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## Abstract

The booster synchrotron utilization facility (BSF) is a facility which utilizes the four fifths of available beam pulses from the KEK booster synchrotron. The BSF control system includes the beam line control, interactions with the PS central control room and the experimental facilities, and the access control system. A brief description of the various components in the control system is given.

## 1. Introduction

The Booster Synchrotron Utilization Facility (BSF) was organized in 1977 for the effective use of available beam pulses from the booster synchrotron. The booster synchrotron has a capability of producing about 50 beam pulses in one main ring cycle. The first nine pulses are injected to the main ring, and the other beam pulses are available in the BSF for the purpose of neutron scattering experiments, meson science and medical science. The design of the BSF control system was commenced in early 1978 and the construction was almost completed at the end of the fiscal year 1979 except for some parts of computer software and a checking system for radioactive contamination. These were finished before the middle of June 1980, when the first beam was injected.

The BSF control system has to provide the beam line control and access control system. However, for designing the new control system it was a very important factor how to deal with the beam dump line control system which had already been constructed in 1977. In the dump line power supplies for transport magnets and vacuum system were controlled by means of KEK standard modules[1]. We have finally applied the following items for designing the new control system.

1) The control of the BSF beam line is made using the mini-computer system, whereas the dump line control system is retained in the present status. However, the information on the dump line is gathered by the

computer system and displayed on the CRT terminal.

2) A new set of vacuum pumps is installed near the middle point of the BSF line. The controller of the pumps is incorporated into the dump line control system.

3) The beam pulses for the BSF are selected in the BSF control room, not in the central control room (CCR), since the sophisticated demand for the beam pulse sequence from the experimental facilities is expected in future.

4) The beam profile monitors along the dump and BSF beam line are controlled in the BSF control room. The beam profiles along the dump line can be also seen in the CCR.

5) Access control is performed independently of the CCR because the present access control system in the CCR can not include the whole access points of the BSF in view of capacity.

Figure 1 shows the interconnections of the control equipments. The part of dotted line is now under construction. The outline of the control system is given in Reference 2. In the following sections are described the details of the control components such as:

1) control desk,
2) programmable sequence controller,
3) timing system,
4) computer,
5) access control system,
6) gate monitor, and
7) television system.

The description of the vacuum control is not given in this report because the vacuum controllers were incorporated into the existing vacuum control system. The beam monitor is described in the section of computer (Section 5).

Figure 2 shows the layout of the BSF. The 50 nsec beam pulses are switched to the main ring injection line or to the beam dump line by a pulsed switching magnet PHB1 placed about 17 m downstream from the exit of the booster synchrotron. When the bending magnet VB4 in the downward slope of the beam dump line is turned on, the beam pulses go through the BSF beam line. Another pulsed switching magnet PHB2 is set on the BSF beam line. With the magnet turned off the beam hits directly the neutron production target. The beam can be switched to the left or right hand side, that is, to the particle radiation medical science center or to the meson science laboratory respectively, by choosing the polarity of the magnetic field with an appropriate timing of the triggering pulse.

## 2. Control Desk

At the control desk are made the selection of operation mode and the beam ON/OFF operation. There are three operation modes as BSF, DUMP and MAIN RING INJECTION.

(1) "BSF", where the booster beam is injected into the BSF beam channel.

(2) "DUMP", where a power supply B-2 (magnet VB4) is turned off and the beam goes down to the beam dump room.

(3) "MAIN RING INJECTION", where power supplies B-2 and PB-1 (magnet PHB1) are turned off and the booster beam is used for main ring injection only.

In the BSF mode, the beam switch performs the beam ON/OFF control. The DUMP mode is used during the accelerator study for the booster so as to keep the induced activity in the ring as low as possible. DUMP and MAIN RING INJECTION mode are important to an access control.

The beam switch is interlocked by the following conditions through hardwiring relay logic: 1) dump line injection ready, 2) BSF ready, 3) ON/OFF status of the power supplies necessary for the beam delivery, 4) doors, 5) personal keys, 6) radiation level, 7) vacuum, 8) emergency, 9) troubles in experimental areas, and 10) preset gate. The condition 1) comes from the CCR showing the status of the shield door and the power supplies in the beam dump line. The conditions 2, 3, 6, and 10 come from a programmable sequence controller, which is described in the next section. All the other status is sent from the relevant equipments and connected directly to the relay logic. The beam switch can be turned on when these conditions are all satisfied. The ON/OFF status of the beam switch is taken by the programmable sequence controller, which is in charge of the beam ON/OFF control in the final stage.

On the front panel of the control desk is shown the interlock status as well as beam requests from experimental facilities, beam delivery mode, and beam intensity.

## 3. Programmable Sequence Controller

A programmable sequence controller 5TI-1023 (TEXAS Instruments Inc., hereafter called the sequencer) is used for the decision of beam delivery, safety check, and access control. It has a 5TI-1023A processor of 16 bits/word, 1 K words of program memory, 512 control relays and 512 points of input and output interface. The response of the sequencer is within 30.5 msec in a 50 Hz power line operation. The data terminal ASR733 is equipped through a data link unit. The ASR733 includes a magnetic tape cassette system consisting of two cassette transports, a record controller, and a playback controller. The sequencer program has been saved into the magnetic tape cassette, and can be quickly loaded again in the memory when it is necessary. The ASR733 is also provided with another system commands which are convenient for developing the program.

The sequencer accepts beam request status, decides the beam delivery, and checks the interlock conditions. Beam request status from each facility is READY, PAUSE, REJECT, and PRESET. The meaning of these status is as follows:

(1) READY: Waiting for the beam injection after the experimental conditions are all set.

(2) PAUSE: The beam is not needed. If several beam pulses are injected by the mis-triggering of the ion source of the preinjector or beam line equipments, it causes no serious problems.

(3) REJECT: The beam is inhibited even though it is only one pulse.

(4) PRESET: The name of this status comes from the preset counting value. In the case of biological or medical irradiation, it is necessary to stop the beam immediately when the radiation dose reaches the preset counting value. However, the manual way of beam-off operation by the console operator is too dilatory to stop the beam immediately. In this case another contact signal of preset

gate is sent from the facility, which is used for the beam ON/OFF control. By opening the gate, the beam to the facility is turned off within 30.5 msec, while the beam supply to the other facilities is still continuing. By closing the gate, the beam injection is started again on condition that the beam switch on the control desk is turned on.

The sequencer accepts one of these requests from each facility, and decides the beam delivery. For example, when the meson facility is in the REJECT status the beam can not be delivered to the medical proton facility even if it is in the READY or PRESET status, because the mis-firing of the pulsed switching PHB2 must cause serious damage. The sequencer also checks the status of power supplies, doors, personal keys, radiation level, vacuum, emergency, troubles, and preset gate in the facilities. These conditions except for the power supplies, radiation level and preset gate are doubly checked by the relay circuit in the beam switch and the sequencer. It is noted that the condition for the power supplies is not fixed but variable depending on the beam delivery mode. For example, when the beam is needed by neither the meson facility nor the medical proton facility, the power supply PB-2 for PHB2 should be turned off. In the other case PB-2 must be turned on. Thus, the sequencer is more suitable to evaluate such a variable condition than the hardwiring circuit because the sequencer is easy to program. The beam switch only accepts the final result of the power supply status from the sequencer.

