you want to shut down the control program?
CONFIRM or CANCEL
```

Press **Confirm** to continue the shutdown. At shutdown the control program:

1. Writes `Operator Operator requested shutdown` at the end of the message log.
2. Closes the message log file and treatment log file
3. Closes the connection to the X terminal
4. Writes `Have a nice day` to the console port

The control program graphics disappear from the X terminal screen, which reverts to the gray weave (blank) pattern.

The messages indicate the program was stopped by a controlled shutdown instead of a halt or crash.

The PLC watchdog sets.

After a shutdown, the control program can only be restarted by rebooting the control computer.

5.8.10 Halts and crashes

In addition to operator requested shutdowns, the program can stop in two more ways: it *halts* when the program detects certain conditions, and it may *crash* in response to hardware failures, programming errors, or disturbances in the environment (power, network, etc.). When the program halts or crashes, it does not close any files or write any messages, and the display screen may stop updating or "freeze" instead of clearing. However, the PLC watchdog does set.

It is possible to deliberately halt or crash the program from the terminal (this capability was provided for testing).

To halt the program, type `ctrl-shift-A` (for *Abort*), instead of typing `Q` for *Quit*). This confirmation box appears:

```
CONSOLE CRASH TEST
Are you SURE you want to test Assertion Failure?
CONFIRM or CANCEL
```

To cause various conditions that will crash the program, type these `ctrl-shift` combinations. You will see the indicated message in the confirm box:

- `ctrl-shift-K: Are you SURE you want to test Access Fault/Bus Error?`
- `ctrl-shift-L: Are you SURE you want to test Illegal Instruction?`
- `ctrl-shift-W: Are you SURE you want to deadlock the control program?`
- `ctrl-shift-M: Are you SURE you want the TMC task to Access Fault?`
- `ctrl-shift-H: Are you SURE you want the TMC task to deadlock?`

These commands are enabled in experiment mode when a run is not in progress.

5.9 Miscellaneous commands

5.9.1 Refresh

This command causes the control program to reset the TMC, DMC, and LCC, just like it does when the operator selects a new field. It also causes the control program to reread most data files and reload the calibration factors and other data that they contain. In particular, it reads these files: the dose calibration file `dosecal.dat`, the collimator calibration file `mlccal.dat`, the tolerance windows file `tol.dat`, the X-ray port shapes file `ports.dat`, the collimator calibration field shapes file `calfields.dat`, the operator authorization file `oper.dat`, and the daily message file `message.dat`.

This command also causes the display to be redrawn.

This command is enabled whenever a run is not in progress. However, even when a run is in progress, this command causes the display to be redrawn (but it does not reset the controllers or reread the files).

5.9.2 Help

Reads the message of the day file `message.txt` and shows the Help display (fig. A.16). This command is always enabled.

5.9.3 Room Display

This command causes the room display (Fig. A.17), which is always shown on the monitor in the treatment room, to appear in the central region of the therapy console screen also.

Chapter 6

Message boxes

Certain events can cause a message to appear in a *message box* in the bottom half of the screen (Figs. B.5, B.6). Unlike dialog boxes and menus, message boxes do not appear when the operator issues a command. Instead, they appear spontaneously (without operator action) when the control program detects certain events or conditions. However message boxes do not disappear spontaneously. They remain on the display until the operator presses **Acknowledge**, **Confirm**, **START**, **Exit Run**, or whatever the message requests.

(Some dialog boxes also indicate conditions detected by the control program, such as `FILE ACCESS TIMEOUT`. However these only appear after the operator issues a particular command and are therefore described in chapter 5).

Other keys are not disabled when a message box is displayed. It is even possible for a message box to be displayed at the same time as a a dialog box or menu. In this situation most keyboard input goes to the dialog box so the operator can complete the dialog before dealing with the message. **Cancel**, **Acknowledge**, **Confirm**, **Select**, and **Return** go to the dialog box. When the dialog is finished, the dialog box disappears and the message box remains. After that, keyboard input goes to the message box. However **Exit Run** always goes to the message box, even when a dialog box is displayed, because this key is never handled by a dialog box.

This chapter shows each message boxes, describes the events and conditions that cause the message to appear, shows the options offered to the operator, and describes the effect of each option.

Message boxes that indicate events that are expected during standard procedures are gray, as in fig. B.5. There are only two gray message boxes during a normal run, `TREATMENT READY` (section 6.3.1) and `Preset dose delivered` (section 6.5.1). Message boxes that indicate some error or unexpected event are yellow, as in fig. B.6.

When a message box is displayed, its message is also written to a permanent log file. This can be useful for troubleshooting or quality assurance purposes. Usually the log message is the same as one of the lines that appears in the message box. Every log message is described in chapter 7. Past messages can be also be viewed using the MESSAGE LOG display (section 5.8.4, fig. A.14). There are a few exceptions where no log message is written or the wording of the log message is different from the wording in the message box. These exceptions are indicated in this chapter.

When one message box is already displayed, an event might occur that that causes a new message to appear. In that case the new message replaces the earlier one, so the message most recently processed by the control program is always displayed (however this message might not be the one caused by the most recent event in the real world, due to delays in controller polling and task switching). The earlier message boxes cannot be restored to the display, but past messages can be read from the message log or viewed onMESSAGE LOG display.

Most message boxes can only appear during certain treatment phases. It is convenient to describe the messages according the phases where they can appear.

6.1 Before auto setup

6.1.1 Error reading file

This message appears when the control program is unable to read a data file. It may appear at those times when the program attempts to read data files: at startup, when the operator selects particular displays, and when the operator presses the **Refresh** key.

```
ERROR READING FILE
File description file, status at line nn
Press ACKNOWLEDGE key to dismiss message
```

The *file description* elements are described in section 7.4 and the *status* values are described in section 7.2.1.

When this message appears, the contents of control program memory are not changed. None of the data in the file is copied into program memory (even if the error is encountered at some point past the start of the file). All of the previous version of the data remains in program memory (except at startup, when there is no previous version).

Acknowledge causes the message to disappear but has no other effect. Then the operator can attempt to reread the file again by selecting the appropriate display, pressing **Refresh**, or restarting the control program.

6.2 After auto setup

6.2.1 Leaf setup failed

This message appears when an attempt to auto setup the leaf collimator fails. The program checks many conditions before attempting to set up the leaves (section 5.4.6) but the attempt may fail anyway. The second line of the message gives the reason for the failure, for example:

```
LEAF SETUP FAILED
Leaf motion not enabled
Press ACKNOWLEDGE key to dismiss message
```

The second line of the message is one of:

- `Leaf motion not enabled`
- `Collimator in local mode`
- `Leaves not positioned properly, try setup again`

The `Leaves not positioned` message appears after the LCC reports an unrecoverable `Leaf no motion error`.

Acknowledge causes the message to disappear but has no other effect. Then the operator can attempt to auto setup the leaves again.

Auto Setup for the leaf collimator subsystem also causes the message to disappear. This was provided so the message could be dismissed from the LCC auto setup button in the treatment room, but also works from the console terminal and the X-ray ports control box.

This message may also appear after attempting to set up a leaf collimator calibration field or an X-ray port.

6.2.2 Setup timeout

This message appears when the maximum setup time has elapsed after the dosimetry system was set up but it has not been possible to begin a run because not all interlocks have been cleared. The maximum setup time is read from a file; at this writing it is 15 minutes.

At the same time this message appears, the DMC Setup Timeout interlock sets.

```
SETUP TIMEOUT
Setup timer expired
Press ACKNOWLEDGE to dismiss this message
then AUTO SETUP DOSIMETRY to restart treatment
```

Acknowledge causes the message to disappear but has no other effect. Then the operator can auto setup the dosimetry system again.

6.2.3 Start command timeout

This message appears after the control program sends the `CON START` command to the DMC, but the dosimetry relays have not become energized after a timeout has expired. This indicates that the DMC has failed to respond to the `CON START` command. Usually, repeating the `CON START` command (by repeating the **Auto Setup** operation on the dosimetry system) clears the problem.

```
START COMMAND TIMEOUT
CON START sent to DMC but dosimetry relay not activated
Press ACKNOWLEDGE key to dismiss this message
then AUTO SETUP DOSIMETRY to restart treatment
```

Acknowledge causes the message to disappear but has no other effect. Then the operator can auto setup the dosimetry system again.

6.3 Starting the run

6.3.1 Treatment ready

This message appears when all interlocks are clear and the therapy machine is ready to begin a treatment run. In particular, it occurs after the program sends the `CON START` command to the DMC, at the time when the program senses that both dosimetry relays are energized.

This message box is gray because it indicates an expected event.

This condition is also indicated on the therapy console by the lamp under the **START** button. This lamp usually turns on a second or two before the message appears.

At the same time the message appears, the treatment phase changes from Waiting (or Tested OK) to Ready.

The run begins when this message appears. As long as the run is in progress, some commands are disabled.

```
TREATMENT READY
Push START button to begin treatment
or press EXIT RUN key to exit
```

START causes several actions which should result in the beam turning on in the treatment room. The message disappears when the control program first senses any one of these conditions:

- **START** pressed
- Beam plug open
- DMC timer enable on

At the same time the message disappears, the treatment phase changes from Ready to Counting.

Pressing **START** at any time after the lamp turns on, even before the `TREATMENT READY` message appears, has the same effect. If **START** is pressed first, the message may not appear, or may appear briefly and then disappear.

EXIT RUN causes the message to disappear (without attempting to start the run). At the same time the treatment phase changes from Ready to Exited. When the message disappears after **EXIT RUN**, the run ends and most operations are once again enabled.

6.3.2 Start timeout

This message appears when when the maximum start time has elapsed after the TREATMENT READY message was displayed but the operator has not pushed the START button. It replaces the TREATMENT READY box. The maximum start time is read from a file; at this writing it is 30 seconds.

At the same time this message appears, the DMC Start Timeout interlock sets and the treatment phase changes from Ready to Exited.

```
START TIMEOUT
Start timer expired
Press ACKNOWLEDGE to dismiss this message
then AUTO SETUP DOSIMETRY to restart treatment
```

Acknowledge causes the message to disappear but has no other effect. Then the operator can auto setup the dosimetry system again.

6.4 During the run

6.4.1 Low dose rate

This message appears whenever the average dose rate over a defined time interval is less than a minimum acceptable rate. The time interval is DOSE R. TIME WIN. (presently 10 seconds) and the minimum rate is LOW DOSE R. FCT $\times$ DOSE RATE. (presently 0.1 $\times$ 60 MU/min, see also section 1.4.1).

```
LOW DOSE RATE
Low dose rate:  n.nn MU in 0.mm min, x.x MU/min
Press ACKNOWLEDGE key to dismiss message
```

For example `0.60 MU in 0.19 min, 3.2 MU/min` (the interval `0.19 min` is a bit longer than 10 seconds, due to the DMC polling interval).

Acknowledge causes the message to disappear but has no other effect. If the dose rate remains low, the message will appear again after another ten seconds.

6.4.2 Treatment interrupted

This message (fig. B.6) indicates that the control program has detected an interlock during a run (but not a dosimetry interlock), or that the control program has detected that the DMC timer enable signal has turned off during a run (but not because the DMC has ended the run). The message appears when the control program senses any one of these conditions:

- Any interlock set (except dosimetry)
- DMC timer enable off
- **BEAM OFF** pressed at therapy console

When a dosimetry interlock is set, the `TREATMENT STOPPED` message appears instead (section 6.5.5). When the DMC has ended the run, the `TREATMENT FINISHED` message appears instead (sections 6.5.1, 6.5.3).

At the same time the `TREATMENT INTERRUPTED` message appears, the treatment phase changes from Counting (or Resumed or Ready) to Paused. During the Paused phase the beam is off, but the run is still in progress and some operations are still disabled.

```
TREATMENT INTERRUPTED
Beam off pressed at therapy console
To continue, push START button when interlocks are clear
or press EXIT RUN key to terminate treatment
```

The second line of the message describes the interlock. It is one of:

- *`Interlock name`* `interlock`

  The named interlock is set. This message appears when the control program detects that the interlock is set before it detects that the DMC timer enable has turned off.

- `Beam Off pressed at therapy console`

  This message (with `Off` capitalized) appears when the control program detects that the **BEAM OFF** button was pressed before it detects that the DMC timer enable has turned off.

- `Transient` *`Interlock name`* `interlock`

  The named interlock was set, but was clear again when the message appeared.

- *`PARAMETER NAME`* `at` *`xx.x`*

  The named parameter is NOT READY because its value is *xx.x*. If the value is missing (blank), this means the value is uninitialized (no value has been assigned). If the value is a row of asterisks, this means that a discrete indicator parameter (filter or wedge setting) has an invalid value.

- `Transient,` *`PARAMETER NAME`* `at` *`xx.x`*

  The named parameter was NOT READY because its value was *xx.x*, but was READY again when the message appeared.

- *`PARAMETER NAME`* `motion enabled`

- *`PARAMETER NAME`* `motion enable signal inconsistent`

- `Beam off pressed at therapy console`

  This message (with `off` in lowercase) appears in the unusual situation where the beam is off, a run is still in progress, but no message box has appeared, and the operator has pressed the **BEAM OFF** button to cause a message box to appear so he or she can exit the run[1]. In this situation the control program writes the log message `Beam off pressed at therapy console (forced exit)` (section 7.7.10).

- `Beam off`

  The control program has detected that the DMC timer enable has turned off, but the reason is not available. At the time the message was generated, interlocks were clear and no transient interlock was detected, probably because of delays due to polling and task switching.

The `Transient` messages sometimes appear because parameter readiness and some interlocks are not latching. The message appears when the program senses that the beam has turned off, but by this time non-latching conditions may have cleared spontaneously.

After any interlock, even after a transient condition that clears spontaneously, the beam remains off until the operator deliberately restarts it.

[1] This unusual situation was caused (rarely) by a programming error which has since been corrected. This message should never appear.

START causes several actions which should result in the beam turning on again in the treatment room. The message disappears when the control program senses that **START** has been pressed while all interlocks are clear.

At the same time the message disappears, the treatment phase changes from Paused to Resumed. The run is still in progress.

EXIT RUN causes the message to disappear (without attempting to restart the beam). At the same time the treatment phase changes from Paused to Exited. The run ends and most operations are once again enabled. The dosimetry panel LEDs continue to show the dose and time for the run; these remain until the operator selects another field or sets up the dosimetry system again.

6.5 At the end of the run

6.5.1 Preset dose delivered

This message (fig. B.5) appears when the program senses that the beam plug has closed after it receives the `Dose reached` message from the DMC (note that the message does not appear immediately when the `Dose reached` message arrives).

```
TREATMENT FINISHED
Preset dose delivered
Press CONFIRM (or turn X-ray keyswitch) to end this run
then you may select another operation
```

This message box is gray because it indicates an expected event.

At the same time this message appears, the treatment phase changes from Dose delivered to Term. Wait. The run is still considered to be in progress and some commands are still disabled.

Confirm causes the run to finish. The treatment phase changes from Term. Wait to Term. Test. The accumulated parameter values are updated, the accumulated doses file and run files are rewritten, and a record is appended to the treatment log file. The message box disappears. Commands become enabled again. The control program sends the `CON TERM` command to order the DMC to begin its termination self-test. This causes the dose and time for the run to disappear from the dosimetry panel LEDs (that is why we require a deliberate action by the operator to confirm the end of the run).

If X-ray Enable Key status bit value changes from *false* to *true* while this message is displayed, that has the same effect as **Confirm**.

6.5.2 Time exceeded

This message appears when the program senses that the beam plug has closed after it receives the `Time reached` message from the DMC, but the measured dose is within 1.0 MU of the preset dose.

```
TREATMENT FINISHED
Time exceeded, remaining dose less than 1.0 MU
Press CONFIRM (or turn X-ray keyswitch) to end this run
then you may select another operation
```

This situation is not considered a problem because the difference from the preset dose is insignificant; the backup timer expired right before the preset dose would have been delivered. Therefore this box is gray, and it is handled exactly the same as the `Preset dose delivered` case (section 6.5.1, above).

6.5.3 Backup time reached

This message appears when the program senses that the beam plug has closed after it receives the `Time reached` message from the DMC.

```
TREATMENT FINISHED
Backup time reached
Press EXIT RUN
then AUTO SETUP again to deliver the remaining dose
```

At the same time this message appears, the treatment phase changes from Time exceeded to Term. Wait. The run is still considered to be in progress and some commands are still disabled.

Exit Run or the X-ray Enable Key cause the run to finish and the message to disappear, exactly as **Confirm** does at the `Preset dose delivered` message.

6.5.4 Beam plug not closed

When the beam plug is closed, it is not possible for the beam to be on in the therapy room.

This message appears when the program has not sensed tha the beam plug has closed, and the beam plug timeout expires after the program receives the `Dose reached` or `Time reached` message from the DMC. The beam plug timeout is read from a file; at this writing it is 10 seconds.

