FULLY AUTOMATED CONTROL SYSTEM FOR AN MC17F MEDICAL CYCLOTRON

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ABSTRACT

With Positron Emission Tomography (PET) gaining widespread acceptance as a diagnostic imaging modality, the demands of the clinical setting have required simplifying the production of the commonly used positron emitting radionuclides. To achieve this goal the operation of the positive ion 17 MeV proton and 8.5 MeV deuterons MC17F cyclotron and radiochemistry systems has been fully automated.

This paper gives an overview of the control system hardware configuration and software for operation.

INTRODUCTION

As PET moves into the clinical realm, the generation of radiolabelled tracers must be accomplished in a new way.
The goal has been to automate the operation of the cyclotron and radiochemistry to the extent that it can be viewed as a generator system for radionuclides which can easily be operated by a technician thereby alleviating the need for highly specialized personnel to produce routinely used radionuclides and radiochemicals[1]. It was necessary to introduce a high degree of automation into the accelerator control system to minimize the actions required of an operator.

The MC17F control system has been configured around a Siemens Simatic 135U programmable logic controller. The Simatic was chosen among other reasons for the extensive instruction set including floating point arithmetic and the adaptability of the system to this particular application. The operator interface consists of a separate CPU module, a high resolution CRT and a dedicated keyboard featuring function keys.

The cyclotron, targetry and chemistry systems which synthesize simple forms of labelled positron emitting compounds called precursors may be operated in either an automated or manual mode. Operation is principally menu-driven.

The automatic mode only requires specifying the radionuclide product to be produced and the irradiation parameters. Cyclotron system start-up, beam extraction with optimization of extraction efficiency and monitoring of system interlocks are fully automated. Control of the precursor chemistry system for Carbon-11, Nitrogen-13, Oxygen-15 and Fluorine-18 is incorporated and catalytic reactions automated.

The manual operation mode allows access to all cyclotron and chemistry parameters should it be desireable to modify their values. The table below shows the compounds which are produced.

Table 1 Precursor compounds

Radionuclide	labelled precursor
Carbon-11:	$^{11}CO_2$, ^{11}CO, $H^{11}CN$
Nitrogen-13:	$^{13}NH_3$, $^{13}NO_x$
Oxygen-15:	$^{15}O_2$, $C^{15}O$, $C^{15}O_2$, $H_2{}^{15}O$
Fluorine-18:	$^{18}F^-$, $^{18}F_2$

HARDWARE DESCRIPTION

The MC17F control system consists of the hardware configuration shown in figure 1.

The major parts of the system are housed in a standard 19" rack and consist of the Siemens Simatic 135 U PLC with the CPU 928 processor with 64 kbyte and two I/O racks. To monitor and steer the MC17F a combination of approximately 550 discrete and 60 analog I/O channels were used.

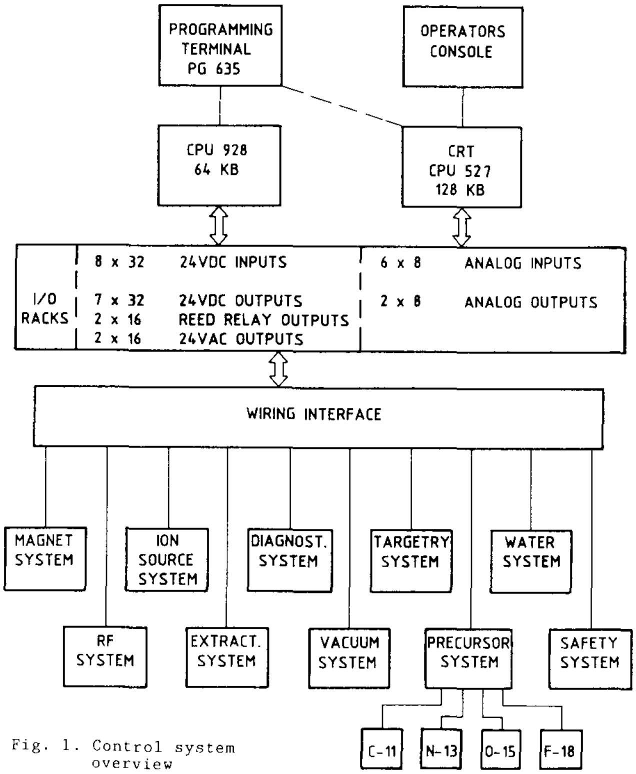

Fig. 1. Control system overview

A wiring interface routes signals from the assorted modules in the racks to the respective subsystems requiring control. A parallel system has been provided for facility safety loops using both software interlocks and a safety loop hardwired to the ion source power supply and RF control unit. Dee voltage and ion source are only permitted when both loops are closed.