As for the radiation level the situation is similar, and the beam switch only accepts the final result. The condition for preset gate indicates that the preset gate should be opened before the beam switch on the control desk is turned on. This condition ensures that the final decision of the beam injection to the medical facility is made by the medical users themselves by closing the preset gate contact. The sequencer sends such preset gate status to the beam switch.

After checking these conditions the sequencer sends "BSF ready" to the beam switch if they are all satisfied. With the beam switch turned on, the sequencer opens the gate for the beam request signals which are sent to the CCR. However, in case of the preset mode requested from the medical center, this gate is opened with the preset gate closed.

Another important role of the sequencer is to select the doors which are accessible from the standpoint of radiation safety. According to the operation mode the sequencer selects the doors, and sends the choices to an access control system. Details of an access control are given in Section 6.

## 4. Timing System

A beam-gate, linac quadrupole timing pulse[3] (linac Q), booster magnetic field top pulse (B.TOP), extraction kicker trigger pulse (B.EXT), and 1 MHz clock are transmitted from the CCR. The beam-gate is a gate pulse of about 2 sec in width which corresponds to an excess of the booster beam pulses over the main ring injection. In this gate we can extract the beam pulses from the booster in any form of a pulse sequence.

The request for the beam pulse sequence is made from the experimental users. The arrangement of the beam sequence is programmed by using the "BSF programmer". The output of the BSF programmer (arc-gate) is sent back to the CCR and fed into the arc-triggering system of the preinjector. Figure 3 illustrates the timing relation of these signals. The transition of the voltage level of the beam-gate is synchronized to the B.TOP. The beam injection to the main ring is made during the high level period of 0.5 sec in width. The low level period of 2.0 sec is available for the BSF beam injection. In the fiqure the signal on each line of experimental areas shows the signal programmed by using the BSF programmer. The transition of the voltage level is synchronized to the linac Q and its interval has a width of integral multiples of 50 msec each. The linac Q, which is 0.66 msec earlier than the arc-triggering pulse, is necessary for the arc-gate to be in time to trigger the ion source of the preinjector. As is discussed in the previous section they are gated by the sequencer output. Unless these signals are inhibited by the sequencer, the arc-gate equals to the logical OR of the programmed signals. When the sequencer inhibits the beam injection to some experimental areas, the relevant beam pulses can not be extracted from the ion source of the preinjector.

Figure 4 shows the BSF programmer. The constitution of the CPU part of the BSF programmer is shown in Fig. 5. It has a microprocessor of INTEL8085 provided with 16 K bytes ROM and 4 K bytes RAM. The external timing signals such as beam gate and linac Q are interfaced through a digital input unit. The beam injection pattern at the initialization with the power switch turned on is given by the diode pin matrix board. Tasks for digital input/output and display are excuted in a time sharing mode using the internal 2 msec clock. Beam selection is made on the console panel, which can be seen in Fig. 4. The INTEL8279 keyboard/display interface is used for displaying the current beam injection pattern. The output of VIDEO RAM is transmitted to the CCR and connected to the CATV system.

Timing clocks and trigger pulses are used for synchronizing the equipments to the booster cycle. Triggering a pulsed switching magnet, taking beam profile data, rotating a neutron chopper, etc. should be done in a synchronized mode. These signals are distributed to each facility through the driver and gate circuits. Figure 6 shows the block diagram of the circuits together with the BSF-programmer.

## 5. Computer

The computer is a MELCOM-70 mini-computer (M-70) manufactured by MITSUBISHI Electric Corporation. The M-70 is composed of 64 K words (16 bits/word) of core memory, a 5 M words disc and peripheral equipments such as process input and output controllers, a system typewriter, a dot printer, a card reader, and two CRT display terminals with keyboards. The process input and output controllers are provided with a program controlled channel (PCCH) and a direct memory access channel (DMA), and contain process interface units by means of which BSF equipments are interfaced. Figure 7 shows the constitution of the M-70 system.

The software system is based on the real time disc operating system RDOS and the batch disc operating system BDOS, which are described in the M-70 user's guide (JM-SR00-32A). Under the RDOS the monitor can supervise the sixteen levels of tasks. In the present system level zero is used for real time disc monitor utility, and the other ten levels are allocated to the application programs in the foreground. The batch processing programs are not included in these levels because the core memory size is limited. The batch programs, such as a renewal of the calibration constants, limitting values of tolerance, and the name list of the personal key owners, are executed independently under the BDOS.

Programs are written in FORTRAN and assembler language. Various kinds of routines that include a graphic package, and process input and output package, make it easier to write application programs. The number of process inputs and outputs is listed in Table 1. Outline of some foreground programs are briefly described below.

5-1 Power Supply Control

There are twenty power supplies in the BSF beam line, and eleven in the dump line. In some cases plural magnets are connected in series to one power supply to reduce the number of power supplies[4].

As for the steering magnets single magnet is connected to one power supply. Power supplies in the BSF line are controlled by the M-70 although for the dump line only the status information is gathered and displayed on the CRT terminal. ON/OFF operation is performed by pointing an ON/OFF selection field with a light-pen on the CRT screen. The "CRT input subtask" decodes the address of the selected point and makes a queue for the ON/OFF operation. The queue is passed to the "process output subtask" where ON/OFF signal is created and fed to the power supplies through the digital output units. The polarity of the power supplies for the steering magnets is changed in a similar way.

The UP/DOWN control is performed by an UP/DOWN routine included in the PFS (process fast scan subtask). The PFS can be initiated whenever we want by using the light-pen selection on the CRT screen. After the selection is made the PFS is initiated every one second by the user timer routine incorporated in the monitor. The shaftencoder which consists of a rotary coder and a counter unit is used for an man-machine interface. The UP/DOWN routine reads the counting value of the shaftencoder every one second, and calculates the difference between the previous and the present value. After that, it generates the pulse train proportional to the difference and the digital output signal for the UP/DOWN polarity. The pulse train and the polarity signals are fed into the stepping motor module equipped in each power supply. When the UP/DOWN control is not necessary, the UP/DOWN routine can be skipped by the light-pen selection.

## 5-2. Beam Monitoring

Fifteen beam profile monitors and ten current monitors are installed in the beam line. A beam profile monitor is the type of a multi-wire secondary emission monitor and consists of 32 by 32 horizontal and vertical tungsten wires on an insulated frame. The beam profile signals are read out through an analogue multiplexer. The beam current monitor is a current transformer of a toroidal core which is made of the permalloy film of 50 μm in thickness. The output pulse of the secondary winding is directly coupled to the 50 Ω transmission line.

The GDP (graphic display subtask) takes the beam profile data through DMA synchronizing to the B.EXT. The way of data acquisition is the same as that reported in Reference 5 except for the profile monitor controller (PMC). The interactive part of the PMC with the computer is modified to fit our system. Figure 8 shows the block diagram of the interaction between the M-70 and the PMC. The timing chart of the interaction is illustrated in Fig. 9. When the BREAK key of the graphic terminal is depressed, the GDP is initiated and enters command input mode. The number of profile monitor to be displayed is input as a command through the keyboard. Then the GDP activates the DMA I/O routine and sets the "READY" flag. The first LINAC Q after the arrival of the READY signal reverses J-K flip-flop, and the GATE is opened. The timing pulses triggered by B.EXT are fed into the external synchronizing unit. The interval of the pulses is chosen to be 200 μsec. Analogue data of beam profile are taken through AI (analogue input) channel via DMA synchronizing to the timing pulse. The ADC unit has functions of multiplexing and sample/hold, and operates at 100 KHz of throughput rate. Fifteen profile data having the same channel number are sampled simultaneously at one timing pulse. The AI process is repeated 32 times and the gate is closed. After the completion of AI process the GDP resets the "READY" flag. The obtained profile data are displayed on the graphic terminal about 5 seconds. Unless the new command is input the GDP enters the new cycle of data acquisition and display. The termination of the GDP is made by "stop" command through the keyboard of the graphic terminal or system typewriter. Figure 10 shows the beam profiles along the beam line.