```
BEAM PLUG NOT CLOSED
Verify beam is off -- Contact cyclotron operator
Press EXIT RUN key to self-test and clear dosimetry
```

At the same time this message appears, the treatment phase changes from Dose delivered or Time exceeded to Term. Wait. The run is still considered to be in progress and some commands are still disabled.

Exit Run or the X-ray Enable Key cause the run to finish and the message to disappear, exactly as **Confirm** does at the `Preset dose delivered` message.

6.5.5 Treatment stopped

This message occurs when the control program detects some condition involving the dosimetry system that should cause the run to be stopped. The second line of the message describes the condition. For example,

```
TREATMENT STOPPED
Inconsistent or corrupted dose B 577.4 MU
Press EXIT RUN key to terminate treatment
```

These are the conditions that are checked:

- `Dose A` *`nnnn.n`* `MU out of range`
- `Dose A` *`nnnn.n`* `MU out of range after END`
- `Dose B` *`nnnn.n`* `MU out of range`

- `Dose B nnnn.n MU out of range after END`
- `Elapsed time nnn.nn out of range`
- `Delivered dose exceeds limits A nnn.n B nnn.n MU`
- `Elapsed time exceeds limit nn.nn minutes`
- `Excessive dose detected by therapy computer A nnn.n B nnn.n MU`
- `Inconsistent or corrupted dose A nnn.n MU`
- `Inconsistent or corrupted dose B nnn.n MU`
- `Simultaneous corrupted dose A nnn.n B nnn.n MU,`
- `DMC ERROR nn ;Error message`
- `DMC conversion error at string`
- `DMC error type after COMMAND`
- `DMC error`
- `Therapy sum relay activated, should be de-activated. Stop DMC.`

The `out of range` conditions indicate that the DMC has indicated a dose or time that is outside the range of possible values (at this writing the limits are 999.8 MU and 99.99 min, see table 1.1).

`Excessive dose detected` indicates that the DMC has reported a dose that exceeds the preset value (plus a 1.0 MU tolerance), but has not sent a `Dose reached` or `Time reached` message. An excessive dose must be detected on at least two successive polling samples, but just one channel is sufficient.

`Delivered dose exceeds limits` indicates that the DMC has reported a dose that exceeds the preset value (plus the 1.0 MU tolerance) after it has sent a `Dose reached` or `Time reached` message. An excessive dose must be detected on at least two samples, but on just one channel.

`Elapsed time exceeds limit` indicates that the DMC has reported an elapsed time that exceeds the preset value (plus a 0.05 min tolerance), but has not sent a `Dose reached` or `Time reached` message. Excessive time is reported on the first sample.

`Inconsistent or corrupted dose` indicates the dose reported by the DMC on successive samples decreased by any amount or increased by an amount greater than a 5 MU *jump tolerance*. However the program ignores apparently erroneous readings that occur for only one sample on one

channel (these are taken to be noise). The jump or decrease must occur simultaneously on both channels, or must persist for two (or more) consecutive samples on one channel.

`DMC ERROR` indicates that the DMC has sent an error message to the control program. The DMC error message is included (for example `DMC ERROR 47 ;Dose when FC closed!`).

`DMC conversion error at ...` indicates that the DMC has sent an unintelligble response to the `OUT ALL` polling command. The response string is included (for example `DMC conversion error at :. 7!^G`).

`DMC` *`error type`* `after ...` indicates that the DMC has sent an erroneous response to a command. The command is included (for example `DMC conversion error after OUT SETD TIME`). The error types are described in chapter 7.

`DMC error` indicates an error involving the dosimetry system. Details are not available.

`Therapy sum relay activated` indicates that the control program has sensed (via the PLC) that the therapy sum relay is closed when it should be open. The control program has sent the `CON STOP` command to the DMC to force the dosimetry relays to open. This should cause the beam to turn off, despite the problem with the therapy sum relay. The DMC Error interlock is not set.

It is possible that more than one of these conditions might occur at almost the same time. In that case only the latest (most recent) message remains on the screen. There should be a log message for each condition, however.

If the `TREATMENT STOPPED` message appears in a phase where the dosimetry relays are normally closed, the program sends the `CON STOP` command to the DMC. This should cause the DMC to open the dosimetry relays, turning the beam off.

When this message appears, the treatment phase changes to Stopped. The run is still considered to be in progress and some commands are still disabled.

Exit Run finishes the run and causes the message to disappear. The dosimetry LEDs retain the dose and time for the run until the operator selects another field or sets up the dosimetry system again. It is not possible to resume a stopped treatment.

6.5.6 Operation still pending

There is one situation where the control program partially restores a previous message. When a new `ACKNOWLEDGE` message replaces an earlier `EXIT RUN` message, and the operator presses

Acknowledge to dismiss the new message, this version of the earlier message appears:

```
TREATMENT INTERRUPTED OR STOPPED
(Operation still pending)
Press EXIT RUN key to terminate treatment
```

The message is worded this way because the first two lines of the original message are lost. This message makes it possible for the operator to finish the run (otherwise the only escape would be the **BEAM OFF** button, section 6.4.2).

EXIT RUN finishes the run.

6.6 Any time

6.6.1 Therapy watchdog

This message appears when the control program senses (via the PLC) that the Watchdog A OK interlock is set (section 1.5.29).

```
THERAPY WATCHDOG
Therapy watchdog has timed out
Press ACKNOWLEDGE key to dismiss message
```

Acknowledge causes the message to disappear and has no other effect.

The watchdog must be reset by pressing the appropriate pushbutton in the power supply room after the cause of the interlock is fixed.

6.6.2 Therapy sum relay error

This message appears when the control program senses (via the PLC) that the therapy sum interlock relay is activated when it should be de-activated, or vice-versa. The only exception occurs during a run when the relay is found to be activated (clear) when it should be de-activated (set); that situation is handled by `TREATMENT STOPPED` instead (section 6.5.5).

```
THERAPY SUM RELAY ERROR
Therapy sum relay activated, should be de-activated
Press ACKNOWLEDGE key to dismiss message
```

(or `Therapy sum relay de-activated, should be activated`)

Acknowledge causes the message to disappear but has no other effect.

In this condition the Therapy Sum Relay Inconsistency interlock is set (section 1.5.20). It is not possible to run in this condition because it only occurs when some interlock is set (such as the dosimetry interlock, or the therapy sum interlock itself).

6.6.3 Dosimetry relay error

This message appears after the dosimetry system self-test, or during a run after any event that should cause the dosimetry relays to open, if the dosimetry relays are still closed (after a delay which is read from a file, 2 seconds at this writing).

```
DOSIMETRY RELAY ERROR
Dosimetry relay 1 closed, should be open
Press ACKNOWLEDGE key to dismiss message
```

The second line of the message provides details. It may say:

- `Dosimetry relay closed, should be open`
- `Dosimetry relay 1 closed, should be open`
- `Dosimetry relay 2 closed, should be open`
- `Dosimetry relays 1 and 2 closed, should be open`

If no relay is identfied by number, it means the error was transient (both relays were open when the message appeared).

Acknowledge causes the message to disappear but has no other effect.

In this condition the DMC Error interlock is set (section 1.5.17). It is not possible to run in this condition because the DMC Error interlock is included in the Therapy Sum interlock.

6.6.4 Beam path problem

This message appears when the control program senses (via the PLC) that the Path Error status bit has made a transition from *false* to *true*. The PLC sets this bit *true* when it detects an inconsistency among the path element signals (section 1.6.2).

```
BEAM PATH
Beam path problem detected, increased gamma radiation pos-
sible
Press ACKNOWLEDGE key to dismiss message
```

Acknowledge causes the message to disappear but has no other effect.

It is not possible to run in this condition because of a hardwired interlock.

Usually the last line of the message is as shown above. However, if the message appears when a message is already displayed at the end of a run, the last line of the message is `Press EXIT RUN key to terminate treatment`. In this situation **Exit Run** causes the message to disappear and finishes the run. **Exit Run** must be used, even if the first message said `Press CONFIRM ...`.

6.6.5 Safety trace inconsistency

This message appears when the control program senses (via the PLC) that the Safety Inconsistent status bit has made a transition from *false* to *true*. The PLC sets this bit *true* when it detects an inconsistency among the safety trace signals (section 1.6.2).

```
SAFETY TRACE
Safety trace inconsistency detected
Press ACKNOWLEDGE key to dismiss message
```

Acknowledge causes the message to disappear but has no other effect.

It is not possible to run in this condition because of a hardwired interlock.

Usually the last line of the message is as shown above. However, if the message appears when a message is already displayed at the end of a run, the last line of the message is `Press EXIT RUN`

`key to terminate treatment`. In this situation **Exit Run** causes the message to disappear and finishes the run. **Exit Run** must be used, even if the first message said `Press CONFIRM ....`

6.7 X-ray ports

6.7.1 No leaf setup

This message appears when the operator pushes one of the X-ray port pushbuttons or prescribed field pushbuttons on the X-ray controller box or the mobile pedestal, but some condition prevents setting up the requested port or field.

```
NO LEAF SETUP FROM PUSHBUTTON
Leaves in local mode
Press ACKNOWLEDGE key to dismiss message
```

The second line of the message gives the reason. It is one of:

- `Leaves in local mode`
- `Attempt setup when LCC error interlock is clear`
  `(This message indicates that the LCC Error interlock is set)`
- `Leaf calibration factors not valid`
- `No prescribed field`

The last message can only appear when the operator presses the **Prescribed Field** button.

Acknowledge causes the message to disappear but has no other effect.

‘

Chapter 7

Log messages

Many events cause the program to write a *log message*. Each log message consists of a time stamp and an event description. Five hundred to fifteen hundred messages are logged on a typical treatment day. Most of these messages are not normally displayed to the operator (they are not the same as the display messages that appear in on-screen message boxes, see chapter 6). Log messages are provided for machine troubleshooting and diagnostics, and also for record-keeping and patient-related quality assurance.

The control program writes each log message to the therapy control computer console port. If a console terminal is connected, it shows the most recent 24 messages (which scroll away as new messages are written). The program also writes each message to a *message buffer* in control program memory. This buffer stores the most recent 4500 messages. Press the **Messages** key to display the contents of the buffer, press the up and down arrow keys to scroll through the buffer (section 5.8.4, fig. A.14). The control program also attempts to write out each message to the *message log* file (section 4.2). The message log file can be displayed or printed by utilities on the host computer. Fig. 7.1 shows the beginning of a log file, showing the messages that are written when the program starts up normally. Fig 7.2 shows a segment from another example, showing the messages that are written during one treatment run and the preparation for another. Fig 7.3 shows yet another example, showing the messages that are written during experiment mode as the operator enters some preset parameter values, starts a run, a proton interlock occurs, and the operator resumes the run. In these figures, dots `. . .` indicate where messages have been omitted to save space.

Messages are written out to the file as soon as they are generated, so the file is up to date. It is possible that problems with the network or host computer may prevent some messages from being written. These messages will be missing from the file but are still shown on the console terminal and are present in the in-memory buffer. The operator can use the **Write File** command (section 5.8.7) to write out the entire contents of this buffer on demand, after problems with the network or host

```
13-MAY-2002 10:20:11 Starting
13-MAY-2002 10:20:11 Log file /cntsdata/log/iso/iso2002-0513-102011.log, fileno
13-MAY-2002 10:20:11 Treatment record file /cntsdata/log/iso/isotr2002-0513-1020
13-MAY-2002 10:20:11 Dose cal file, success at line 18
13-MAY-2002 10:20:11 Collimator cal file, success at line 120
13-MAY-2002 10:20:11 Tolerances file, success at line 7
13-MAY-2002 10:20:11 Ports file, success at line 25
13-MAY-2002 10:20:11 Collimator cal fields file, success at line 4
13-MAY-2002 10:20:11 Operator file, success at line 24
13-MAY-2002 10:20:11 Daily message file, success at line 4
13-MAY-2002 10:20:11 Prescription file, success at line 379
13-MAY-2002 10:20:11 Accumulated dose file, success at line 100
13-MAY-2002 10:20:11 Run file, success at line 1
13-MAY-2002 10:20:11 tIntlk spawned, task id 32246352
13-MAY-2002 10:20:11 Console enable interlock clear
13-MAY-2002 10:20:11 Relay error interlock clear
13-MAY-2002 10:20:11 Beam Off interlock clear
13-MAY-2002 10:20:11 TMC serial port /tyCo/1 open
13-MAY-2002 10:20:11 tTMC spawned, task id 33189332
13-MAY-2002 10:20:12 tLCC spawned, task id 33168912
13-MAY-2002 10:20:12 DMC serial port /tyCo/3 open
13-MAY-2002 10:20:12 LCC serial port /tyCo/2 open
13-MAY-2002 10:20:12 tDMC spawned, task id 33127084
13-MAY-2002 10:20:12 tPLC spawned, task id 33106664
13-MAY-2002 10:20:12 Isocentric therapy console ready
13-MAY-2002 10:20:13 Collision interlock clear
13-MAY-2002 10:20:15 Beam plug closed
13-MAY-2002 10:20:15 Pedestal interlock clear
13-MAY-2002 10:20:59 PLC watchdog relay on (OK)
...
```

Figure 7.1: Log messages written at startup

```
...
14-MAY-2002 08:55:44 Selected patient 3948 (index 1)
14-MAY-2002 08:55:48 Selected field 4 (index 21), a.25.r    boost              1
14-MAY-2002 08:55:50 Setting up wedge  wedge rot.  flat. filter  leaves  DMC
14-MAY-2002 08:55:50 Reset phase
14-MAY-2002 08:55:51 Self-Test phase
14-MAY-2002 08:56:01 Tested OK phase
14-MAY-2002 08:56:14 Waiting phase
14-MAY-2002 09:02:23 Pedestal interlock clear
14-MAY-2002 09:02:58 Door closed
14-MAY-2002 09:03:01 CON START sent to DMC, Ready phase, run started
14-MAY-2002 09:03:01 Dosimetry relay 1 on
14-MAY-2002 09:03:02 Dosimetry relay 2 on
14-MAY-2002 09:03:02 | TREATMENT READY
14-MAY-2002 09:03:02 | Push START button to begin treatment
14-MAY-2002 09:03:02 | or press EXIT RUN key to exit
14-MAY-2002 09:03:06 START button pressed
14-MAY-2002 09:03:06 Counting phase
14-MAY-2002 09:03:08 Beam plug open
14-MAY-2002 09:03:12 DMC timer enable on
14-MAY-2002 09:03:14 Writing run file, success at line 1
14-MAY-2002 09:05:55 Dosimetry relay 1 off
14-MAY-2002 09:05:55 DMC timer enable off
14-MAY-2002 09:05:56 Dosimetry relay 2 off
14-MAY-2002 09:05:56 DMC END   00 ;Dose reached! *
14-MAY-2002 09:05:58 Dose delivered phase
14-MAY-2002 09:05:59 Beam plug closed
14-MAY-2002 09:06:00 Term. Wait  phase
14-MAY-2002 09:06:00 | TREATMENT FINISHED
14-MAY-2002 09:06:00 | Preset dose delivered
14-MAY-2002 09:06:00 | Press CONFIRM (or turn X-ray keyswitch) to end this run
14-MAY-2002 09:06:00 | then you may select another operation
14-MAY-2002 09:06:06 > Exit Run
14-MAY-2002 09:06:06 Run finished in termwait phase
14-MAY-2002 09:06:06 Writing accumulated dose file, success at line 104
14-MAY-2002 09:06:06 Writing run file, success at line 1
14-MAY-2002 09:06:07 Term. Test phase
14-MAY-2002 09:06:16 Selected field 5 (index 22), r10P inf  boost
14-MAY-2002 09:06:16 Reset phase
14-MAY-2002 09:06:19 Filter, wedge already set up
14-MAY-2002 09:06:19 Setting up   leaves  DMC
14-MAY-2002 09:06:19 Reset phase
14-MAY-2002 09:06:19 Self-Test phase
14-MAY-2002 09:06:30 Tested OK phase
14-MAY-2002 09:06:43 Waiting phase
...
```

Figure 7.2: Log messages written during a treatment run

```
...
08-JAN-2002 16:05:07 Experiment file, success at line 229
08-JAN-2002 16:05:08 Selected study 1
08-JAN-2002 16:05:10 Selected field 5, 10.0 cm square field
08-JAN-2002 16:05:10 Reset phase
08-JAN-2002 16:05:12 | WEDGE TYPE  NONE  30 deg  45 deg  60 deg
08-JAN-2002 16:05:13 > NONE (menu_item 0)
08-JAN-2002 16:05:13 | WEDGE ROT  0 deg  90 deg  180 deg  270 deg
08-JAN-2002 16:05:16 > 90 deg (menu_item 1)
08-JAN-2002 16:05:18 | EDIT SETTING
08-JAN-2002 16:05:18 | Enter value for DOSE between 0.0 and 999.8 MU:
08-JAN-2002 16:05:21 > 800 (3 chars)
08-JAN-2002 16:05:22 Setting up wedge  leaves  DMC
...
08-JAN-2002 16:07:49 Setting up DMC
08-JAN-2002 16:07:49 Reset phase
08-JAN-2002 16:07:50 Self-Test phase
08-JAN-2002 16:08:00 Tested OK phase
08-JAN-2002 16:08:13 Waiting phase
08-JAN-2002 16:08:16 CON START sent to DMC, Ready phase, run started
08-JAN-2002 16:08:17 Dosimetry relay 1 on
08-JAN-2002 16:08:17 Dosimetry relay 2 on
08-JAN-2002 16:08:17 | TREATMENT READY
08-JAN-2002 16:08:17 | Push START button to begin treatment
08-JAN-2002 16:08:17 | or press EXIT RUN key to exit
08-JAN-2002 16:08:18 START button pressed
08-JAN-2002 16:08:20 Counting phase
08-JAN-2002 16:08:21 Beam plug open
08-JAN-2002 16:08:26 DMC timer enable on
08-JAN-2002 16:10:11 Proton interlock set
08-JAN-2002 16:10:12 DMC timer enable off
08-JAN-2002 16:10:12 Proton interlock clear
08-JAN-2002 16:10:13 Paused phase
08-JAN-2002 16:10:13 Transient Proton interlock
08-JAN-2002 16:10:13 | TREATMENT INTERRUPTED
08-JAN-2002 16:10:13 | Transient Proton interlock
08-JAN-2002 16:10:13 | To continue, push START button when interlocks are clear0
08-JAN-2002 16:10:15 Beam plug closed
08-JAN-2002 16:10:20 Door open
08-JAN-2002 16:10:36 Pedestal interlock set
08-JAN-2002 16:10:57 Pedestal interlock clear
08-JAN-2002 16:11:18 Door closed
08-JAN-2002 16:11:21 START button pressed
08-JAN-2002 16:11:22 Resumed phase
08-JAN-2002 16:11:23 Beam plug open
08-JAN-2002 16:11:28 DMC timer enable on
...
```

Figure 7.3: Log messages written during an experiment mode run

are resolved.

The following sections show describe all the log messages.

7.1 Dialog and message box messages

The message log provides a complete record of all the messages shown to the operator and all of the operator's responses. All the contents of every dialog box and menu (chapter 5), and every message box (chapter 6), are also written as log messages. In addition, all the keystrokes that the operator types in response to these messages are logged.

Log messages that reproduce dialog and message box contents always begin with the vertical bar character `|`. Messages that reproduce the operator's typed input always begin with the right angle bracket `>`. Here is an example. Other examples appear near the top of Fig. 7.3.