In order to permit rapid scan times of parameters a separate CRT CPU 527 with 128 kbyte communications processor is used. This allows graphics display, rapid parameter updating and operator interface text to be presented on the operations console without creating a load on the main processor.

The operator interface is a modified Simatic CP527 with a keyboard and high resolution CRT. In addition to the 16 function keys, numerical key pad and cursor controls, three tuning dials and a moving coil meter for analog beam current monitoring have been incorporated.

SOFTWARE

Most of the accelerator and chemistry control software is written in program blocks (PB). There is generally one program block for each subsystem. The programming language chosen for the PBs was the control system flow chart form (CSF) since it was most suited for this application.

The PBs call on sub routine function blocks some of which are supplied by the manufacturer others must be user developed. Organisation blocks (OB) identify in which order the various program and function blocks are to be executed. The system firmware reads OB1 for the normal cyclic program execution. Other OBs are called by the firmware in case of external or internal interrups, execution error, system restart and so forth. System reactions to these occurrences are therefore programmed.
A program block overview is shown in figure 2.

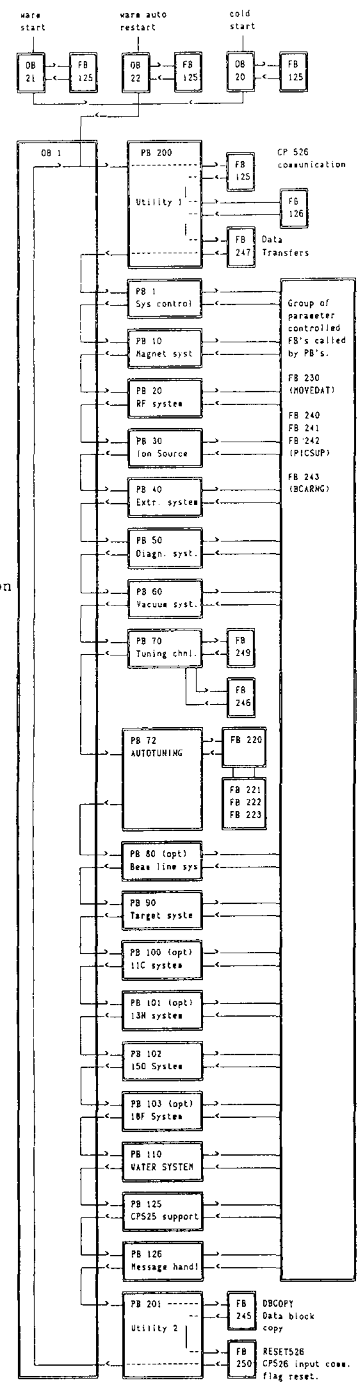

Fig. 2. Program Organisation

OPERATION DESCRIPTION

Operation of the radionuclide production system is through the commands assigned to function keys located on the keyboard. CRT pages provide system status information by means of dynamic text, data and figure fields. Function key assignments can be selected and the commands currently assigned are shown at the bottom of the CRT screen.

Parameter values may be modified by the cursor movement keys which move the cursor between data input fields on the screen and the numerical key pad. The data is transferred to the PLC when the confirmation key is pressed.

The CRT pages are organised as shown in figure 3.

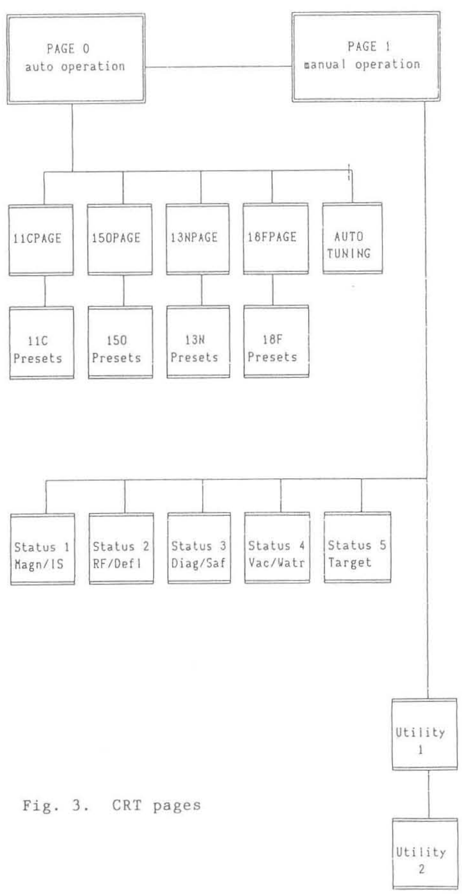

Fig. 3. CRT pages

Page 0 is the page used during normal operation. Status information is given by means of colored fields where yellow, green and red are used to define off, on and error respectively. Dynamic text fields are color coded white in order to indicate a dynamic field. Output bar fields are used to represent the most important parameters such as cyclotron beam current and target pressure. Data input fields requiring parameter values are color coded violet for easy identification by the operator. Figure 4 shows CRT page 1.