The current monitor output is fed into a sample/hold module, and integrated with an ADC and counter module synchronizing to every beam injection. The "interrupt subtask" takes these integrated values by an interrupt input synchronizing to the 12 GeV PS cycle of about 2.5 sec in width. The obtained data are converted into the values in units of protons per pulse or protons per second. They are used for display on the console panel and are transmitted to CCR via a satellite computer S-2[6]. Integrated values are available for operations record.

## 5-3. Others

Any other information on the beam line, experimental facilities, and safety status is displayed on the character terminal. Surveillance program checks these data periodically. When it finds an incorrect status or a value out of tolerance, an alarm bit is created. According to the alarm bit, a colour code is added to the item in trouble on the character screen to inform an operator of the accident. The alarm message is also printed out on a system typewriter for recording.

Operation, access, and contamination records are accumulated in a disc file. These records can be always printed out in an arranged form.

The computer is linked to the CCR computer network to inform a beam intensity along the beam line. The interface equipments are digital input and output units which are installed in both process input and output controllers. The M-70 renews the digital output value every 2.5 seconds, and a satellite computer S-2 takes these data at an appropriate time interval. No other communication on this line is made at present.

## 6. Access Control System

During the BSF operation, beam lines, a cable pit, experimental areas, and a transfer tunnel are all controlled areas for radiation safety. Ten access points are under control. Figure 11 shows the controlled areas and the access points. Permission from the radiation control room is necessary for the access to these areas. In long shutdowns permission is not required for the access to experimental areas.

Access to these areas depends upon the operation mode. Accessible doors are selected by the sequencer as follows:

(1) BSF: neutron scattering experimental area and meson experimental area,
(2) DUMP: all areas except for a primary beam line, and
(3) MAIN RING INJECTION: all areas.

All doors of these controlled areas are electrically locked. One who accesses to the door has to, for the first time, contact the control room by an interphone placed both inside and outside of the door. For an accessible door, the power of the door control unit which is placed near the interphone can be switched on from the control room. The electric lock is released by performing a key operation on the door control panel. Entering or leaving is made under TV surveillance from the control room. For the access to the primary beam line through the door No. 1 in Fig. 11, it is necessary to use a particular key which is reserved on a personal keyboard. Removing or replacing the key is recorded by the M-70 as the personnel entering or leaving the primary beam line. These keys also interlock the beam switch and power supplies, i.e. when they are removed from the key board it becomes impossible to turn on the beam switch and the relevant magnet power supplies such as PB-1 and B-2. This interlock system ensures the personnel in the beam line from the beam injection.

## 7. Gate Monitor

The radioactive contamination of whole human body surface and equipments is checked by a gate monitor which is located inside the entrance door to the primary beam line. All persons entering the primary beam line must leave through the same door after checking the contamination.

Gas flow counters (helium + isobutane) and NaI scintillation counters are used for checking human body surface and equipments respectively. A detection sensitivity for body surface is within 7 x $10^{-6}$ μCi/$cm^2$ calibrated by $U_3O_8$ β-ray, and that for equipments within 10 nCi calibrated by Cs γ-ray. The measuring time is ten seconds. If the contamination is found at either body surface or equipments, the person can not pass through the gate. In the case the person should clean the body surface using the shower and/or leave the equipments in the beam line tunnel to cool down the radioactivity. The contamination is recorded by both the M-70 and a recorder provided for the gate monitor. Figure 12 shows the gate monitor viewed from the beam line side.

## 8. Television System

Closed-circuit television CCTV is required for the purpose of surveillance of the access points, the beam channel, and experimental areas especially around the neutron and the meson production targets. Video signals from each point are connected to a multiplexer and displayed on the access and control consoles.

Video information on the beam sharing status is transmitted to the CCR through the video RAM of the BSF programmer. The signal is modulated and distributed anywhere in KEK by means of calbe television (CATV) system. The channel number allocated to BSF is 3. The refinement of the video information is in progress. The new information will cover the users' beam request status, beam pulse number, beam intensity and beam profile. The beam intensity in the beam line is also transmitted to the CATV system via a computer linkage.

## Acknowledgements

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## Reference

1. T. Kamei, K. Ishii, and E. Kadokura: KEK Accelerator-1 (1973).
2. Y. Irie: Proceedings of ICANS-IV, KEK, Tsukuba (1981) 406.
3. K. Ishii, E. Kadokura, T. Kamei, and S. Ninomiya: KEK-Accelerator-1 (1976).
4. Y. Irie, M. Kumada, I. Sakai, H. Sasaki, H. Someya, and K. Tanabe: KEK 81-11.
5. Z. Igarashi, K. Uchino, T. Katoh, H. Ishimaru, and S. Shibata: Proceeding of the 2nd Symposium on Accelerator Science and Technology, Tokyo (1978) 165.
6. T. Katoh, K. Uchino, T. Kamei, M. Tejima, T. Takashima, K. Ishii, S. Ninomiya, and E. Kadokura: KEK-Preprint 77-1 (1977).