```
16-MAY-2002 06:20:27 | EDIT SETTING
16-MAY-2002 06:20:27 | Enter value for TEMPERATURE between 19.0 and 28.0 C:
16-MAY-2002 06:20:31 > 22.3 (4 chars)
```

The operator's input is represented by the string of text that the operator typed (`22.3` here), or the value of the menu selection that the operator selected (`90 deg` in Fig. 7.3), or the name of the function key that the operator pressed (`Exit Run` etc.). After the operator's input, the program shows additional information in parentheses (`4 chars` here, `menu_item 1` in Fig. 7.3).

The message log often provides additional information, besides what is displayed to the operator. Only one dialog box or message box can appear on the screen at one time, but some incidents cause more than one message to be logged.

7.2 Message elements

The program creates most messages by filling in *message templates* with *message elements*. For example these messages

```
Writing run file, success at line 1
Writing accumulated dose file, comm.  timed out at line 0
```

are both instances of the template

```
Writing file description file, status at line nn
```

The *status* element is used in several contexts. Its values are described in the following subsection. The *file description* element is described in section 7.4.

7.2.1 Status values

The same status values are used for files and controllers. This element is indicated *status*. A few status values apply only to files, or only to controllers.

- `success`

  Normal successful operation.

- `open error`

  The program could not open the file or controller port. File open errors usually mean the protection on the file is wrong, but might also mean the file is missing or has been renamed.

- `read error`

  The operating system reported that the read attempt (file or controller) failed.

- `conversion error`

  The format of the file or controller message is incorrect (a letter was found where a number was expected, etc.).

- `range error`

  The value of a number in the file or controller message is wrong (usually this means the value is outside the expected range, but might also mean that a value that was read back did not match the value that was sent).

- `capacity exceeded`

  The file or controller message contains too many items to load into available control program memory.

- `close error`

  The operating system reports that it could not close the file. The file may be corrupted.

- `end of file`

  End-of-file was reached where the program expected more data.

- `write error`

  The operating system reported that the write attempt (file or controller) failed.

- `comm. timed out`

  The controller did not respond to a command before the timeout expired.

  The control program did not attempt to read or write the file because the server timed out on a previous attempt (the line number is always 0 in this case).

- `unexpected string`

  The controller sent an unexpected (uncommanded) message. If this message appears repeatedly, that usually means that the control program and the controller have become unsynchronized. This condition can usually be cleared by selecting the field again to cause the program to reset the controller.

- `reset error`

  The controller did not respond correctly to a reset command.

7.3 Startup and shutdown messages

These messages are written at startup (Fig. 7.1) or shutdown.

```
Starting
Task task spawned, task id nnnnnnnn
Isocentric therapy console ready
Operator requested shutdown
```

The values of *task* are:

- `tIntlk` (Parameter and subsystem status, software interlocks)
- `tTMC`
- `tLCC`

- tDMC
- tPLC

There is no spawned message for the tUser task. This task runs when the program starts up and then spawns all the others. It also handles the user interface, graphics, all file operations.

Several file messages and device messages are also written at startup.

7.4 File messages

The program logs this message when any file is read.

File description file, *status* at line *nn*

The values of *status* are described in section 7.2.1. Here are the values of *File description*. The corresponding file names appear in Table 4.4.

- Dose cal
- Collimator cal (leaf collimator calibration factors)
- Collimator cal fields (leaf collimator calibration field sizes)
- Tolerances
- Ports (X-ray port leaf settings)
- Operator
- Prescription
- Experiment
- Daily message
- Accumulated dose
- Run (Run-in-progress indicator)

The program logs this message when any file is written (except appending messages to the end of the log file or treatment record file is not logged).

`Writing` *`file description`* `file,` *`status`* `at line` *`nn`*

Here are the values of *`file description`* (note that some are lowercase). The corresponding file names appear in Table 4.7.

- `collimator cal`
- `Log message`
- `Treatment record`
- `TMC message`
- `LCC message`
- `DMC message`
- `PLC message`
- `accumulated dose`
- `run`
- `stored field`

When status is *success*, line number *nn* is the number of non-comment lines in the entire file (the program always reads or writes the entire file, except when it appends messages to the end of the log file or treatment record file). Otherwise, *nn* is the line number where the error occurred. It is zero if the file could not be opened, read or written at all.

In addition, these messages about the message log file and treatment record file are logged at startup, and when new versions of the files are opened at midnight every night.

`Log file` *`directory path`*`/iso`*`yyyy-mmdd-hhmmss`*`.log, fileno` *`nn`* `open`

`Treatment record file` *`directory path`*`/isotr`*`yyyy-mmdd-hhmmss`*`.log, fileno` *`nn`* `op`

The directory path is coded into the program (different versions of the program might specify different paths). The filename includes a timestamp indicating when the file was created. For example at startup

```
01-JUL-1999 15:49:37 Log file /cntsdata/log/iso/iso1999-0701-154937.log, fileno
```

and then at midnight

```
02-JUL-1999 00:00:00 Log file /cntsdata/log/iso/iso1999-0702-000000.log, fileno
02-JUL-1999 00:00:00 Log file /cntsdata/log/iso/iso1999-0701-154937.log closed
```

When an attempt to read or write a file times out, the program logs this message

```
File server not responding, using in-memory contents
```

Then the program stops attempting to read or write files (so this message only appears in the in-memory log message buffer). Subsequently, the program just logs

File description `file, comm.  timed out at line 0`

instead of attempting to read or write files, except for the patient list. When an attempt to read the patient list succeeds, the program logs

```
Prescription file, success at line nnn
File server responding, reading and writing files again
```

Each incident where the file server stopped responding is indicated in the message log file by the preceding pair of messages. The earlier `not responding` and `timed out` messages only occur in the in-memory message buffer. To save these messages, the operator must use **Write File** to write out the buffer contents (section 5.8.7).

7.5 Controller messages

The program writes these messages when it successfully initializes the ports at startup. Each controller is always associated with the same port.

```
TMC serial port /tyCo/1 open
LCC serial port /tyCo/2 open
DMC serial port /tyCo/3 open
```

If there is ever a problem communicating with a controller, the program logs one or more of the following messages.

CONTROLLER status after *COMMAND*
CONTROLLER status at *response*
CONTROLLER ERROR *nn ;Error message*
CONTROLLER unexpected message *message*
CONTROLLER error

Values of *CONTROLLER* in these messages are

- TMC
- LCC
- DMC

Messages for the PLC have a different format.

In these messages *COMMAND* is the text of the command to the controller, *response* is the text of the response from the controller, *nn* is the error number from the controller, *Error message* is the text of the error message from the controller, and *message* is the text of the unexpected message from the controller.

7.5.1 DMC messages

The program writes one of these messages when the DMC reports that the preset dose or time has been reached:

- DMC END 00 ;Dose reached! *

- `DMC END 02 ;Time reached!  *1`

Messages concerning problems with the dosimetry system are described in section 7.7.9 below.

7.5.2 PLC messages

After an error, the program attempts three more times to reestablish communication with the PLC. After the fourth error, the program shuts down the PLC task. The only way to recover from this situation is to restart the control program. Here is an example

```
iso2002-0111-000000.log:11-JAN-2002 15:42:20 PLC Receive response
failed
iso2002-0111-000000.log:11-JAN-2002 15:42:20 PLC 1 error --
count 1
iso2002-0111-000000.log:11-JAN-2002 15:42:20 PLC Send command
failed
iso2002-0111-000000.log:11-JAN-2002 15:42:20 PLC 1 error --
count 1
iso2002-0111-000000.log:11-JAN-2002 15:42:20 PLC Send command
failed
iso2002-0111-000000.log:11-JAN-2002 15:42:20 PLC 1 error --
count 2
iso2002-0111-000000.log:11-JAN-2002 15:42:20 PLC Send command
failed
iso2002-0111-000000.log:11-JAN-2002 15:42:20 PLC 1 error --
count 3
iso2002-0111-000000.log:11-JAN-2002 15:42:21 PLC Send command
failed
iso2002-0111-000000.log:11-JAN-2002 15:42:21 PLC 1 error --
count 4
iso2002-0111-000000.log:11-JAN-2002 15:42:21 PLC Error
iso2002-0111-000000.log:11-JAN-2002 15:42:21 PLC Error Limit
Reached ‘
iso2002-0111-000000.log:11-JAN-2002 15:42:21 PLC Task Shutting
Down
```

The message `PLC Receive response failed` is logged if the PLC does not respond to the control program at all.

Other log messages indicate problems with subsequent PLC communications:

- `PLC Send command failed`
- `PLC Receive response failed`
- `Error reading Temperature Sensor`
- `Illegal Temperature value`
- `Temperature Conversion Error`
- `PLC Read Pressure1 error`
- `Illegal Pressure 1 Value`
- `PLC Read Pressure2 error`
- `Illegal Pressure 2 Value`
- `PLC Modicon 1 error`
- `PLC Modicon 2 error`
- `XRay status error`
- `XRay achieved error`
- `Therapy Sum Interlock error`
- `PLC Enable error`
- `PLC Watchdog error`
- `Incorrect PLC Watchdog response`
- `PLC Read Error`
- `PLC Error`

7.6 Session messages

These messages indicate events in the treatment session (Fig. 7.2).

```
Operator NAME logged in
Selected patient nnnn (index nn)
Selected study n (index nn)
Selected field n (index nn), field name
Operator NAME logged out
```

Here *NAME* is the operator's name in the authorization file, *nnnn* and *n* are the patient number and study number from the prescription file, and *field name, n* is the field name from the prescription file and the field sequence number assigned by the program (which is not the field number in the prescription file, but which does appear on the field list screen). The (index *nn*) indicates the index of the patient (study) or field in the in-memory database.

The program does not log the patient name so there are no privacy or confidentiality issues involved in displaying log files (the patient number is not a universal identifier, it is only used within the department).

The program does not log transitions from therapy mode to experiment mode or vice versa. The mode is indicated each time the patient list (or study list) is selected (see fig. 7.3).

7.7 Treatment sequence messages

7.7.1 Treatment phases

The program writes these messages to log each transition into a new treatment phase (section 1.7, chapter 2):

- Reset phase
- Self-Test phase
- Tested OK phase
- Waiting phase
- CON START sent to DMC, Ready phase, run started
- Counting phase
- Dose Delivered phase

- `Term. Wait phase`
- `Term. Test phase`
- `Terminated phase`
- `Paused phase`
- `Resumed phase`
- `Time Exceeded phase`
- `Stopped phase`
- `Exited phase`

In addition, the program writes this message when the run ends (which might occur in several phases):

- `Run finished in` *`phase name`* `phase`

7.7.2 Interlocks and status bits

The program writes these messages to log transitions of these status bits:

- `START button pressed`
- `Beam plug open (closed)`
- `DMC timer enable on (off)`
- `Beam path problem bit on (off)`
- `Safety trace inconsistency bit on (off)`
- `PLC watchdog relay on (OK) (off (not OK))`
- `X-ray enable keyswitch on (off)`

The entries here mean that the program logs both `DMC timer enable on` and `DMC timer enable off`, etc. However only the on-transition of the START button is logged (the off-transition is performed automatically by a one-shot, so its occurence is not informative).

The program writes these messages to log transitions of these interlocks:

- `Door closed (open)`
- `Dosimetry relay 1 on (off)`
- `Dosimetry relay 2 on (off)`
- `Dosimetry relays 1 and 2 on (off)`

The last message in this group is logged when the two dosimetry relays change state in the same PLC polling cycle, so the program cannot tell which changed first (a polling cycle is about 0.2 second, much briefer than the 1 second resolution of the log timestamps).

The program writes this message to log transitions of the pressure/temperature interlock:

- `P/T interlock set (clear), (more information)`

The `(more information)` part contains the pertinent pressure/temperature status message (Table 1.7), and the values of the pressure, temperature, and correction factor when the interlock set (cleared).

The program writes this message to log the transitions of the remaining hardware interlocks:

- *`Interlock name`* `interlock set (clear)`

Where *`Interlock name`* is one of

- `Collision`
- `Door`
- `Console enable`
- `Pedestal`
- `Relay error`
- `Proton`
- `Beam Off`

At this writing the `Collision` interlock has never been connected and we have never logged a `Relay error` interlock.

Unlike the interlock messages described in section 7.7.8 below, which only appear when the beam is turned off when an interlock sets, the preceding messages appear whenever the interlock or status bit changes in either direction in any treatment phase.

7.7.3 Auto setup messages

`Setting up` indicates the auto setup operation.

`Setting up` *`parameters`*

The value *`parameters`* is one or more of:

- `wedge`
- `wedge rot.`
- `flat.  filter`
- `leaves`
- `DMC`

The following subsections describe the messages that are written when there are exceptions to the normal treatment sequence.

7.7.4 Invalid prescription selected

The program logs one or more of these messages when a field is selected whose prescribed values are invalid. These messages also appear on acknowledge boxes (see section 5.4.5). There is just one acknowledge box, but there may be several messages in the log.

- *`PARAMETER NAME`* `value` *`nn.n`* `out of range`

- FILTER value *n.n* inconsistent
- LEAF *nn* value *nn.n* causes collision

The program does not log a message to indicate that the operator selected a field despite a warning (that the the prescribed dose has already been delivered, for example). If such field is actually treated, this is indicated in the treatment record.

7.7.5 Auto setup cannot be performed

If the auto setup operation, cannot be performed, one or more of these messages is logged. These messages also appear on acknowledge boxes (see section 5.4.6). There is just one acknowledge box, but there may be several messages in the log. In these messages the value -10000 indicates a missing or uninitialized value.

- *PARAMETER NAME* overridden
- *PARAMETER NAME* value *nn.n* out of range
- *PARAMETER NAME* in local mode
- TMC error interlock set
- FILTER value *n.n* inconsistent
- Filter, wedge already set up
- LCC error interlock set
- LEAF *nn* value *nn.n* causes collision
- Leaf calibration factors not valid
- Leaves in local mode
- DMC error interlock set
- Dose calibration factors not valid
- No preset dose
- Preset dose *nnnn.n* out of range
- Preset time *nnn.nn* out of range

In the case of a pressure/temperature problem, this pair of messages is logged:

- `Pressure/temperature correction factor not valid`
  `P/T status, P/T values`

where *`P/T status`* is one of the status messages in Table 1.7, and *`P/T Values`* are the values of the calibration factors relevant to the message.

This message is logged in therapy mode only (in experiment mode, setup proceeds):

- `FILTER value` *`n.n`* `inconsistent`

In addition, additional messages that do not appear on the screen may be logged:

- `Filter, wedge already set up`
- *`CONTROLLER`* `setup already in progress`

7.7.6 Auto setup fails

If the TMC auto setup fails one or more of these messages is logged.

- *`PARAMETER NAME`* `motion not enabled, cancel auto setup`

If the leaf collimator auto setup fails one of these messages is logged.

- `Leaf motion not enabled, cancel auto setup`
- `Collimator in local mode`
- `Unrecoverable leaf no motion error`

This message may be logged.

- `Recoverable leaf no motion error`

If collimator setup from the X-ray controller or mobile pedestal button fails, one of these messages is logged

- `Leaves in local mode`
- `Attempt setup when error interlock is clear`
  `(This message indicates that the LCC Error interlock is set)`
- `Leaf calibration factors not valid`
- `No prescribed field`

If auto setup of any parameter times out, this message is logged.

- *`PARAMETER NAME`* `setup timed out`

7.7.7 Timeouts

If the setup timer (section 6.2.2) or start timer (section 6.3.2) expires, a message is logged:

- `Setup timer expired`
- `Start timer expired`

7.7.8 Interlocks

If an interlock occurs after the beam turns on, then the program logs one of these messages when the beam turns off. The message identifies the interlock. Usually this is similar to them message that appears in the `TREATMENT INTERRUPTED` message box (section 6.4.2). The message is one of

- `Beam Off pressed at therapy console`
  The operator has pressed the **BEAM OFF** button.

- *Interlock name* interlock

  The named interlock is set.

- Transient *Interlock name* interlock

  The named interlock was set, but was clear again when the message appeared.

- *PARAMETER NAME* at *xx.x*

  The named parameter is NOT READY because its value is *xx.x*. If the value is missing (blank), this means the value is uninitialized (no value has been assigned). If the value is a row of asterisks, this means that a discrete indicator parameter (filter or wedge setting) has an invalid value.

- Transient, *PARAMETER NAME* at *xx.x*

  The named parameter was NOT READY because its value was *xx.x*, but was READY again when the message appeared.

- *PARAMETER NAME* motion enabled

- *PARAMETER NAME* motion enable signal inconsistent

The Transient messages sometimes appear because parameter readiness and some interlocks are not latching. The message appears when the program senses that the beam has turned off, but by this time non-latching conditions may have cleared spontaneously.

If the operator clears the interlock and turns the beam on again, the program logs one of these message when it senses the DMC Timer Enable bit turn on.

- Beam on - interrupted treatment resumed

7.7.9 Treatment stopped

If the program detects a condition involving the dosimetry system that should cause the run to be stopped, the program logs one or more messages. Usually one of these is the measage that appears in the TREATMENT STOPPED message box (see additional description of each message in section 6.5.5). There is just one message in the box, but there may be several messages in the log.

- Dose A *nnnn.n* MU out of range

- Dose A *nnnn.n* MU out of range after END

- Dose B *nnnn.n* MU out of range
- Dose B *nnnn.n* MU out of range after END
- Elapsed time *nnn.nn* out of range
- Delivered dose exceeds limits A *nnn.n* B *nnn.n* MU
- Elapsed time exceeds limit *nn.nn* minutes
- Excessive dose detected by therapy computer A *nnn.n* B *nnn.n* MU
- Inconsistent or corrupted dose A *nnn.n* MU
- Inconsistent or corrupted dose B *nnn.n* MU
- Simultaneous corrupted dose A *nnn.n* B *nnn.n* MU,
- DMC ERROR *nn ;Error message*
- DMC conversion error at *string*
- DMC *error type* after *COMMAND*
- DMC error
- Therapy sum relay activated, should be de-activated. Stop DMC.

One of these messages is logged when a transient occurs which is not serious enough to stop the treatment.

- Single sample corrupted dose A *nnn.n* MU
- Single sample corrupted dose B *nnn.n* MU

7.7.10 Forced exit

The program writes this message when the operator presses the **BEAM OFF** button during a run when the beam is already off (this causes an EXIT RUN message box to appear).

- Beam off pressed at therapy console (forced exit)

7.7.11 Other beam off messages

When the control program senses the DMC Timer Enable status bit change from *true* to *false* in certain phases, it logs the message

- `Beam off in` *`phase name`* `phase`

where *`phase name`* is the name of a treatment phase, one of

- `counting`
- `ended`
- `paused`
- `resumed`
- `stopped`
- `exceeded`

In other phases, the program logs a `DMC timer enabled off` message instead (see below).

7.7.12 Other messages at the end of the run

The control program logs these messages at the end of a run when it displays the message boxes that show similar messages (chapter 6).

- `Beam plug not closed`

7.8 Other display messages

The control program logs these messages when it displays the message boxes that show similar messages (section 6.6). Most of these can occur when no run is in progress.

- `Therapy watchdog has timed out`
- `Low dose rate: n.nn MU in 0.mm min, x.x MU/min`
- `Therapy sum relay activated, should be de-activated`
- `Therapy sum relay de-activated, should be activated`
- `Dosimetry relay closed, should be open`
- `Dosimetry relay 1 closed, should be open`
- `Dosimetry relay 2 closed, should be open`
- `Dosimetry relays 1 and 2 closed, should be open`
- `Beam path problem detected`
- `Safety trace inconsistency detected`

7.9 Miscellaneous messages

The control program logs this message when it is is unable to update the display promptly. Usually this occurs when the program is busy processing events, or there are delays in the network, host computer, or X terminal. The program continues communicating with controllers and setting software interlocks during these incidents (which resolve spontaneously)

- `Interlock pipe full, status display not updating`

The control program will log a message if the operating system indicates certain internal operations are not successful:

- `Couldn't operation`

For example `Couldn't start relay watchdog`. At this writing the program has never logged one of these messages.

The program logs this message at the **Set time** command (section 5.8.8).

- `Reset time from host`

The program logs this message each time an operator logs in. It monitors memory use.

- `Memory Alloc:` *`nnnnnnnn`* `Free:` *`nnnnnnn`*

The purpose of this message is to confirm that sufficient free memory remains after program revisions, and there are no memory leaks (indicated by a continual increase in allocated memory and decrease in free memory). At this writing there are usually about 24 MB allocated and 8 MB free (for example `Memory Alloc: 24234064 Free: 8702552`).

7.10 Operator messages

The operator can invoke the **Log Message** command to type in a message at any time. The operator's message is time-stamped and is written to the message buffer and log file, just like any other log message. Unlike most other messages, an operator's message is usually all uppercase (because we usually leave the X terminal shift lock on). At this writing we have only used operator messages to indicate the reason for shutdowns, as in the next-to-last message in this example:

```
03-NOV-1999 16:24:58 SHUTDOWN, RESTART TO TEST NEW BOOT DIRECTORY
LINK 03-NOV-1999 16:25:59 Operator requested shutdown
```

Chapter 8

Displays

This chapter describes the graphics shown on the control program X-terminal display. It describes how the contents of the screen indicate the values of the state variables desscribed in chapter 1. Appendix A (at the end of this report) shows a picture of each display and also shows an example of every type of dialog box and menu described in chapter 5 and message box described in chapter 6.

8.1 Display overview

The control program display (Figs. A.1 etc.) is divided into several regions. All regions except the central region display the values of session state variables (section 1.1) and are always visible. These regions are described in the following subsections. The central region displays the values of some subset of the other state variables, depending on which display has been selected by the operator. These displays are described in the following sections.

8.1.1 Display updates and the on-screen clock

The contents of the screen are updated frequently to show the current values of all the variables. The display is usually updated each time a controller is polled and each time the operator presses a key. The display is not updated on regular periodic schedule. There may be several updates per second, or more than a second may pass between updates.

The only exceptions occur when the program cannot update the display because it is waiting to read or write files. Usually these delays are barely noticeable but in the worst case the program may wait

up to 15 seconds (this timeout interval is stored in a file so it can easily be changed).

During intervals when the display is not updating, the control program continues to communicate with the controllers, compute parameter and subsystem readiness, and set software-controlled interlocks, even while these activities are not immediately indicated on the display.

The current date and time appear on the display in the region at the lower right corner. This clock updates each time the display updates, even when nothing else on the display changes. The clock usually advances at frequent but irregular intervals, indicating controller polling and keystrokes. It serves as an indicator that the program is running and is not waiting to read or write a file.

If the display stops updating for more than 15 seconds, it probably means the program has crashed. Sometimes, but not always, the screen reverts to the blank (gray weave) pattern when the program crashes.

8.1.2 Status Lamps

At the top of the screen is a row of subsystem status lamps. The color of each lamp shows the status of its subsystem (section 1.9). The status values NOT READY, READY, and OVERRIDE are indicated by red, dark green, and yellow, respectively.

The lamp for the DOSIMETRY subsystem only is colored light green when its status NOT READY but all its interlocks are clear except Dosimetry Relay 1 or Dosimetry Relay 2, and the treatment phase is Waiting or Ready (fig. A.9). In this condition the DMC is ready to begin a run, but the control program is waiting for other interlocks (not in the dosimetry system) to become clear before it sends CON START to command the DMC to close the dosimetry relays.

8.1.3 Patient or experimental study

The patient or experimental study indentification appears under the status lamps at the left. In therapy mode the background is white and only the patient identification appears. In experiment mode the background is yellow and EXPERIMENT precedes the study number and name (fig. A.10, etc.). The patient number and name are shown exactly as they appear in the prescription file (which is usually generated automatically from the computer treatment plan). The patient number here is the one that identifies the patient in the treatment planning system (it is not the hospital ID number). In experiment mode the study number and study name are shown exactly as they appear in the experimental studies file.

8.1.4 Field

The field indentification appears under the status lamps at the right. In therapy mode the background is white, in experiment mode it is yellow. The field name is shown exactly as it appears in the prescription file (which is usually generated automatically from the computer treatment plan). In experiment mode the field name is shown exactly as it appears in the experimental studies file.

8.1.5 Operator

The operator identification appears at the lower left. It is shown exactly as it appears in the operator authorization file (which is the same as the operator types at the keyboard to log in)[1]. When no operator is logged in, No operator appears here.

8.2 Displays

8.2.1 Startup

While the control program is starting up, before it is ready for an operator to log in, the central region of the display shows a red box with the message `CNTS Startup In Progress` (no figure). Usually this display appears very briefly.

8.2.2 Login

The LOGIN display (fig. A.1) appears after startup before an operator logs in, and then each time the **Logout** command is executed until the next operator successfully completes the login procedure (section 5.4.1). While an operator is typing a username, the characters echo in the Username cell. While an operator is typing a password, the username remains and asterisks echo in the Password cell. The cell where the typed input goes has the wider border. If the operator presses **Cancel**, both cells become blank again.

[1] In the figure the operator identification appears in lowercase. At this writing we always assign identifiers in upper case, but this convention is not enforced by the program.

8.2.3 Patients

The PATIENTS display (fig. A.2) appears when an operator logs in in therapy mode (section 5.4.1), and when the **Patient List** command is executed (section 5.4.2).

There is an entry in the list for each patient in the prescription file. Patients appear in the list in the same order they first appear in the prescription file (which is the chronological order they were first transferred from the treatment planning system).

The entry for the currently selected patient (if any) is highlighted in the list. When the display first appears, it shows the page that includes the current patient, and the triangular cursor in the left column is at the entry for the current patient. If no patient is selected, the cursor is at the first entry in the list. The up and down arrow keys move the cursor and page through the list, and **Select** selects the patient at the cursor (sections 5.1.3, 5.3.1 and 5.4.3).

There may be several pages of patients. If there is another page following the currently displayed page, a downward pointing arrow appears to the left of the last visible entry on the list. If there is a preceding page, an up-arrow appears by the first entry.

In each entry, the #, PATIENT NAME, and HOSPITAL ID columns show that patient's number, name, and hospital identification number exactly as they appear in the prescription file. The patient number is the one that identifies the patient in the treatment planning system. The DATE column shows the transfer date from the prescription file, which is the date that the patient's data was first transferred to the prescription file from the treatment planning system.

The background (behind the list of patients) is colored gold.

8.2.4 Studies

The STUDIES display (fig. A.3) is similar to the PATIENTS display, except it shows a list of experimental studies instead of patients, there are no DATE and HOSPITAL ID columns.

The first study is always the study copied from the most recently selected patient.

The background is colored orange to help distinguish it from the patients display.

8.2.5 Therapy fields