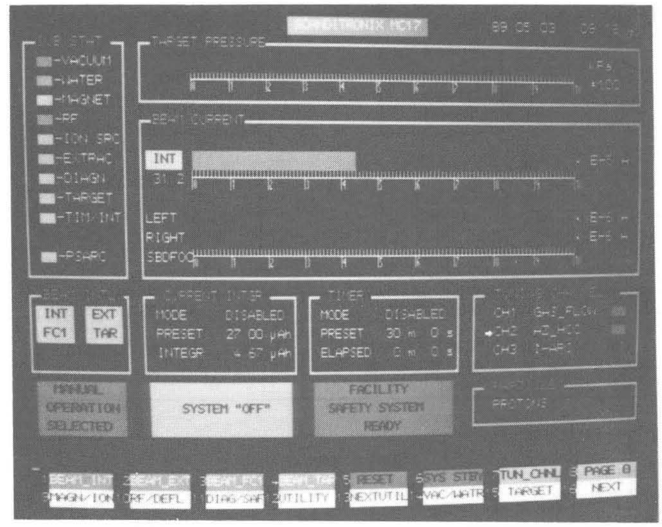

Fig. 4. CRT page 1

The operator may at any time view other pages where detailed system information is available. Should an interlock fault situation arise during operation, the subsystem in question will be identified and the operator can then call up the specific subsystem page to diagnose the condition. Figure 5 gives an example of a status page.

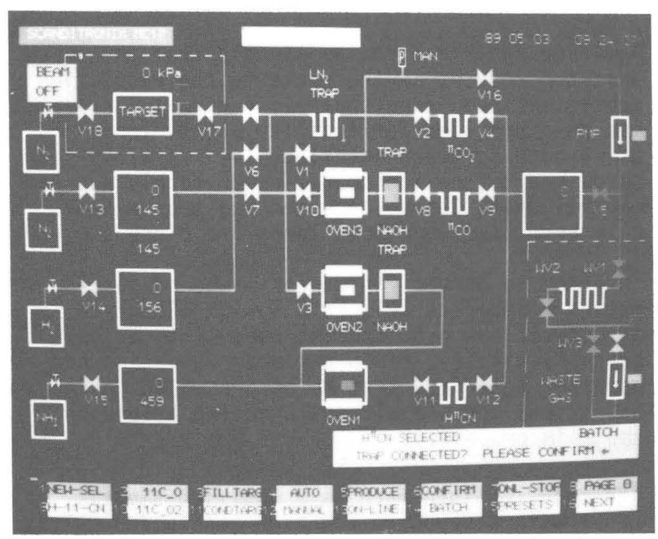

Fig. 5. C-11 precursor processing

Radionuclide production begins by the operator choosing the precursor to be produced. Pressing $C^{15}O$, for example, initiates sequences for changing particles from protons to deuterons, if necessary, and indexing the proper target into the irradiation position[2]. Requesting "System Standby" starts up all necessary systems and ramps power supplies up to predetermined values. The operator must then enter the beam current that is desired and either the irradiation time or the integrated current for the bombardment.

Depressing "Beam On" initiates an auto tune sequence. An iterative proportional tuning loop varies the main field setting and harmonic extraction coils azimuthal settings to optimize transmission out of the cyclotron. The autotuning sequence is governed by preset goals for the transmission values. These minimum levels for acceptable transmission values can be user modified. When the full set of conditions are fulfilled, the target is irradiated according to parameters set up by the operator. At EOB the radionuclide processing is initiated by an operator key command which carries out the conversion, in this case, of $^{15}O_2$ to $C^{15}O$ by the oxidation of activated charcoal at 1000°C [3].

In the manual operation mode, three incremental encoders connected to an input module may be used to vary the system parameters. The supporting software allows the operator to dynamically assign any of twelve possible parameters to the encoder tuning modules. The manual mode is primarily intended for use during service and maintenance.

CONCLUSION

The high level of automation afforded by the MC17F control system provides the type of clinical operation characteristics required by the hospital setting. The system design and software creates an easily grasped and operated production system which permits operation by non-specialist personnel.

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