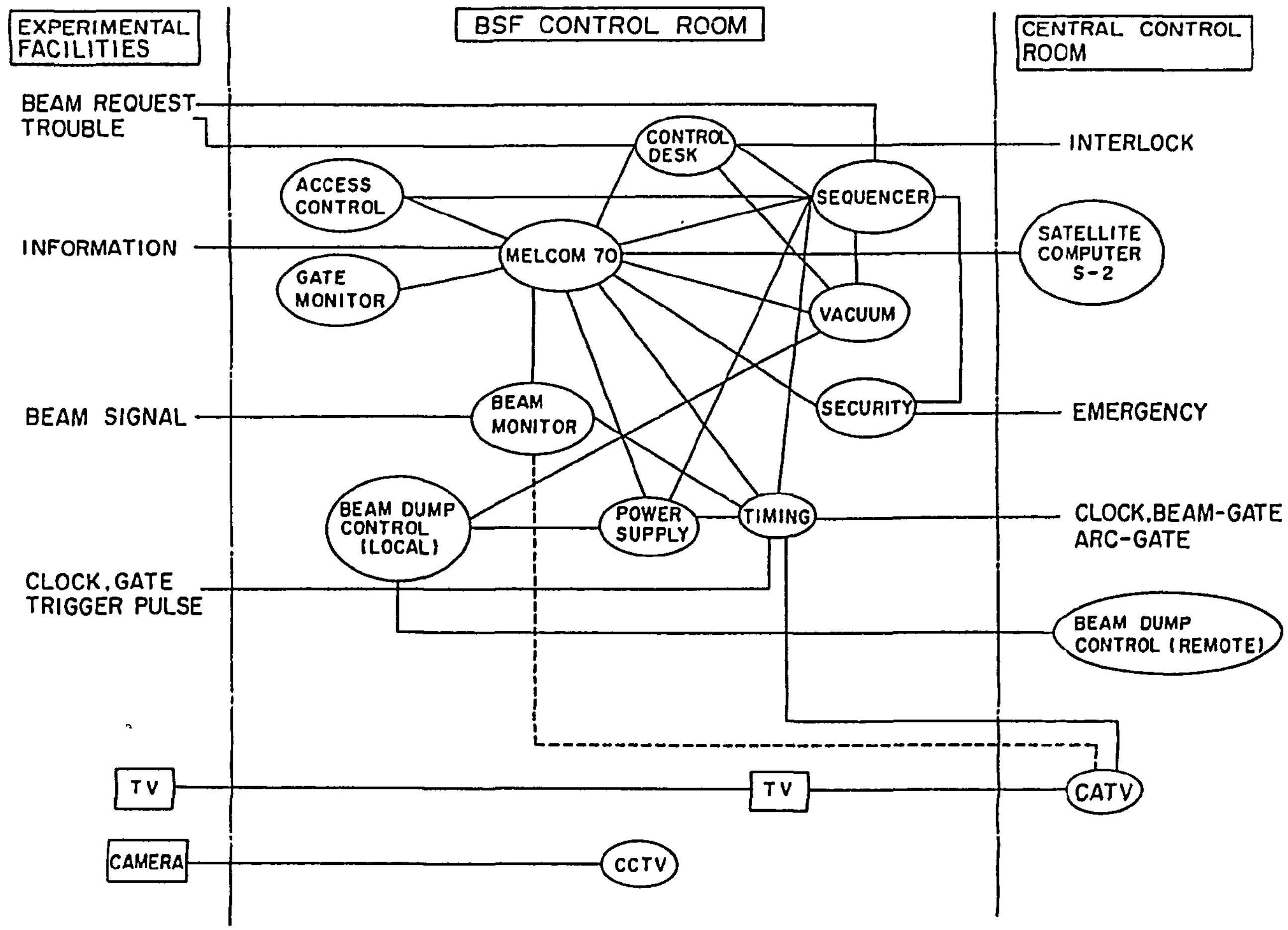



Fig. 1 The schematic diagram of the hardware interconnections.

Table 1 The numbers of process input/output points for the MELCOM-70 system.

| SIGNAL | | NUMBER |
|---|---|---|
| PCCH | | |
| INTERRUPT INPUT | CONTACT | 1 |
| | VOLTAGE LEVEL | 1 |
| DIGITAL INPUT | CONTACT | 333 |
| | VOLTAGE LEVEL | 50 |
| | ISOLATED VOLTAGE LEVEL | 209 |
| DIGITAL OUTPUT | CONTACT | 43 |
| | VOLTAGE LEVEL | 27 |
| | ISOLATED VOLTAGE LEVEL | 94 |
| PULSE TRAIN OUTPUT | ISOLATED VOLTAGE LEVEL | 20 |
| DMA | | |
| EXTERNAL SYNCHRONIZER | VOLTAGE LEVEL | 1 |
| ANALOGUE INPUT | | 73 |
| TOTAL | | 852 |

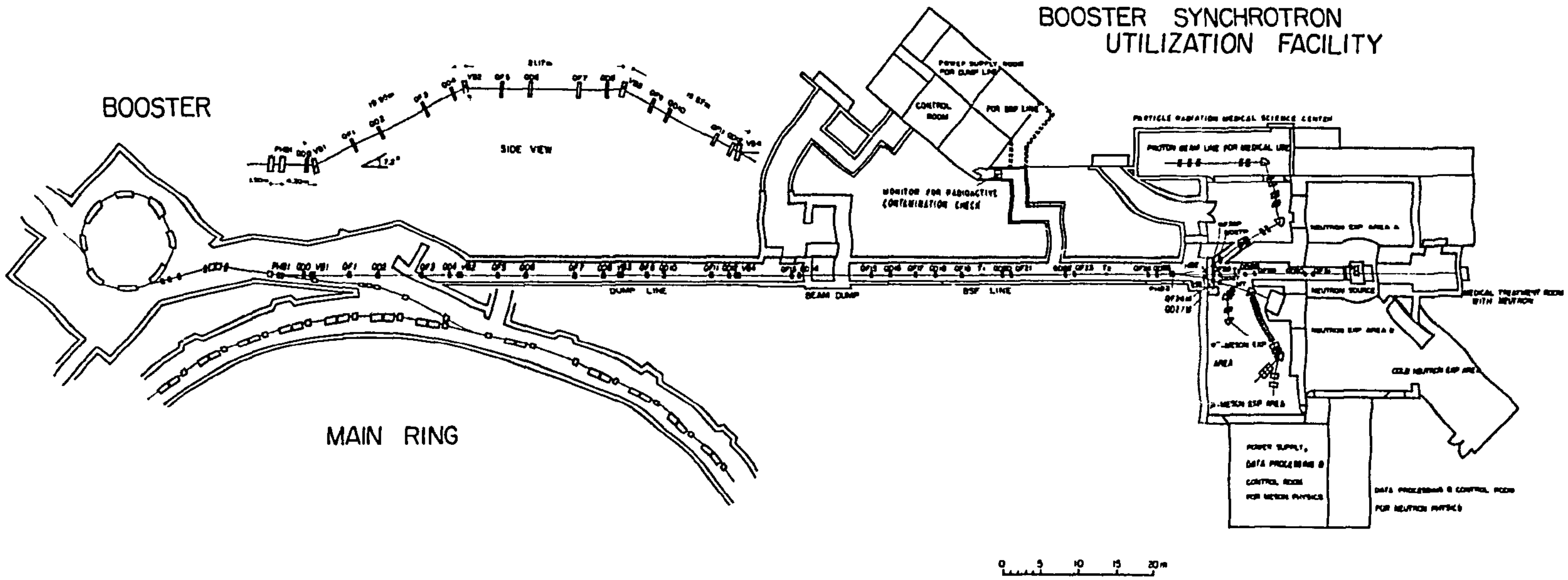



Fig. 2 The layout of Booster Synchrotron Utilization Facility (BSF).

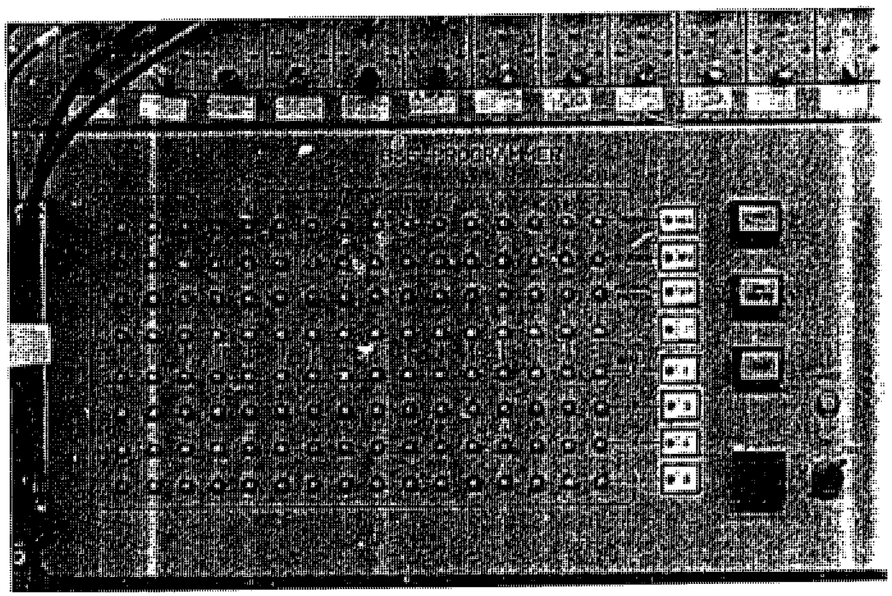


Fig. 4  The BSF programmer used for timing control.