The THERAPY FIELDS display (fig. A.4) appears when the **Field List** command is executed (section 5.4.4).

There is an entry in the list for each field for the current patient. The entry for the currently selected field (if any) is highlighted in the list. When the display first appears, it shows the page that includes the current field, and the triangular cursor in the left column is at the entry for the current field. If no field is selected, the cursor is at the first entry in the list. The up and down arrow keys move the cursor and page through the list, and **Select** selects the field at the cursor (sections 5.1.3, 5.3.1 and 5.4.5).

There may be several pages of fields. If there is another page following the currently displayed page, a downward pointing arrow appears to the left of the last visible entry on the list. If there is a preceding page, an up-arrow appears by the first entry.

In each entry, the # column shows the field number. Fields are numbered in the order they appear in the prescription file, which is the chronological order they were transferred from the treatment planning system. Fields do not appear in order of their field number. Instead, fields are collected into groups based on the value of the completion flag (section 1.3, table 1.3) that appears in the STATUS column. Therapy fields appear first (blank in STATUS column), then film fields (F), then exceeded fields (E), then completed fields (C), then superceded fields (S) appear last. Within each group, fields appear in order of increasing field number.

In each entry, FIELD NAME shows the field name exactly as it appears in the prescription file. TRANSFERRED BY shows the date the field was transferred into the prescription file from the treatment planning program, and the username (on the treatment planning computer) of the therapist who performed the transfer. STATUS shows the value of the completion flag (the value X (other) is displayed as a blank). FRAC shows the accumulated and then the prescribed values of the FRAC (treatment days) parameter. MU/F shows the prescribed value of the DOSE parameter, and TOTAL MU shows the accumulated and then the prescribed values of the TOTAL MU parameter, rounded to the nearest MU (section 1.2, especially 1.2.1 and 1.2.4). If the value of the dose warning flag is not zero (section 1.3, table 1.3), an asterisk appears in the STATUS column and three asterisks appear in the accumulated value position in the TOTAL MU column. If the operator selects a field where the STATUS column is not blank, the program issues a warning (section 5.4.5).

If the THERAPY FIELDS display is on the screen during a therapy run, the accumulated FRAC, TOTAL MU, and possibly STATUS update when the run ends.

The color of the border around the list is dark green.

8.2.6 Experiment fields

The EXPERIMENT FIELDS display (no figure) is similar to the THERAPY FIELDS display, except it shows a list of experiment fields instead of therapy fields, the only columns are # and FIELD NAME.

The color of the border around the list is pale blue to help distinguish it from the therapy fields display.

8.2.7 Field summary

The FIELD SUMMARY display (fig. A.5) appears when the **Field Summary** command is executed (section 5.5.1).

In therapy mode the background of this display is dark brown (or brick red). In experiment mode the background is gold.

This display shows a table of information about the parameters and subsystems listed in the NAMES column:

- DOSIMETRY
- GANTRY
- COLLIMATOR
- WEDGE TYPE
- WEDGE ROT
- FILTER
- LEAVES
- TURNTABLE

DOSIMETRY and LEAVES refer to subsystems and the other names refer to parameters. For parameter descriptions etc. see section 1.2, tables 1.1, and 1.2. For subsystem descriptions see section 1.9 and tables 1.15 and 1.16.

The STATUS column shows the status of the parameter or subsystem. For parameter status see section 1.2.7 and for subsystem status see section 1.9.

The STATUS column shows the three status values READY, NOT READY and OVERRIDE in dark green, red and yellow, respectively. For the dosimetry subsystem only, the entry says MODIFIED when the status is overridden and the color is yellow. For the dosimetry subsystem only, the entry says WAITING and the color is light green when the dosimetry subsystem status lamp at the top of the display is light green (section 8.1.2 above).

In experiment mode the status of the GANTRY and COLLIMATOR parameters are not checked, so the STATUS entries are left empty (no text) and the color is white.

The PRESCRIBED column shows the prescribed values of the parameters, except the preset value of the dose is shown and the LEAVES entry is blank. In experiment mode there is no prescribed value for GANTRY and COLLIMATOR so these entries are blank also. For an explanation of prescribed and preset values see sections 1.2.1 and 1.2.2. The background color in this column is always white.

The ACTUAL column shows the actual (measured) values of the parameters sensed by the controller (section 1.2.3). The values appear in the format described in table 1.1. If the actual value lies outside the range shown in the table, five asterisks ***** appear in the table entry (this always occurs when the WEDGE TYPE, WEDGE ROT or FILTER is in transit between the discrete positions listed in the table). The entry for LEAVES is always blank. If other actual values are not available (because of a controller error, for example) their entries are blank also. The background color of the entry indicates parameter or subsystem status: white, pink, and pale yellow indicate READY, NOT READY and OVERRIDE, respectively. If the status of a parameter is not checked (for example GANTRY and COLLIMATOR in experiment mode) the background color is white.

The ACTUAL entry for DOSIMETRY is a special case. It is made blank when a field is selected and remains blank until the program begins polling the DMC at the beginning of the run (chapter 2, section 3.4). When the program is polling the DMC during the run (starting with the Ready phase, before the beam is on in the treatment room, and including the Paused phase when the beam is off) this entry shows accumulating... in red (fig. B.6). The entry does not show the actual dose value read from the DMC because this would necessarily lag the value shown on the dosimetry panel LED displays, and might be incorrect if there is a problem communicating with the DMC. When the program determines the official dose for the run (section 1.2.5) this entry shows the official dose in black (fig. B.5). If the program detects an error that causes the dose warning flag to be set (section 1.3), this entry shows a row of asterisks in black.

The MOTION L/A column shows the control mode for motion parameters sensed by the PLC (section 1.2.6). A single control mode signal applies to the entire LEAVES subsystem, and its value appears here. The value is usually AUTO or LOCAL. If the motion control signal is unavailable

(because of a controller error, for example) the entry is blank. The entry is always blank if the parameter or subsystem does not have a control mode signal (usually because it is not a motion at all, as with DOSIMETRY). The background color in this column is always white.

The MOTION D/E column shows the motion drive signal for motion parameters sensed by the PLC (section 1.2.6). A single motion drive signal applies to the entire LEAVES subsystem, and its value appears here. The value is usually ENABLED or DISABLED. If the PLC reports that the motion drive signal is inconsistent, the entry is shows five asterisks *****. The backround color is white when the value is DISABLED and is yellow when the value is ENABLED or inconsistent (figs. A.5, A.7). The entry is blank if the parameter or subsystem does not have a motion drive signal (usually because it is not a motion at all, as with DOSIMETRY). The background color of these entries is always white.