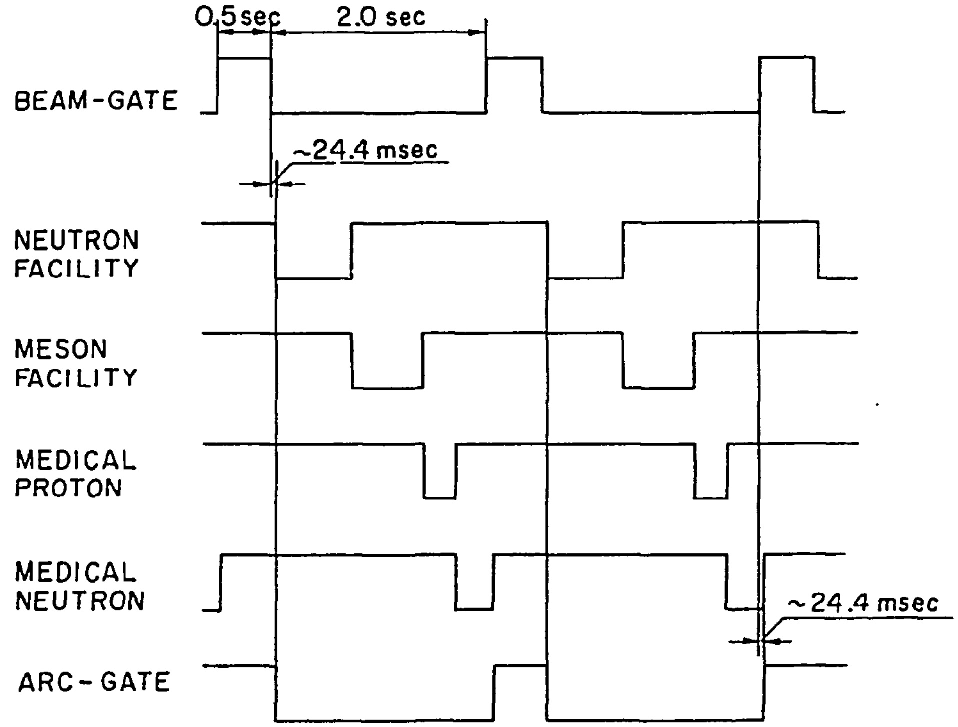



Fig. 3 Timing relation of the beam-gate, users' request programmed on the BSF programmer and the demand signal for beam injection into the BSF (arc-gate). See in the text.

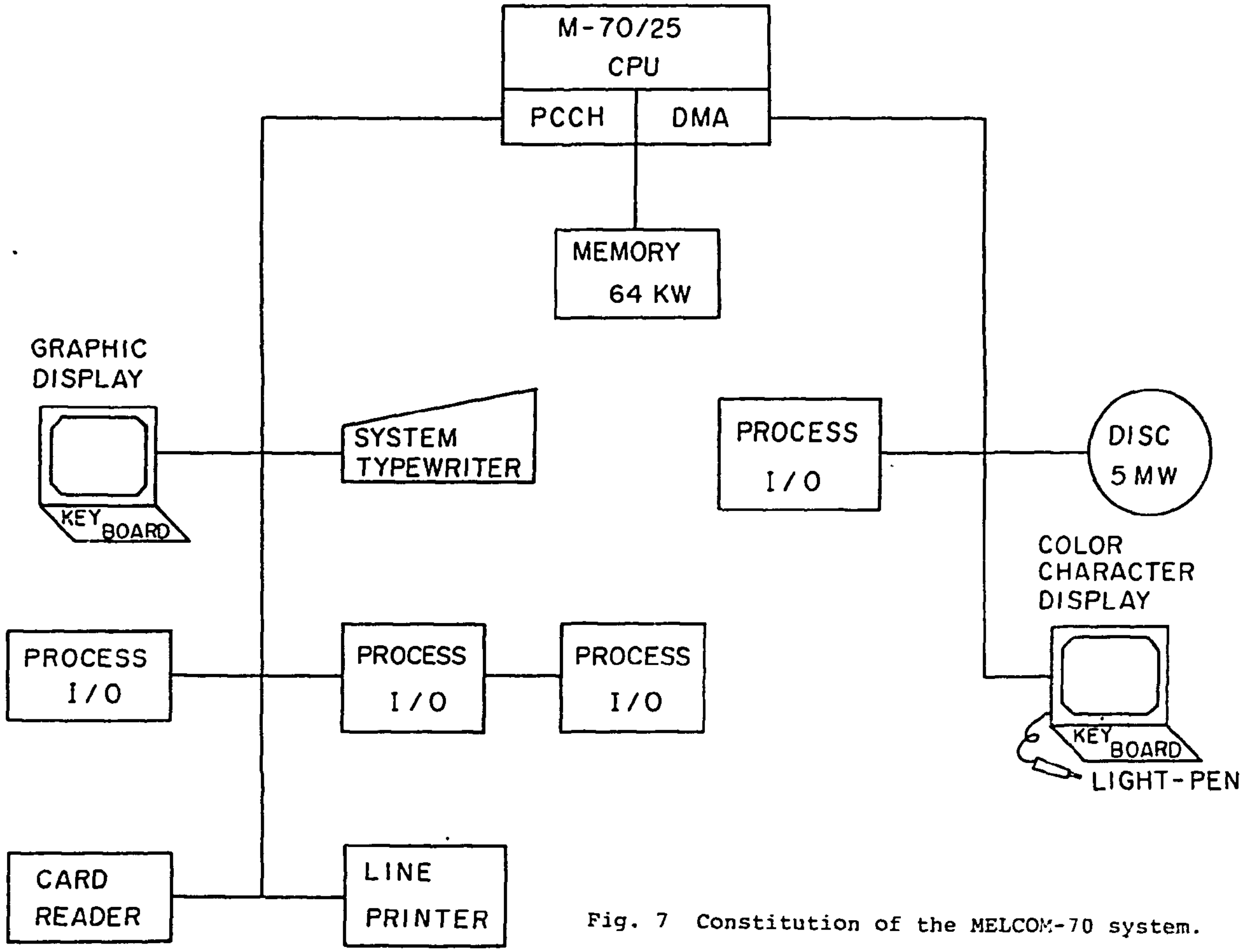



Fig. 7 Constitution of the MELCOM-70 system.

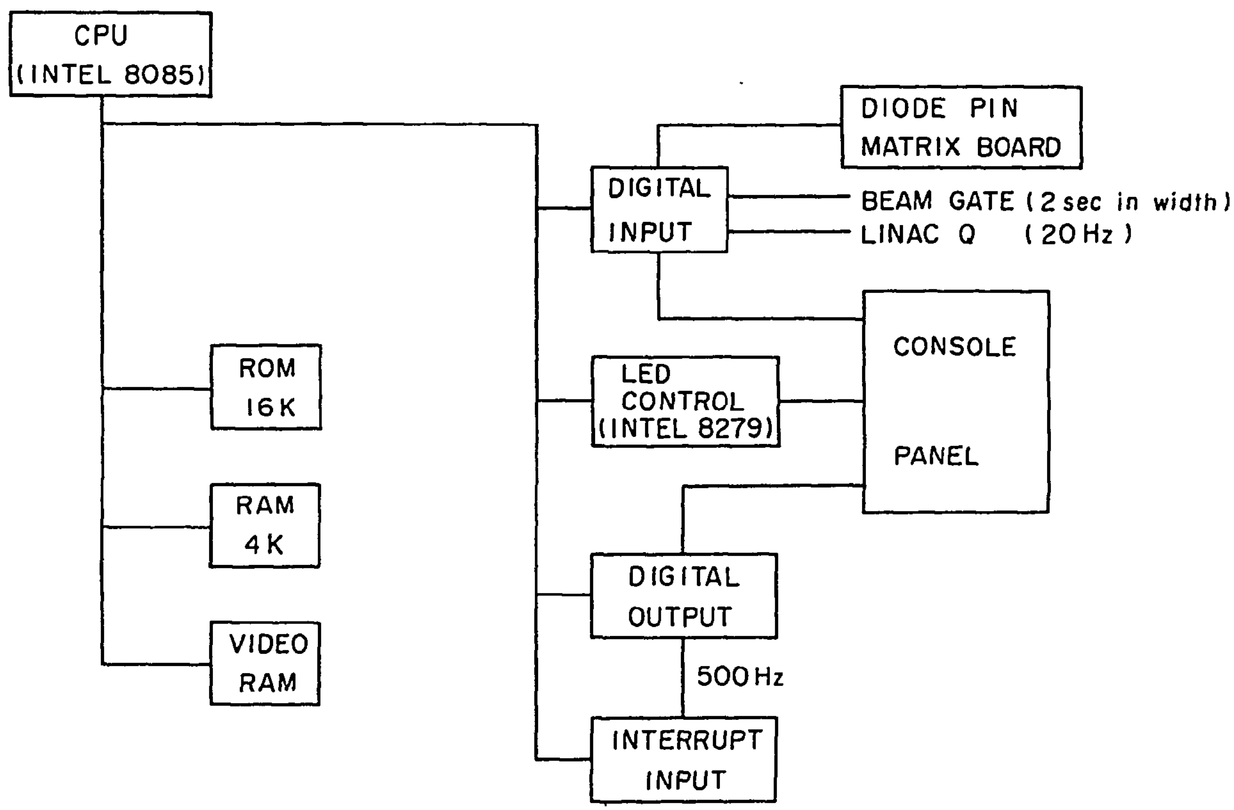



Fig. 5 Constitution of the CPU part of the BSF programmer.

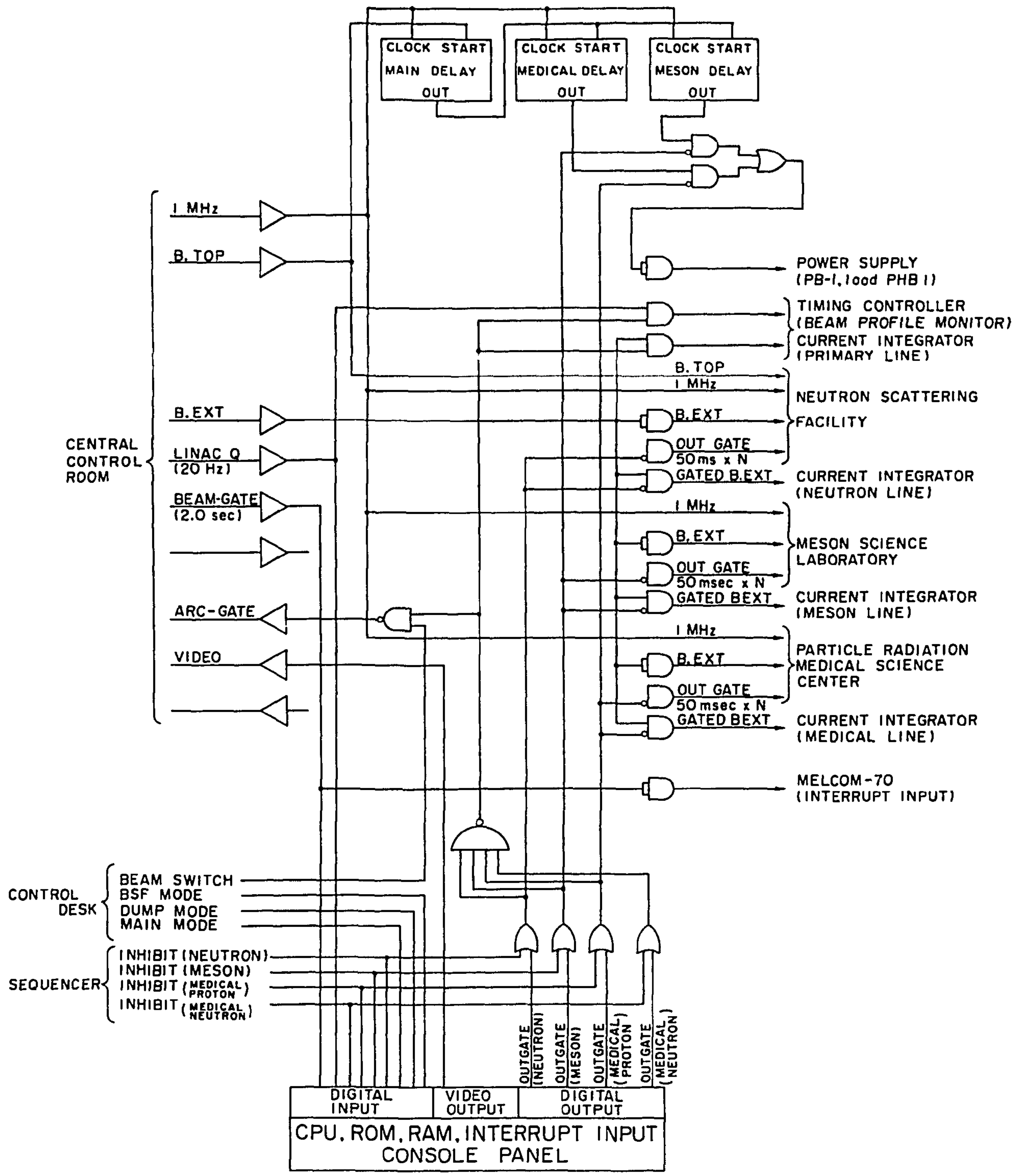



Fig. 6 Block diagram of the timing system.