A yellow indicator lamp labelled AUTO SETUP appears at the bottom of this display when the Auto Setup in Progress interlock is set, indicating that an auto setup operation for any subsystem is in progress (section 1.5.27, fig. A.5). When the interlock is clear, the lamp disappears.

Interlock lamps appear at the bottom of this display when those interlocks are set: DOSIM RELAY, DOOR, PEDESTAL, PRESS/TEMP, and DMC ERROR. When each interlock is clear, its lamp disappears.

8.2.8 Gantry/Couch

The GANTRY/COUCH display (fig. A.6) appears when the **Gantry/Couch** command is executed (section 5.5.2).

In therapy mode the background of this display is brown. In experiment mode it is light brown.

This display shows a table of information about the parameters in the GANTRY/COUCH subsystem listed in the NAMES column:

- GANTRY
- COLLIMATOR
- TURNTABLE
- TOP
- HEIGHT
- LATERAL

- LONGITUDINAL

The columns in the table are the same as in the FIELD SUMMARY display, and the meaning of the table entries is the same (section 8.2.7 above).

In this display the STATUS and PRESCRIBED entries are always blank for the table motion parameters TOP, HEIGHT, LATERAL, and LONGITUDINAL, because these parameters never have prescribed values. Those entries are blank for all parameters in experiment mode, because none of the parameters on this display have prescribed values then. For the TOP parameter the MOTION D/E entry says (no motor) because there is none, and therefore is no motion control nor motion enable signal. The MOTION L/A entry for TOP is always blank.

At the bottom of the PRESCRIBED column there is a parking place entry where the cursor lies each time the display appears. The operator can use the arrow keys to move this cursor to another entry in this column, in order to override the parameter at that row (section 5.5.2). Fig. A.6 shows the screen as it appears just after the operator has overridden the COLLIMATOR setting. In therapy mode the parking place entry is labelled OVERRIDE and in experiment mode it is labelled (no modify).

Two separate red interlock lamps labelled TMC ERROR and COLLISION each appear at the bottom of this display when the TMC Error and Collision interlocks are set (sections 1.5.3 and 1.5.2, the lamps are not shown in fig. A.6). When each interlock is clear, its lamp disappears.

8.2.9 Filter/Wedge

The FILTER/WEDGE display (fig. A.7) appears when the **Filter/Wedge** command is executed (section 5.5.3).

In therapy mode the background of this display is green. In experiment mode it is light green.

This display shows a table of information about the parameters in the FILTER/WEDGE subsystem listed in the NAMES column:

- WEDGE TYPE
- WEDGE ROT
- FILTER

The columns in the table are the same as in the FIELD SUMMARY display, and the meaning of the table entries is the same (section 8.2.7 above).

At the bottom of the PRESCRIBED column there is a parking place entry where the cursor lies each time the display appears. The operator can use the arrow keys to move this cursor to another entry in this column, in order to override the parameter at that row, or to change the preset parameter value in experiment mode only (section 5.5.3). In therapy mode the parking place entry is labelled OVERRIDE and in experiment mode it is labelled MODIFY.

A yellow indicator lamp labelled AUTO SETUP appears at the bottom of this display when the TMC Auto Setup interlock is set, indicating that an auto setup operation for this subsystem is in progress (section 1.5.5). When the interlock is clear, the lamp disappears.

A red interlock lamp lablelled TMC ERROR appears at the bottom of this display when the TMC Error interlock is set (section 1.5.3, this lamp is not shown in fig. A.7). When the interlock is clear, the lamp disappears.

8.2.10 Leaf collimator

The LEAF COLLIMATOR display (fig. A.8) appears when the **Leaf Collimator** command is executed (section 5.5.4).

The center of the display shows a picture of the collimator leaves (in gray) computed from the actual (measured) leaf parameters sensed by the LCC. The picture is drawn to scale: the inner leaves are narrower, and square fields appear nearly square. The picture is a *beam's eye view* as seen looking out from the beam source (not looking in from the treatment couch).

When the measured value of a leaf position is very near the midline, the picture shows the leaf exactly on the midline. This compensates for small inaccuracies in the leaf position readouts and prevents the picture from showing small gaps between leaves that are actually closed against each other. This adjustment to the picture is made when leaves are no further from the center line than the tolerance shown in table 1.1 (0.15 cm at this writing). However, a larger tolerance is used to compute the status of closed leaves (0.20 cm at this writing), so if the gap in the measured parameter is between 0.15 and 0.20, the picture will show a gap but the leaves will still be READY (see also section 1.2.7).

In the picture, red and blue bars indicate discrepancies beween the prescribed and actual leaf parameter values. Blue bars indicate potential *cold spots* where the prescription calls for the leaf to be further open but the leaf is actually more closed, and red bars indicate potential *hot spots* where the prescription calls for the leaf to be further closed but it is more open. In fig. A.8 the prescribed leaf

parameters describe a kidney shape but the actual parameters indicate the leaves are still set up for the previous field, a more oval shape.

The # columns show the number of each leaf (note that adjacent leaves are not always numbered in consecutive order). The PRESCR columns show the prescribed values of each leaf (also indicated by the red and blue bars). When there is no prescribed value (when no field is selected) these entries are blank. The ACTUAL columns show the actual values for each leaf (also indicated by the gray leaves). The background colors in each ACTUAL entry indicate the status of that leaf. Pale green and yellow indicate READY and OVERRIDE, respectively. Pale blue and pink both indicate NOT READY; blue indicates the leaf is closed too far and pink indicates it is open too far.

When a leaf collimator auto setup is in progress, the control program cannot poll the LCC so it cannot determine the actual leaf positions (section 3.3). At these times the ACTUAL columns are blank with a pink background. The picture of the leaves is replaced by a featureless gray, with the superimposed text SETTING UP *Field Name*.

The bar at the top left of the picture indicates the status of the entire leaf collimator subsystem. It may say COLLIMATOR NOT READY, COLLIMATOR READY or COLLIMATOR OVERRIDE on a background of red, dark green, or yellow, respectively.

The bar at the top right of the picture indicates both the motion auto/local and enabled/disable status (table 8.1). There is a single motion control for all the leaves together.

Control	Drive	Color	Text
(blank)	(Inconsistent)	yellow	******
(blank)	ENABLED	yellow	ENABLED
(blank)	DISABLED	yellow	DISABLED
LOCAL	(Inconsistent)	yellow	LOCAL ******
LOCAL	ENABLED	yellow	LOCAL ENABLED
LOCAL	DISABLED	yellow	LEAVES DISABLED
AUTO	(Inconsistent)	yellow	AUTO ******
AUTO	ENABLED	yellow	AUTO ENABLED
AUTO	DISABLED	white	LEAVES DISABLED

Table 8.1: Leaf motion control indication on leaf collimator display

At the bottom of the left PRESCR column there is a parking place entry where the cursor lies each time the display appears. The operator can use the arrow keys to move this cursor to another entry, in order to override the parameter at that entry, or to change the preset parameter value in experiment mode only (section 5.5.4). In therapy mode the parking place entry is labelled Override and in experiment mode it is labelled Modify.