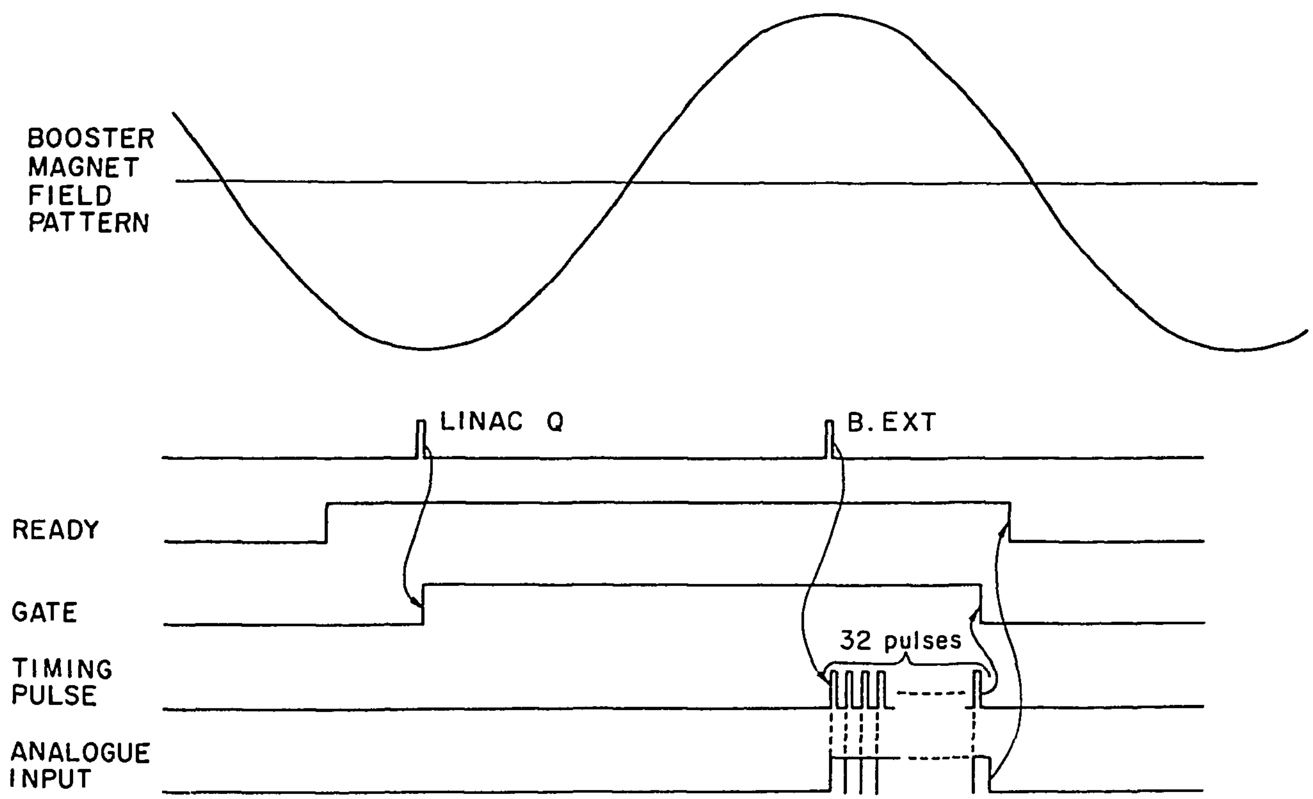



Fig. 9 Timing chart for profile data acquisition.

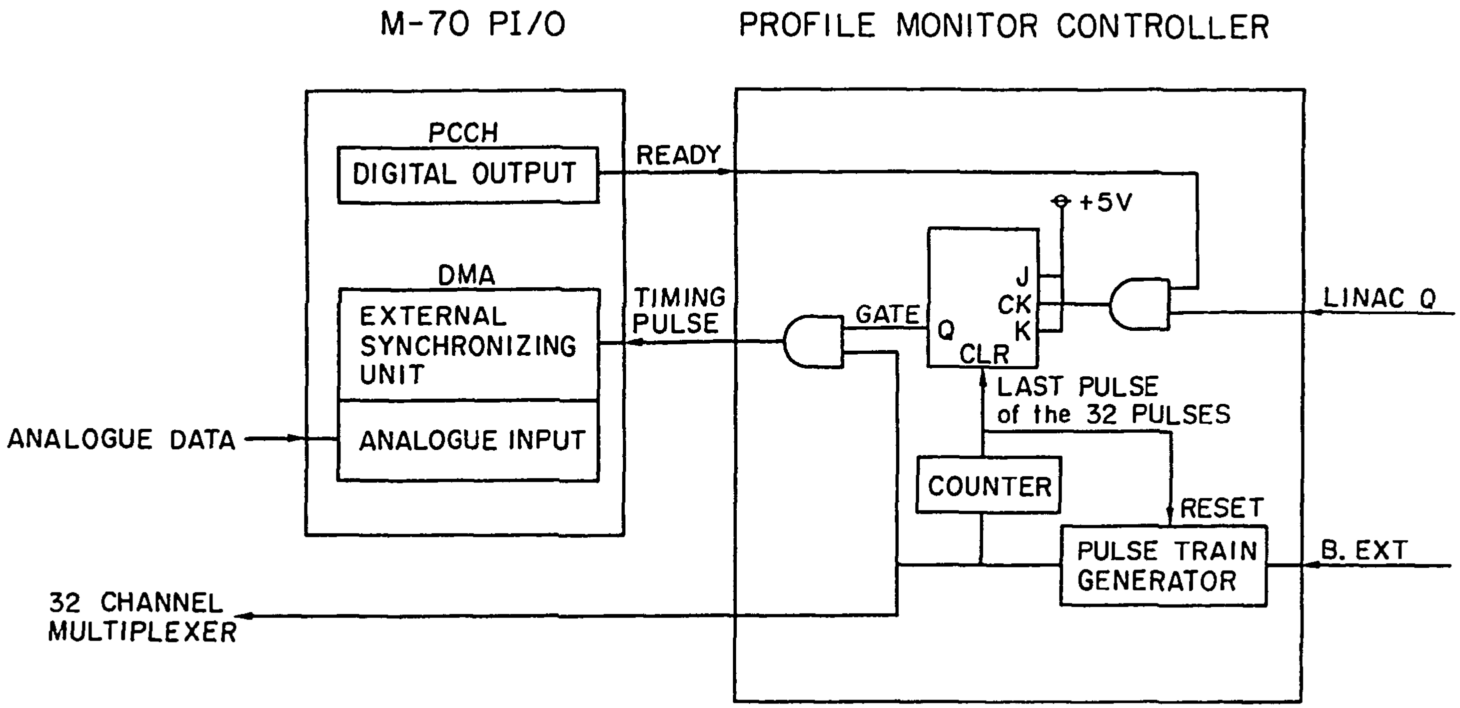



Fig. 8 Block diagram for an interaction between the MELCOM process input/output controller (PI/O) and the profile monitor controller.