A yellow indicator lamp labelled AUTO SETUP appears at the bottom of this display when the LCC Auto Setup interlock is set, indicating that an auto setup operation for this subsystem is in progress (section 1.5.10). When the interlock is clear, the lamp disappears.

A yellow indicator lamp labelled LCC BUSY appears at the bottom of this display after the Select Field operation when the control program begins sending all the leaf collimator calibration to the LCC. When the control program completes sending them all back, the lamp disappears (sections 5.4.5 and 3.3). This takes about ten seconds. No operations are disabled while the LCC BUSY lamp is on. The operator can select **Auto Setup** at this time, but the control program does not command the leaf collimator to set up until the LCC BUSY lamp turns off.

Two separate red interlock lamps labelled LCC ERROR and COLLIM CAL. each appear at the bottom of this display when the LCC Error and No Leaf Coll. Cal. Available interlocks are set (sections 1.5.9 and 1.5.8, the lamps are not shown in fig. A.8). When each interlock is clear, its lamp disappears.

8.2.11 Dosimetry

The DOSIMETRY display (fig. A.9) appears when the **Dosimetry** command is executed (section 5.5.5).

In therapy mode the background of this display is purple (or magenta). In experiment mode it is pink.

The upper part of this display shows the dosimetry parameters DOSE and TIME in a small table. The exact meaning of the values for these parameters is described in section 1.2.

The following paragraphs describe the entries in the DOSE row.

The PRESCRIBED column shows the prescribed value for daily DOSE for the currently selected field, which is read from the prescription file. The same prescribed value appears in both rows. In experiment mode there is no prescribed dose and these entries are blank.

The PRESET column shows the preset value for the DOSE intended to be delivered during the run currently being set up or performed. In therapy mode the preset dose is usually the same as the prescribed dose but a different preset value may be entered by the operator or assigned by the control program. In experiment mode there is no prescribed dose so the operator must enter the preset dose at some point (it persists when a new field is selected) and these entries remain blank until then. The same preset value appears in both rows. This is the dose value that is loaded into the DMC.

The ACCUMULATED column is made blank when a field is selected and remains blank until the program begins polling the DMC at the beginning of the run (chapter 2, section 3.4). When the program is polling the DMC during the run (starting with the Ready phase, before the beam is on in the treatment room, and including the Paused phase when the beam is off) this entry shows accumulating... in red. The entry does not show the actual dose value read from the DMC because this would necessarily lag the value shown on the dosimetry panel LED displays, and might be incorrect if there is a problem communicating with the DMC. When the program determines the official dose for the run (section 1.2.5) this entry shows the official dose in black (fig. B.5). If the program detects an error that causes the dose warning flag to be set (section 1.3), this entry shows a row of asterisks in black.

At the end of the run the program stops polling the DMC and usually commands to DMC to perform its termination self-test. The official dose (or asterisks) remain on the screen until the next field is selected and the entries become blank again.

In the TIME row, the PRESCRIBED value is the backup time for the run calculated by the control program from the preset (not prescribed) dose (section 1.2.1). The PRESET value is the same as the prescribed value unless the operator enters a different value. It is this preset value that is actually loaded into the DMC. The ACCUMULATED column is blank from the time the field is selected until the start of the run. During the run, this column shows three dots ... in red. After the program assigns the official dose, this column shows ... (the elapsed time reported by the DMC at the time the official dose was assigned). ...?

At the bottom of the PRESET column there is a parking place entry where the cursor lies each time the display appears. The operator can use the arrow keys to move this cursor to the DOSE or TIME entry in this column, in order to modify the preset value at that row (section 5.5.5). Fig. A.9 shows the screen as it appears as the operator is about to modify the DOSE value. The parking place entry is labelled MODIFY. The preset values can be edited in both therapy and experiment modes.

The lower part of this display shows several interlock lamps arranged in two rows. Each lamp appears when the interlock is set and disappears when the interlock is clear. All of the interlocks are described in section 1.5. The top row shows lamps for these interlocks (labelled as shown) in left to right order:

- Dosimetry Relay 1 [deactivated] *or* Dosimetry Relay 2 [deactivated] (DOSIM RELAY)
- Pressure/Temperature (PRESS/TEMP)
- No Dosim. Cal. Available (DOSIM. CAL)
- DMC Setup Timeout (SETUP TIME)
- DMC Start Timeout (START TIME)

- DMC Auto Setup (DMC SETUP)

The bottom row shows lamps for these interlocks:

- Therapy Door [Open] (DOOR)
- Console Key [Disabled] (KEY)
- Pedestal Key [Enabled] (PEDESTAL)
- Editing in Progress (EDITING)
- DMC Error (DMC ERROR)
- PLC Error (PLC ERROR)

All lamps are red, except AUTO SETUP is yellow. DOSIMETRY is usually red, except during the waiting condition when the dosimetry subsystem status lamp is pale green (section 8.1.2), this interlock lamp is also pale green.

The DOSIMETRY lamp appears when either Dosimetry Relay 1 or Dosimetry Relay 2 or both is set and disappears only when both are clear (it indicates the logical *or* of these two interlocks).

8.2.12 PLC Status

The PLC STATUS display (fig. A.10) appears when the **PLC** command is executed. This display shows all the input and output signals handled by the PLC. It also shows a few items that do not fit anywhere else: the treatment phase and run status. Related signals are grouped in *panels*.

The INTERLOCKS panels show all the interlocks 1.5. Some interlock names are prefixed by M1: or M2: to indicate these are hardware interlocks sensed by Modicon 1 or Modicon 2, respectively. Interlock names without prefixes are software interlocks computed by the control program. The entry for each interlock is red when the interlock is set and green when it is clear.

The THERAPY SUM INTERLOCK panel shows the Therapy Sum interlock output and input (section 1.5.28). The prefix M1: indicates that these signals are handled by Modicon 1. The entry marked C (commanded) shows the interlock output to the PLC computed by the control program. The entry marked O (obtained) shows the status of the therapy sum relay in the hardwired safety trace, as sensed by the PLC. Each entry is red when its interlock signal indicates set and green with

the signal indicates clear. The two entries should show the same value, except for a brief delay after the commanded output changes.

The STATUS BITS panel shows the treatment sequence status bits and the indicator status bits (section 1.6)[2]. Some status bit names are prefixed with M1: or M2: to indicate that these are hardware bits sensed by Modicon 1 or Modicon 2, respectively. The other bits are computed by the control program. The entry for each indicator is off-white when the bit is false and tan when the bit is true.