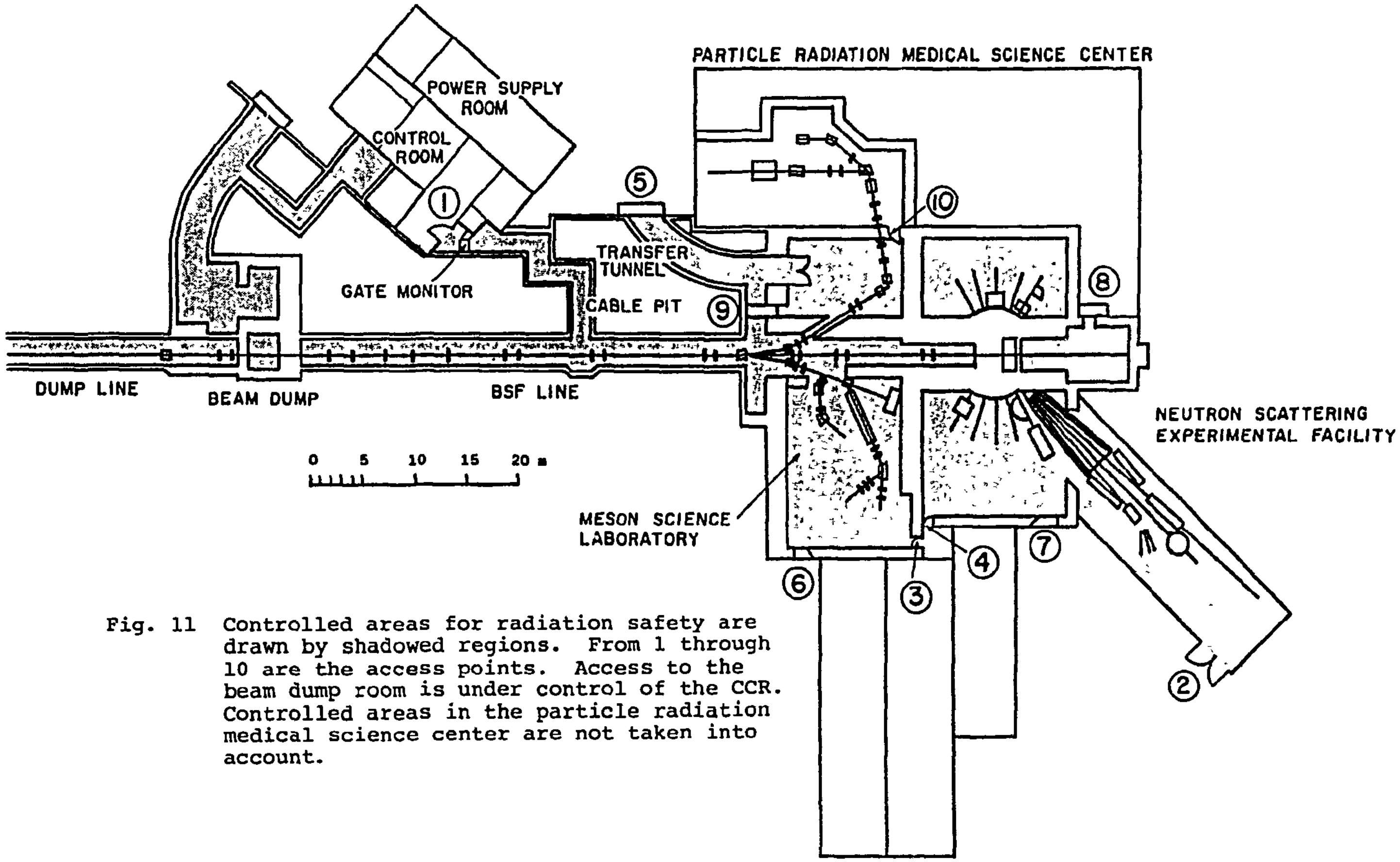
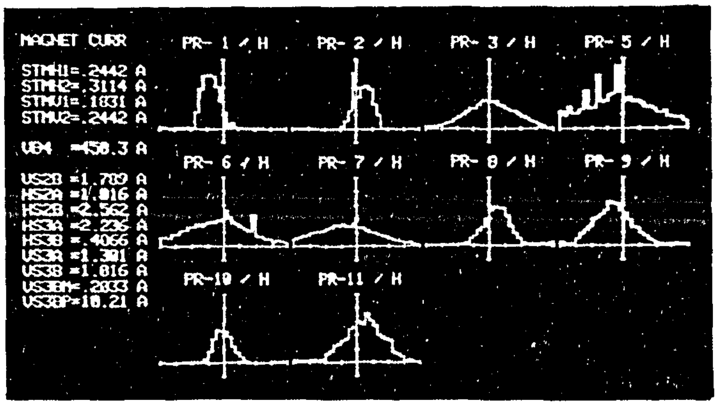
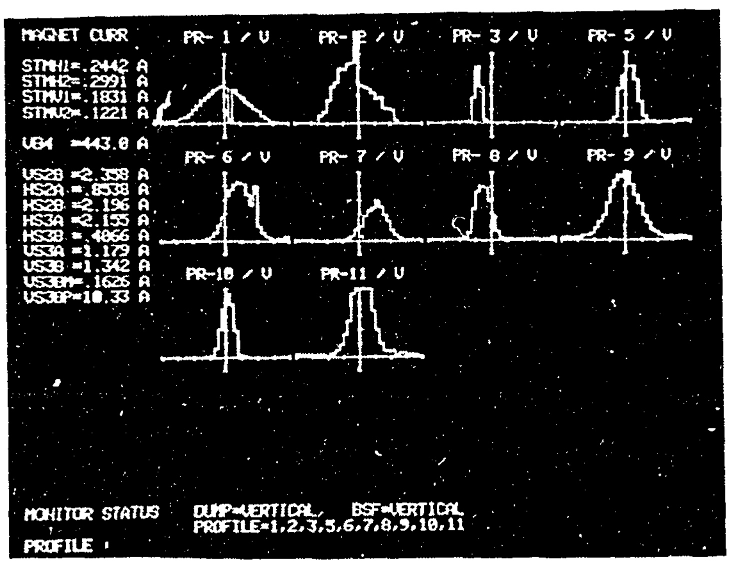



Fig. 11 Controlled areas for radiation safety are drawn by shadowed regions. From 1 through 10 are the access points. Access to the beam dump room is under control of the CCR. Controlled areas in the particle radiation medical science center are not taken into account.




(a)




(b)

Fig. 10 (a) Beam profiles along the BSF beam line in a horizontal direction. Each horizontal step corresponds to 2.5 mm in width.

(b) Beam profiles in a vertical direction.

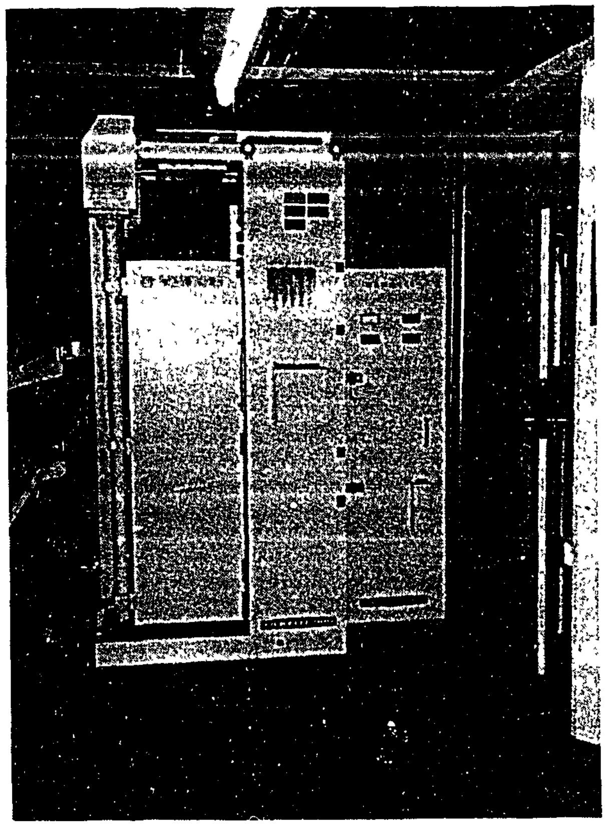


Fig. 12 The gate monitor placed inside the entrance door to the primary beam line. The door seen in the right hand side is used for entrance to the beam line, and the door in the left hand side for entering into the measuring space. The door opposite to the left-handed door (not seen in the figure) is used for leaving.