The MOTION ENABLE panel shows the motion control signals for all the motion parameters (section 1.2.6). Parameter names are prefixed with M2: to indicate that all signals are handled by Modicon 2. The R (enable Request) column shows when the control program has requested the PLC to enable motion for that parameter. Yellow indicates the request is asserted and white indicates no motion is requested. The S (enable Sensor) column shows when the PLC senses that the motion has been enabled. Yellow indicates the motion is enabled and white indicates it is disabled. The I (Inconsistent) column shows when the PLC has determined that the motion enable signals for that parameter are inconsistent. Green indicates consistent, red indicates inconsistent. The A (Auto) column shows whether the PLC senses that the motion drive is in automatic or manual mode. Off-white indicates local, tan indicates automatic.

The X-RAY PORTS panel shows the port film status bits (section 1.6). The name of each bit is prefixed M2: to indicate these signals are handled by Modicon 2. The C (Commanded) column shows when the program has requested the PLC to set up each port. Off-white indicates no request, tan indicates request. The O (Obtained) column shows when the PLC senses that each port has been set up. Off-white indicates the port is not set up, tan indicates the port is set up.

The PRESSURE/TEMPERATURE panel shows the values reported by the two pressure sensors and the temperature sensor (section 1.4.2).

In the small panel at the lower right, DMC PHASE shows the current phase in the treatment sequence and THERAPY RUN STATUS shows when a run is in progress (section 1.7, chapter 2). (These variables are not sensed or controlled by the PLC but there was nowhere else to put them.)

The LEGEND panel documents the color coding used in other panels.

8.2.13 Dosimetry calibration

The DOSIMETRY CALIBRATION display (Fig. A.12) appears when the **Dosimetry Calibration** command is executed. This display shows the dosimetry calibration constants and factors (sec-

[2]The M2:X-ray Enable Key entry is not shown in the figure but appears in the current program version.

tions 1.4.1 and 1.4.2) and also the pressure and temperature values and related constants and factors (section 1.4.3).

There calibration factors panel has two columns, showing two values for several of the factors. The values in the left column are used when the P/T MODE is AUTOMATIC and the values in the right are used in MANUAL mode. The values in use appear in black type and the other values are gray. The two factors DOSE RATE and TIME FACTOR each have only one value which is used in both modes.

The cursor indicates the item which is selected for editing (in experiment mode only), see section 5.7.1. There is no "parking place" for this cursor. When the display appears, the cursor is placed at P/T MODE.

P/T STATUS shows one of the messages described in section 1.4.3, table 1.7. The message text is displayed in black when the Pressure/Temperature interlock (section 1.5.13) is clear and red when it is set.

In addition, this screen shows two items not discused in sections 1.4.1 and 1.4.2.

P/T ENTERED shows the time when the manual PRESSURE or TEMPERATURE was entered, whichever was entered first. When the difference between this time and the current time exceeds P/T DEADLINE, P/T STATUS is assigned the value Manual correction factor expired.

LAST FILE UPDATE shows the date when the `dosecal.dat` file was last revised, and the name of the user on the host computer who revised it. This information is stored in `dosecal.dat` itself.

8.2.14 Leaf collimator calibration

The LEAF COLLIMATOR CALIBRATION display (Fig. A.13) appears when the **LCC Calibration** command is executed. This display shows the leaf collimator calibration constants (section 1.4.4).

The contents update during the calibration procedure (section 5.7.2). The displayed leaf positions update after the control system executes the **Large Calibration Field** and **Midline Field** commands. The displayed calibration factors update after the control system executes the **Write File** command.

8.2.15 Message log

The MESSAGE LOG display (Fig. A.14) appears when the **Messages** command is executed. This display shows the contents of the log message buffer (chapter 7). Press the up and down arrow keys to page through the log (section 5.8.4).

8.2.16 Treatment records

Press `ctrl-7` to show the TREATMENT RECORDS display (no figure). This display shows the contents of the in-memory treatment record buffer. It looks similar to the message log display (Fig. A.14).

8.2.17 TMC, LCC, DMC, PLC communication

Press the **TMC**, **LCC** and **DMC** keys to display the TREATMENT MOTION CONTROLLER (TMC), LEAF COLLIMATOR CONTROLLER (LCC) and DOSE MONITOR CONTROLLER (DMC) communication displays, respectively. Press `ctrl-9` to display the PROGRAMMABLE LOGIC CONTROLLER (PLC) communication display (the **PLC** key shows the PLC STATUS display).

Fig. A.15 shows the LCC display, the others are similar. Each of these displays show a log of recent message traffic (in both directions) between the control program and the controller, with date and time stamps at one minute intervals.

8.2.18 Help

The HELP display (fig. A.16) appears when the **Help** command is executed. It shows a keypad diagram similar to fig. 5.1. It also shows the contents of the message of the day file, `message.txt`.

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Appendix A

Screen pictures: displays

Pictures of every display appear on the following pages.

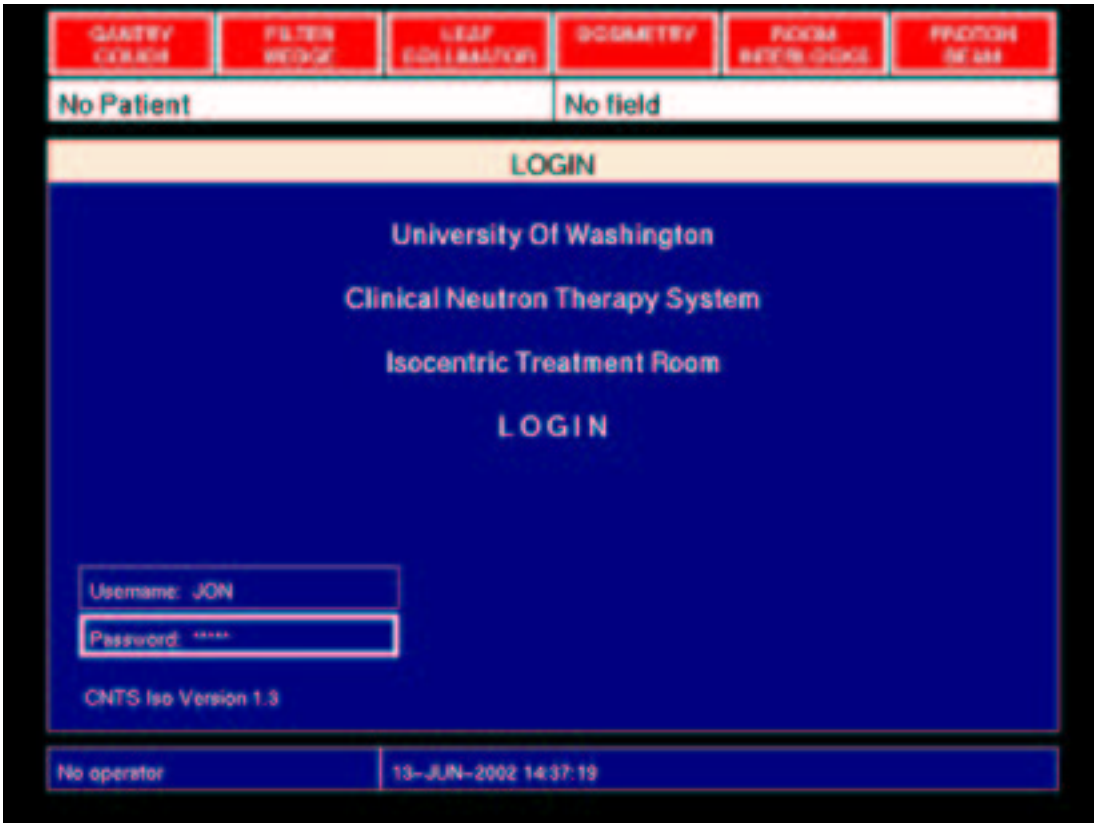

Figure A.1: Login display

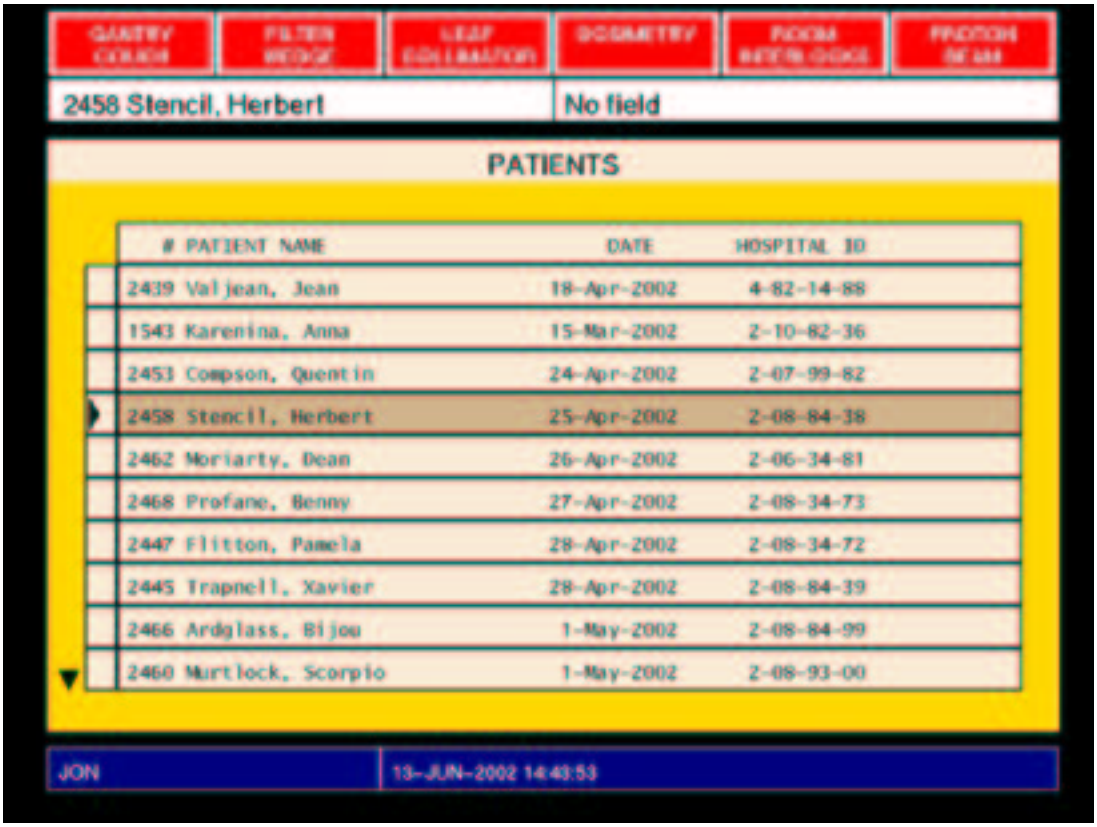

Figure A.2: Patients display

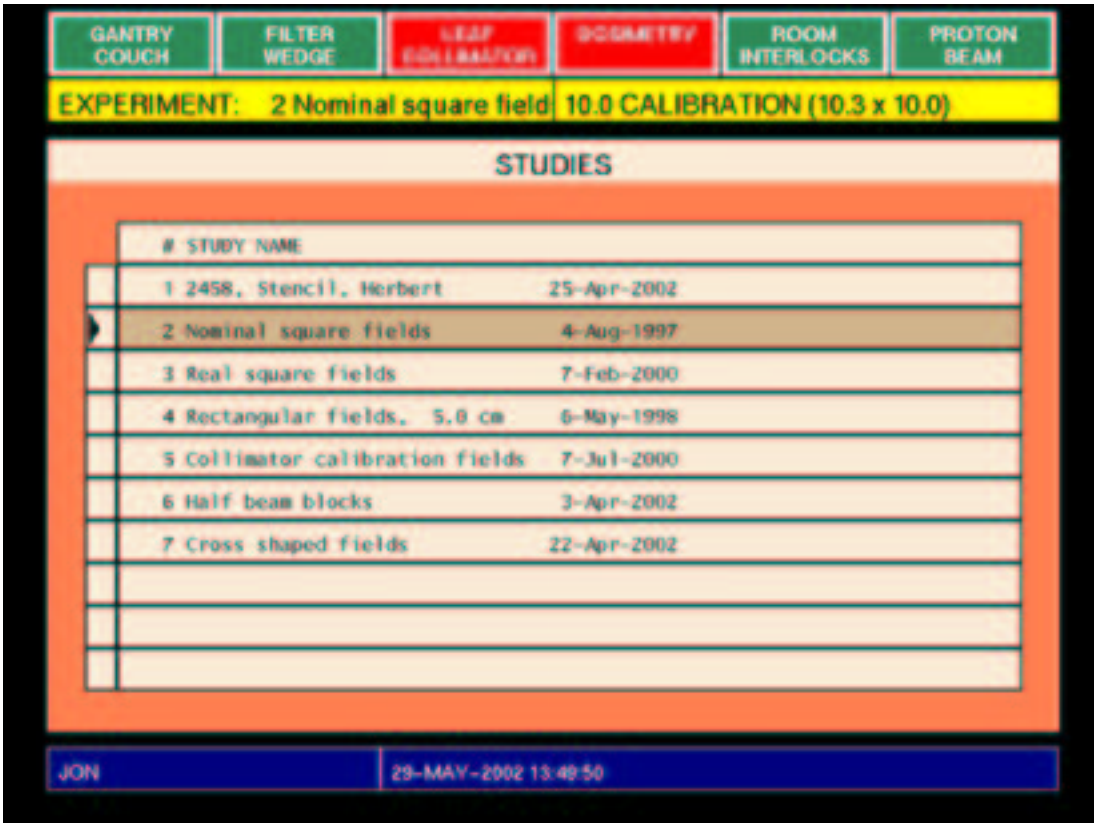

Figure A.3: Experimental studies display

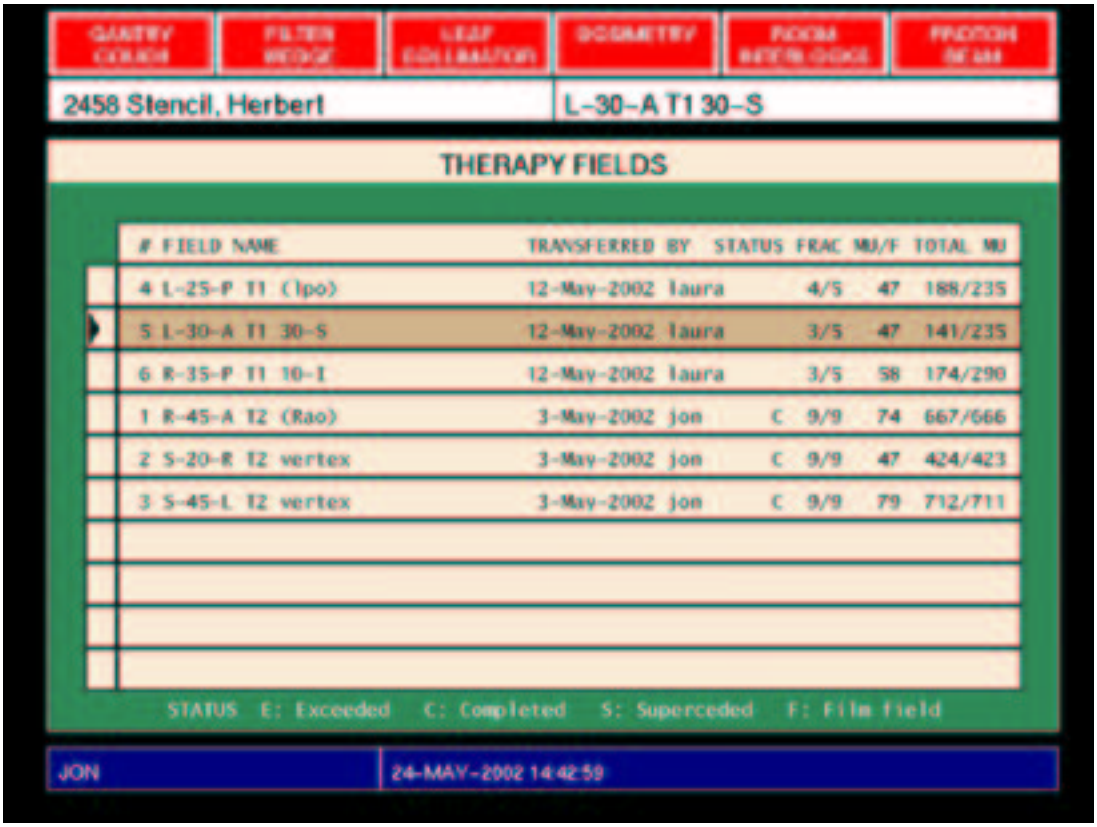

Figure A.4: Therapy fields display

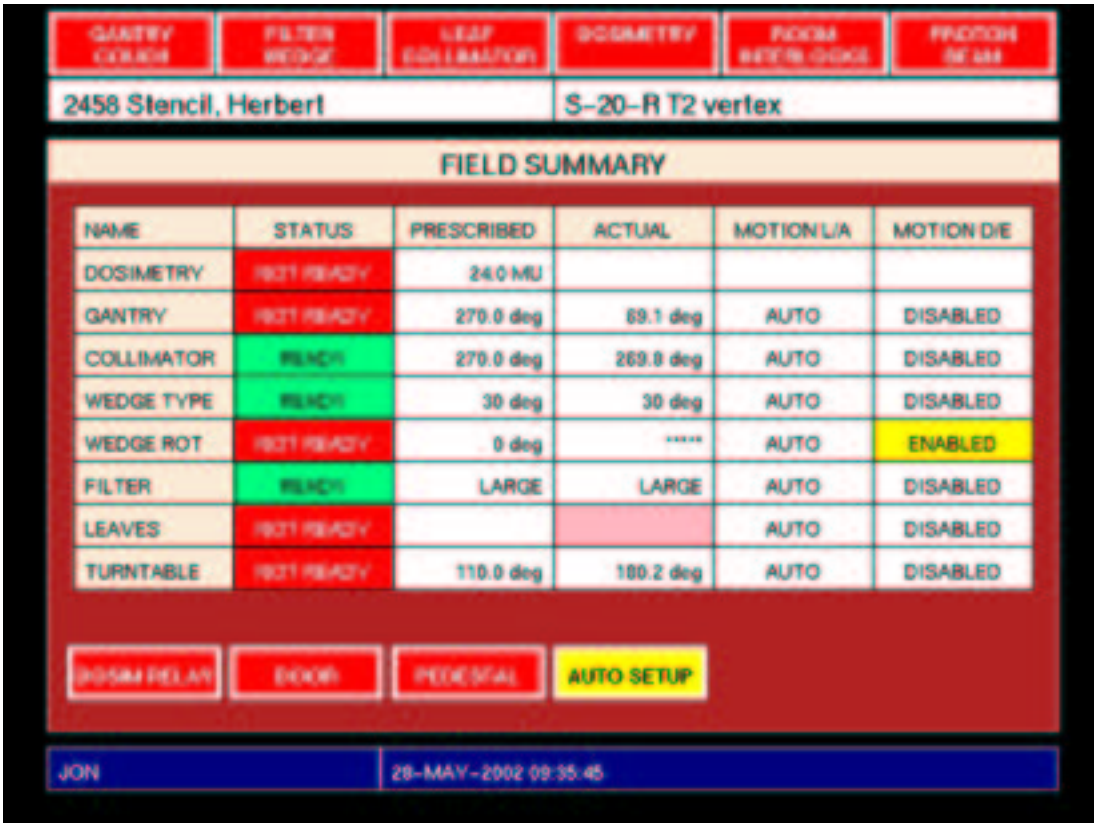

Figure A.5: Field Summary display during auto setup

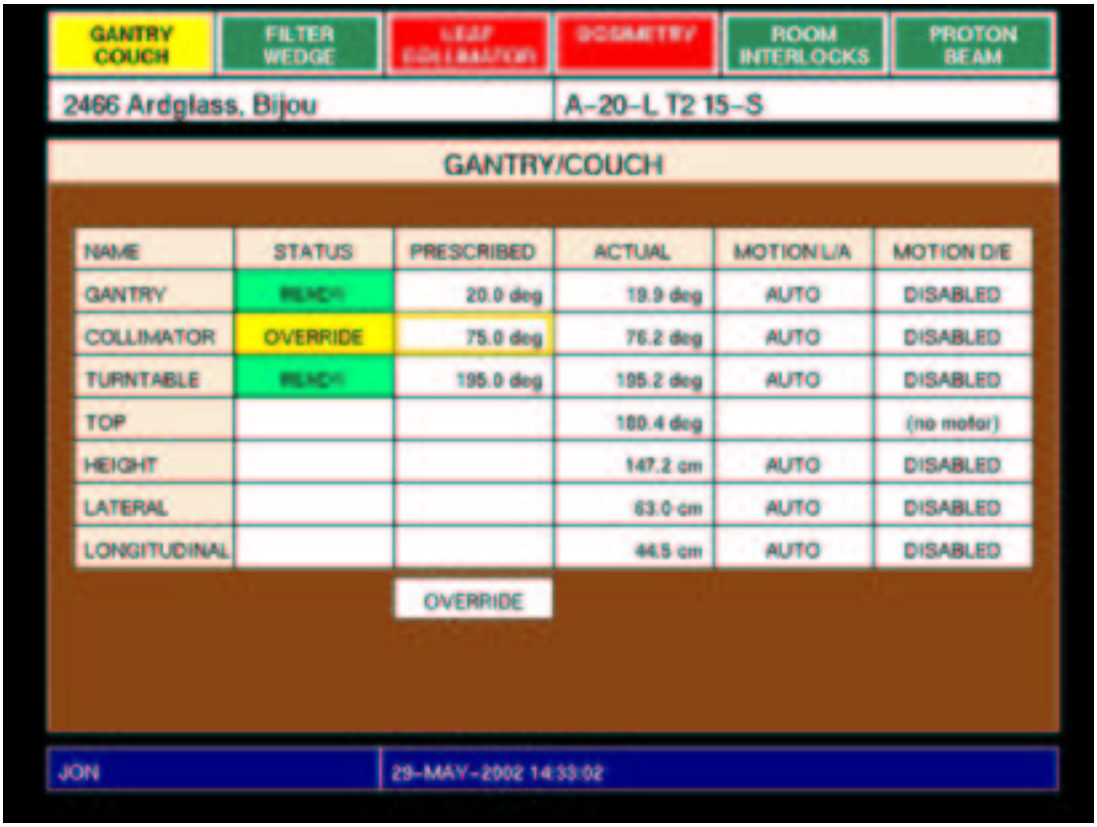

Figure A.6: Gantry/Couch display showing overridden collimator rotation

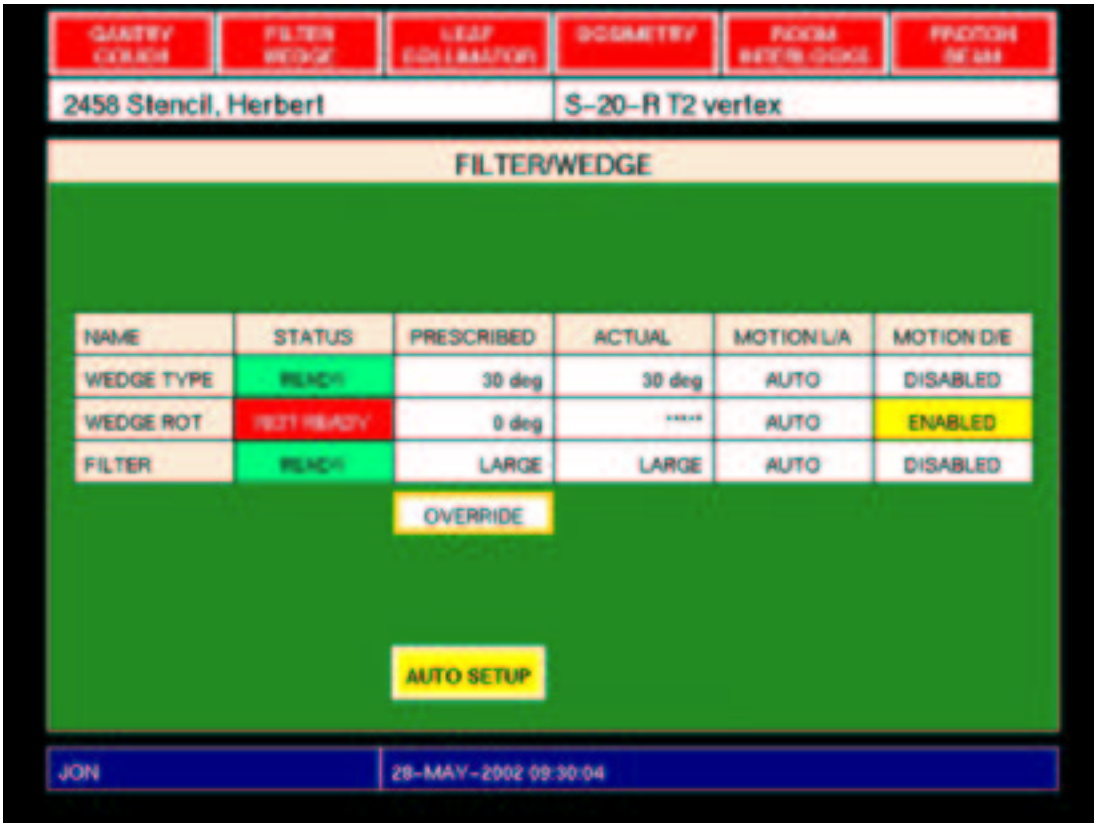

Figure A.7: Filter/Wedge display during auto setup

A.1 Login

A.2 Patients

A.3 Studies

A.4 Therapy fields

A.5 Field summary

A.6 Gantry/Couch

A.7 Filter/Wedge

A.8 Leaf collimator

A.9 Dosimetry

A.10 PLC status

A.11 PLC motions

A.12 Dosimetry calibration

A.13 Leaf collimator calibration

A.14 Message log

A.15 LCC communication

A.16 Help

A.17 Room display

Figure A.8: Leaf collimator display

Figure A.9: Dosimetry display showing cursor positioned to edit preset dose

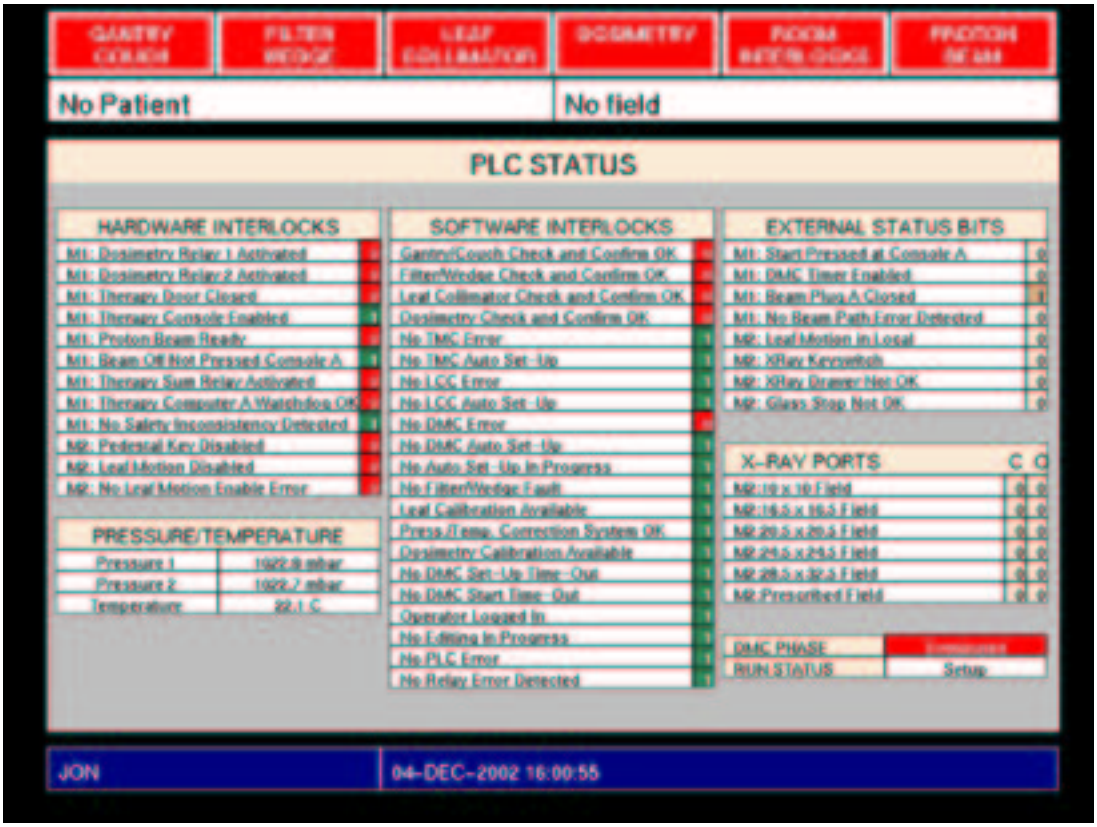

Figure A.10: PLC status display

Figure A.11: PLC motions display

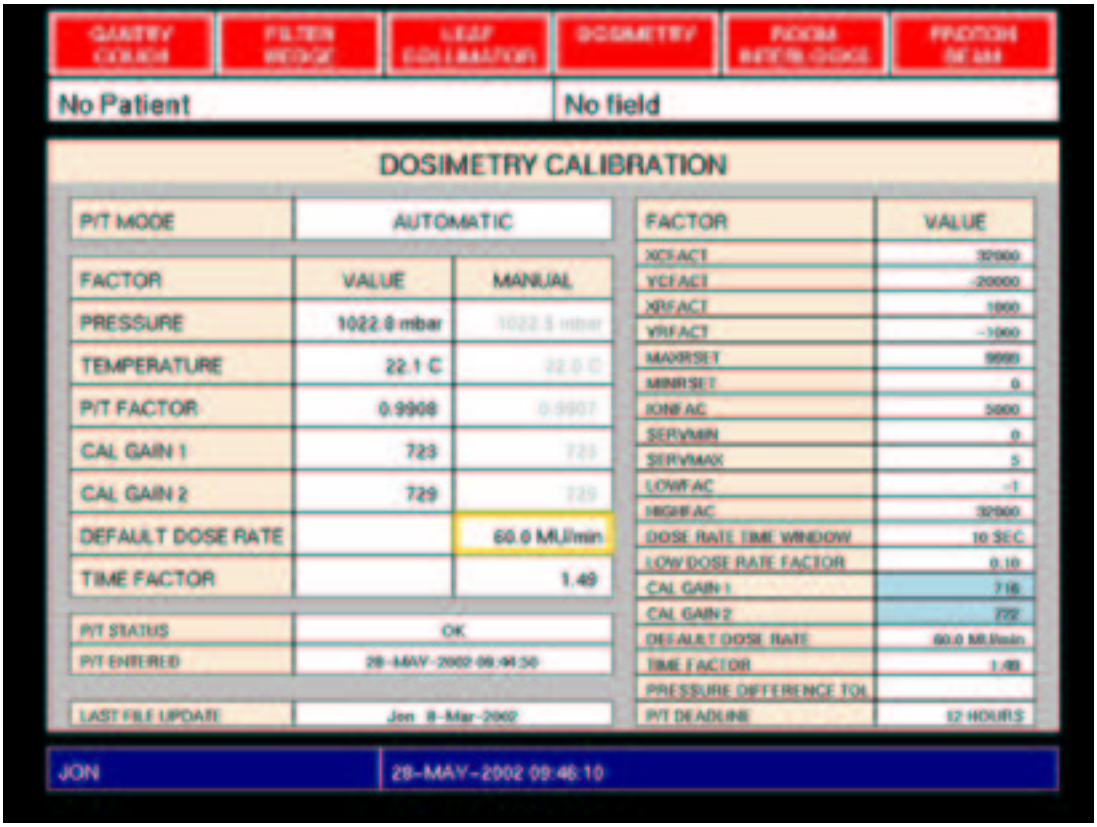

Figure A.12: Dosimetry calibration display showing cursor positioned to edit dose rate

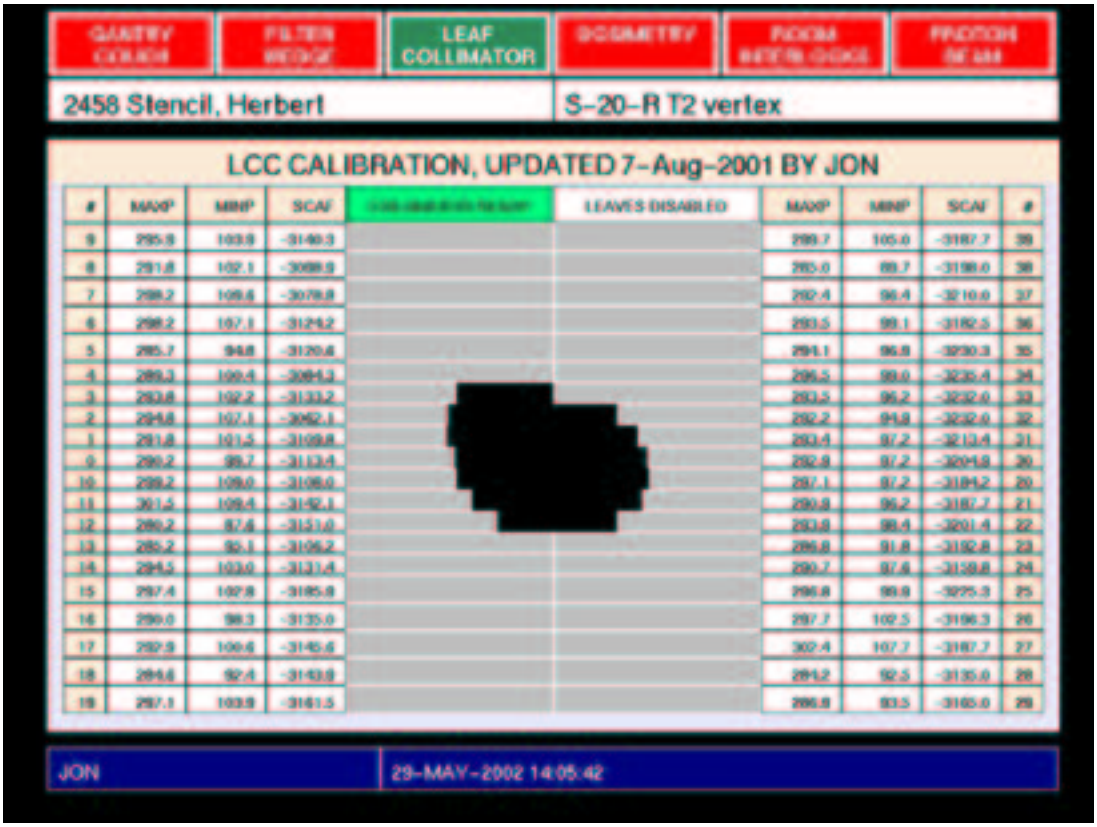

Figure A.13: Leaf collimator calibration display

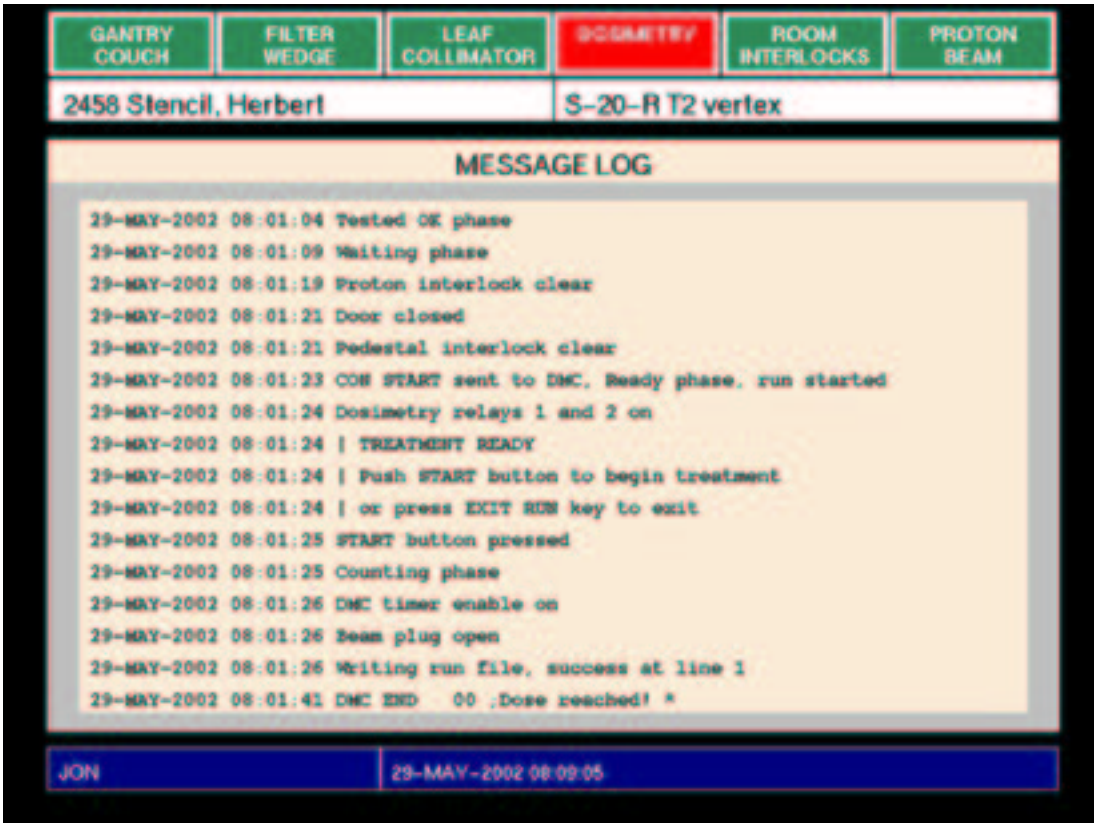

Figure A.14: Message log display

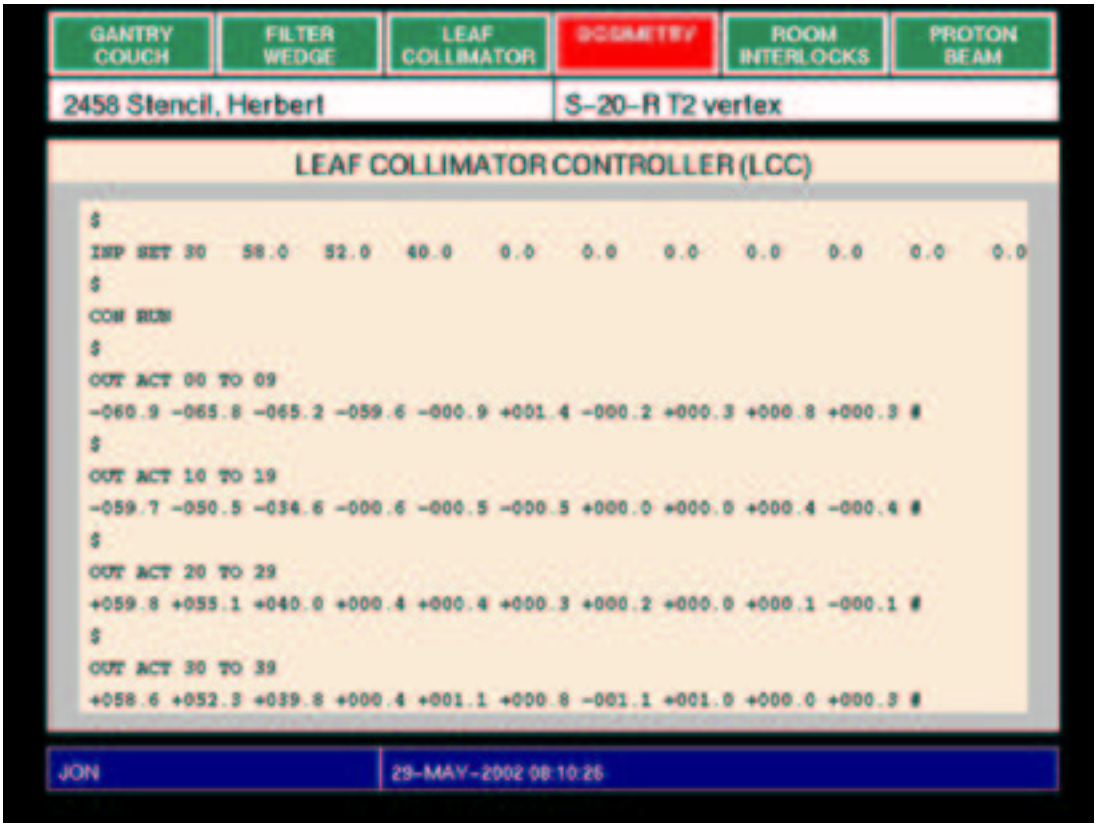

Figure A.15: LCC communication display

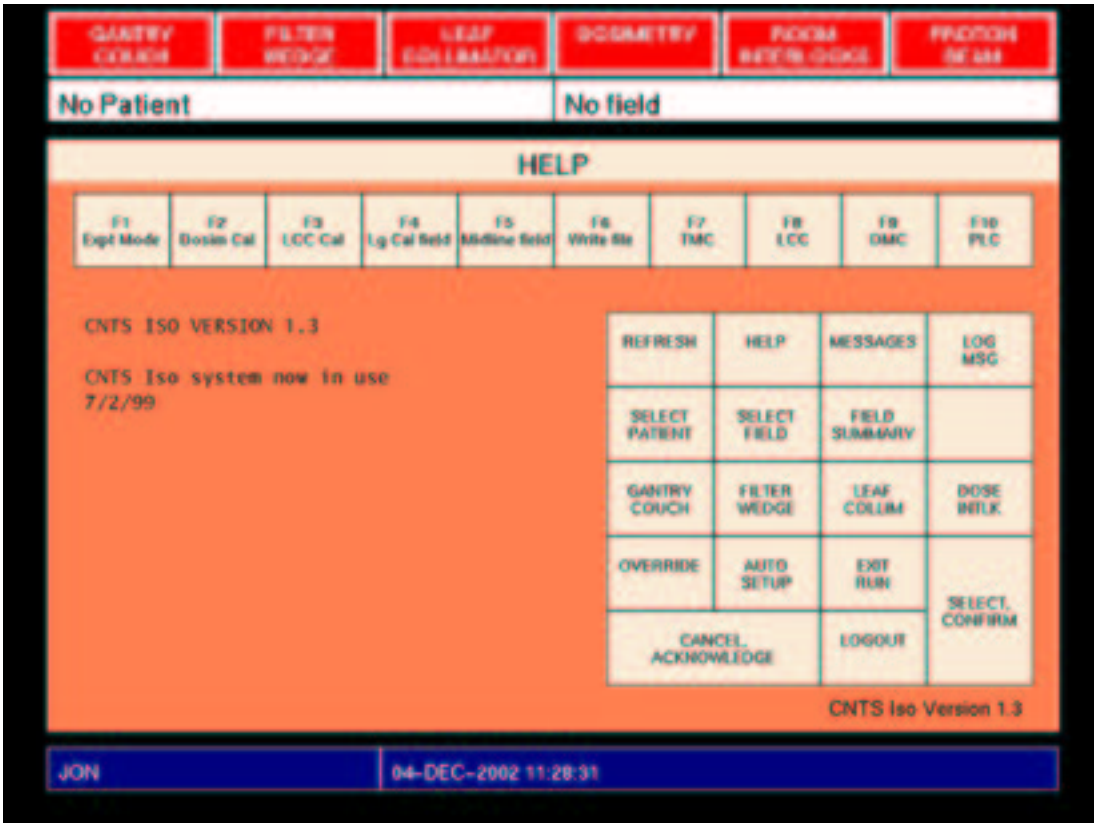

Figure A.16: Help display

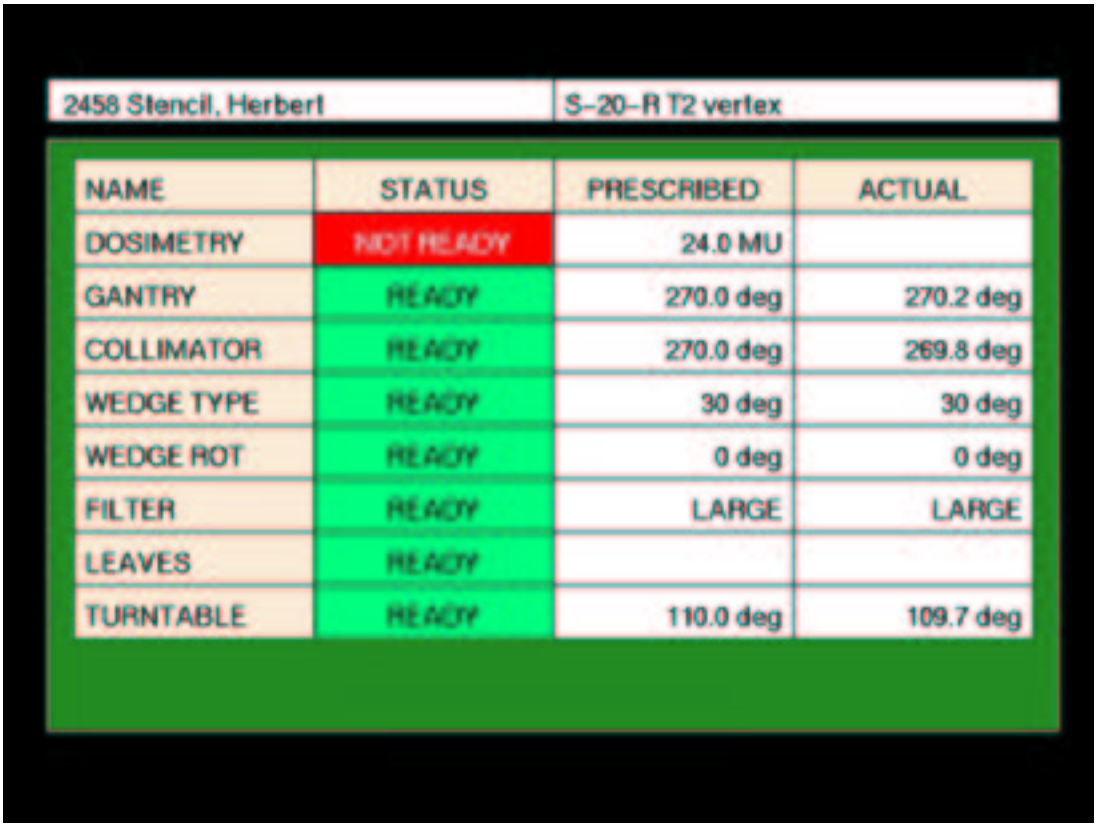

Figure A.17: Room display

Appendix B

Screen pictures: menus and messages boxes

Pictures of every type of dialog box and message box appear on the following pages.

B.1 Dialog box

B.2 Confirmation box

B.3 Acknowledge box

B.4 Menu

B.5 Message box (expected event)

B.6 Message box (warning)

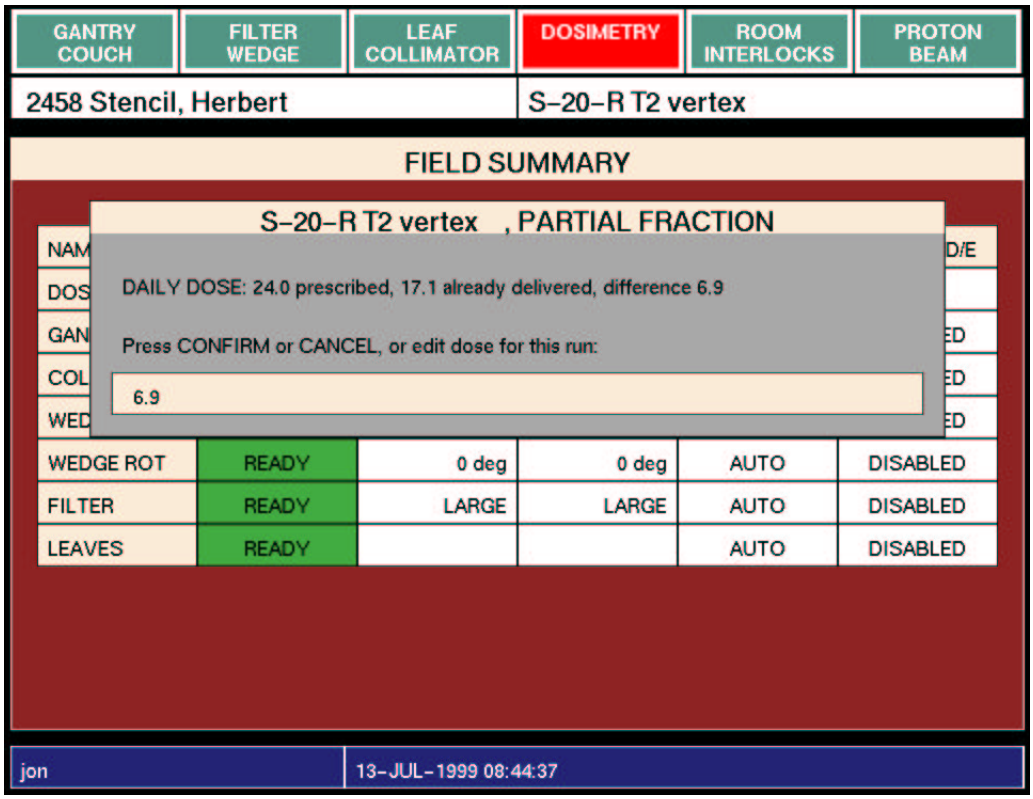

Figure B.1: Dialog box

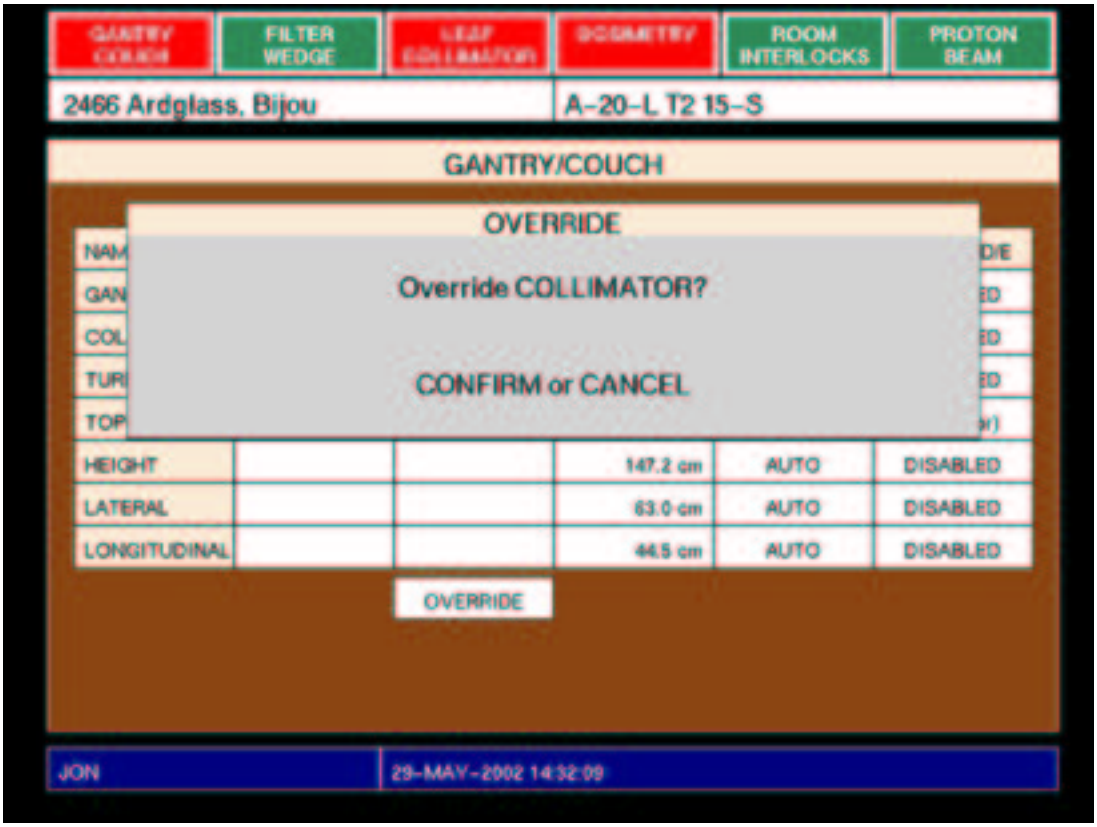

Figure B.2: Confirmation box

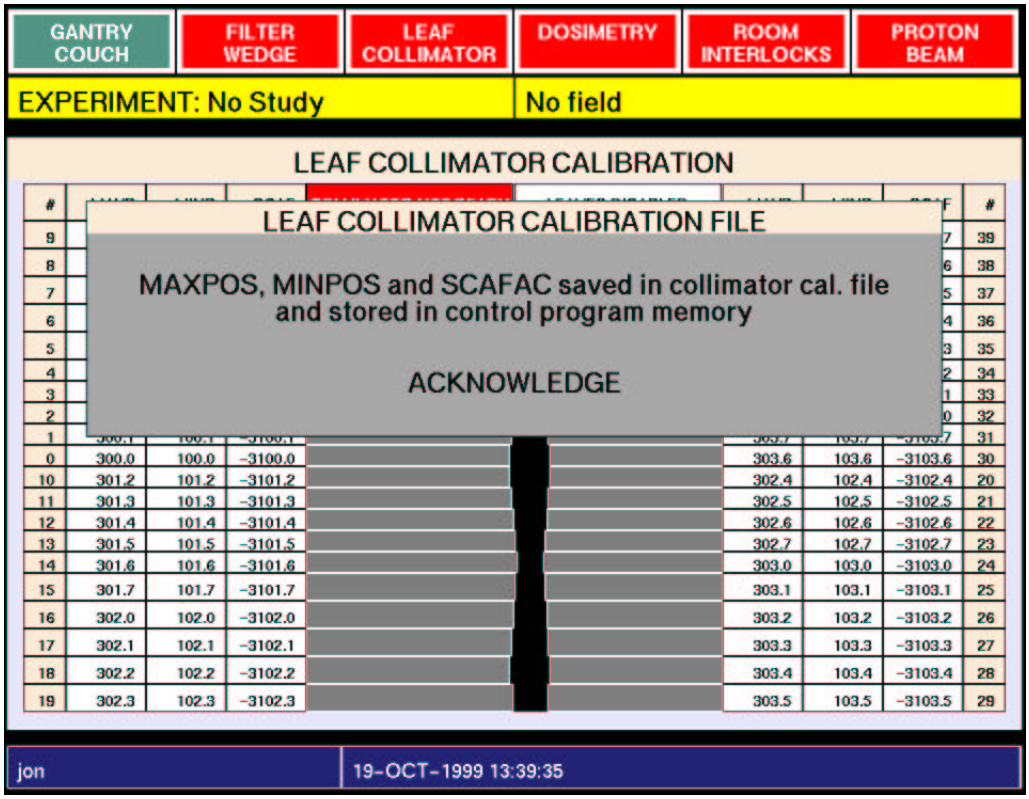

Figure B.3: Acknowledge box

Figure B.4: Menu

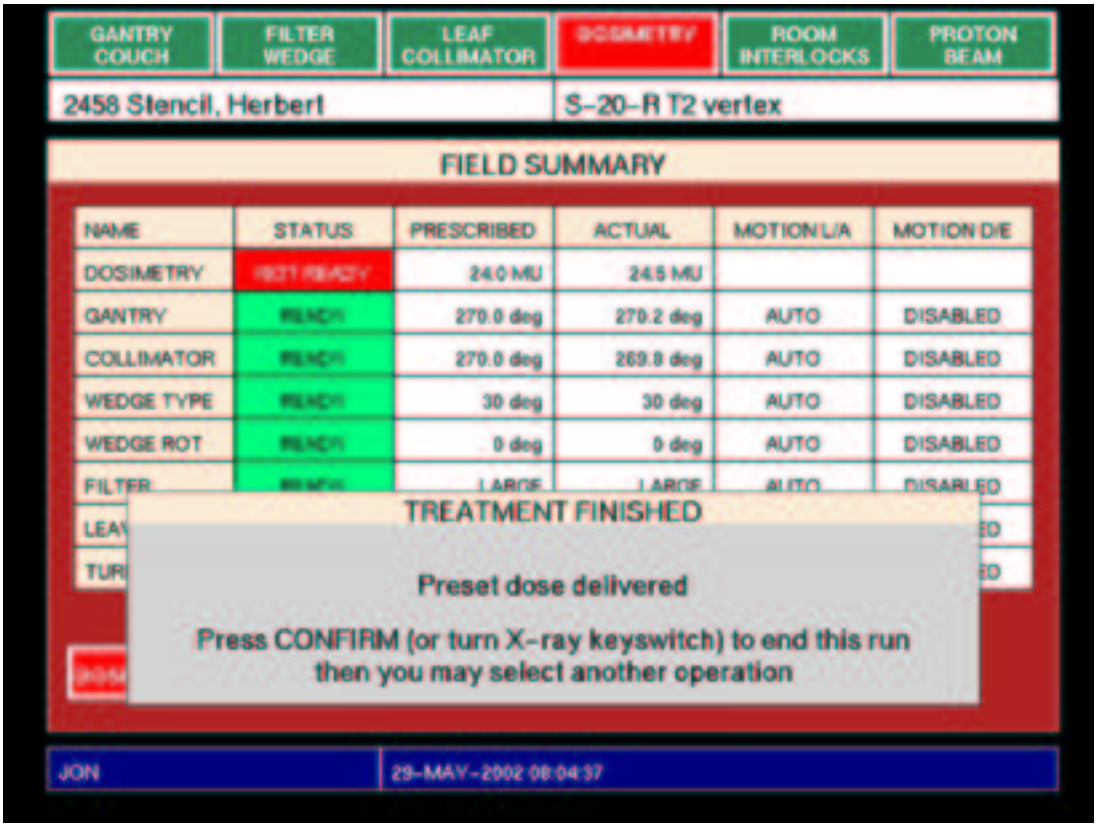

Figure B.5: Message box (expected event)

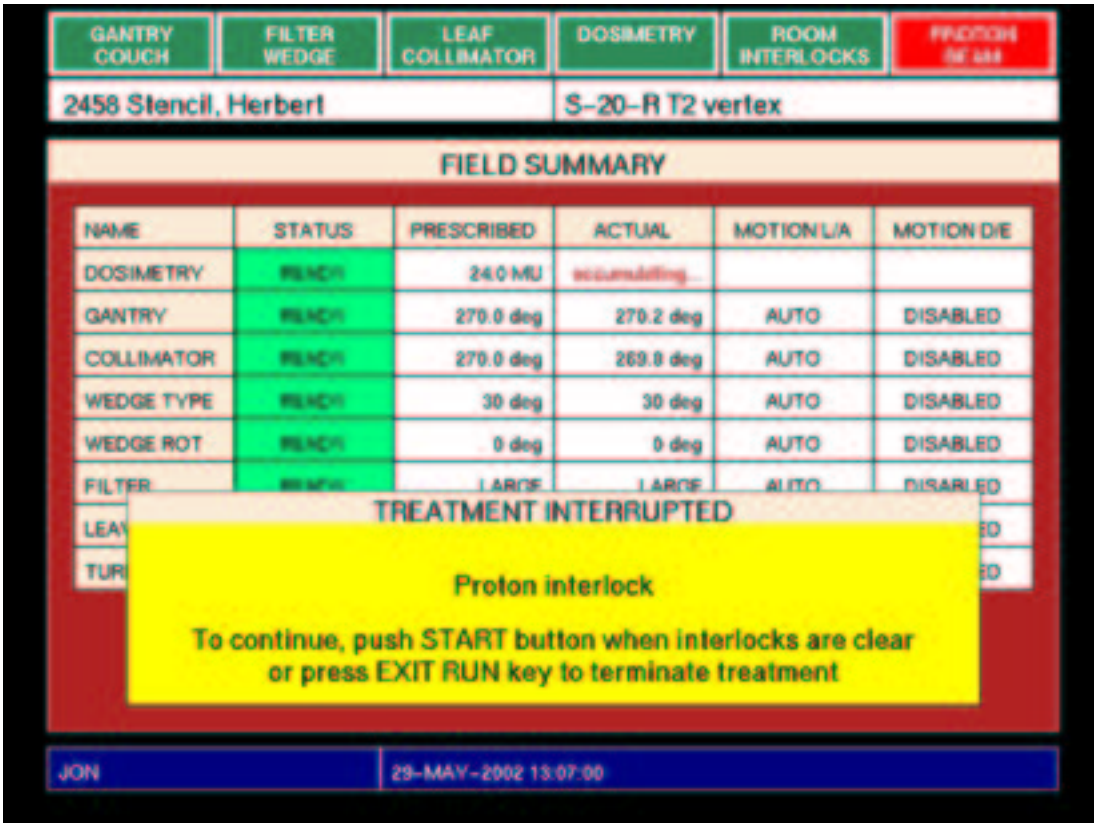

Figure B.6: Message box (warning)