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**NATIONAL SYNCHROTRON LIGHT SOURCE  
ANGIOGRAPHY PERSONNEL PROTECTION INTERLOCK**

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## INTRODUCTION

This document is the National Synchrotron Light Source (NSLS) version of a similar document written in April 1987 by Robert Hettel for operation at the Stanford Synchrotron Research Laboratory (SSRL). It has been rewritten in order to accurately reflect the safety system operation at the NSLS X17B2 beamline Synchrotron Medical Research Facility (SMERF).

The angiography exposure process involves scanning a patient up and down through dual fixed-position x-ray beams; exposure is controlled by opening and closing a fast-acting Safety Shutter mechanism at precise times in relation to the up and down motion of the scan chair. The fast-acting Safety Shutter mechanism is the primary radiation-stopping element protecting the patient while the chair is at rest and while it is reversing directions during the scan. Its fail-safe and fast operation is essential for the safety of the patient.

The NSLS/BNL requirement for redundancy in radiation safety systems dictates that there must actually be two independent shutters protecting the patient, each one capable of stopping the beam. Redundant Safety Shutters also qualify as the primary radiation safety device, allowing access to the Angiography Room in each of the two operating modes, Set-Up Mode and Patient Mode, as long as the area is configured and certified for angiography use.

Operation of X17B2 as a human subject angiography station necessitates the implementation of a personnel protection interlock system that, in conjunction with the Safety Shutters, will:

1. Permit safe access to the patient exposure area while the synchrotron radiation beam is illuminating the upstream dual energy monochromator (to preserve thermal stability of the monochromator).
2. Allow a patient to be imaged by the monochromatized beam under the supervision of a Responsible Physician, with scan chair motion and precision shutter actuation regulated by an angiography control computer, while providing a suitable number of safeguards against accidental radiation exposure.
3. Have different modes of operation to accommodate a) equipment set-up, test, and calibration (Set-Up Mode); and b) patient exposure (Patient Mode).
4. Ensure the quick extinction of the beam if a potentially unsafe condition is detected.

The interlock system which performs these safety functions is called the Angiography Personnel Protection Interlock (APPI).

The APPI Document is organized such that the level of detail changes from a general overview to detailed engineering drawings of the hardware system. The general overview is presented in Section 1.0, "APPI Operational Mode and Procedures". The various APPI components are described in detail in Section 2.0. Section 3.0 presents some simplified logic diagrams and accompanying text. This section was written to allow readers to become familiar with the logic system without having to work through the entire set of detailed engineering drawings listed in the Appendix. Detailed logic specifications are given in Section 4.0. The Appendix also contains a copy of the current APPI checkout procedures.



## 1.0 APPI OPERATIONAL MODES AND PROCEDURES

### 1.1 SMERF

The principal components of the X17B2 APPI are described in the following sections. Figure 1 shows the overall floor plan of the NSLS. The areas requiring interlocks for radiation protection consist of the Monochromator and Angiography Rooms in SMERF (Fig. 2). The Monochromator Room contains the dual energy monochromator, the fast-acting Safety Shutters used to control beam exposure, the photon shutter, and other ancillary angiography equipment. The Angiography Room is the patient exposure area and contains the angiography scanning chair and the detector system. A set of slits mounted in the Monochromator Room wall allow beam to enter the Angiography Room when the fast-acting Safety Shutters are open.

### 1.2 Set-Up Mode

Set-Up Mode is provided so that equipment set-up, alignment, calibration, etc., with beam and without a patient present may be carried out without having to satisfy the complete Patient Mode interlock. Switching between Patient and Set-Up Modes is accomplished with a mode keyswitch in the APPI Relay Panel. The key is available only to the NSLS Safety personnel.

In Set-Up Mode, a Monochromator Room search is first carried out. Section 2.1 describes the operations necessary to interlock and to allow beam into the Monochromator Room. It is very important to realize that at no time, in either mode of operation, can the front-end beamline Safety Shutter be opened from a closed state without the Monochromator Room photon shutter being closed. Once the Monochromator Room is interlocked, with or without beam on the monochromator, the Angiography Room search sequence is as follows:

1.2.1 The doors to the Reception and Fluoroscopy Rooms must be closed and locked from inside the Angiography Room with Kirk keys. These keys are then placed in a key exchange unit located in the Physician Room.

1.2.2 The Angiography Room is searched and a search button, located in the Angiography Room, is pressed. This starts a Search Timer such that the door to the Physician Room must be closed before the time runs out. The Angiography Room lights are automatically turned off and a red warning light is turned on during this Search Timer period (~15 secs.).

1.2.3 After exiting the Angiography Room and closing the Physician Room door, a second search button, located in the Physician Room, is pressed. This search button must also be pressed before the Search Timer period runs out. An audible alarm then sounds.

1.2.4 If the Physician Room door has been closed and the second search button pressed in time, the termination of the Search Timer period will complete the search sequence. The Angiography Room interior lights come back on at the end of the search period. The Physician Room door is locked with a Kirk key which is then inserted in the key exchange unit. All keys are rotated 1/2 turn. This releases the right-most key which may then be transferred to the Solenoid Release Unit where it is turned, thus enabling the photon shutter.

1.2.5 To enable the opening of the fast-acting Safety Shutters, the photon shutter must first be opened by pressing the Scan Switch located at the Physician's Panel. The photon shutter will open only if the fast-acting Safety Shutters are closed. A latching circuit maintains the Scan Switch On condition (indicated by Physician Control Panel Scan Switch Active lights) and the button itself may be released.

1.2.6 If all interlocks are properly satisfied the Physician's Panel will display a "Go" light for the Interlock Go/Fault display and the Scan Switch Enable Lights (one for each logic circuit A and B) will go

on. The fast-acting Safety Shutters may then be opened under computer control.

1.2.7 The system will be reset to its unsearched state and disable the opening of the shutters after an APPI fault or after opening any of the Angiography Room doors after the search sequence is completed. In either case, the search sequence must then be repeated to re-enable the shutters.

1.2.8 Normal closure of the photon shutter is done by pressing the Photon Shutter Close Button on the NSLS Beamline Control Panel. If the fast-acting Safety Shutters are open, they will also close.

### *1.3 APPI System Faults in Set-Up Mode*

1.3.1 The Emergency Stop buttons on the Physician Control Panel (1) or in the Angiography Room (2) are pressed;

1.3.2 Any Angiography Room door is opened when the fast-acting Safety Shutters are not closed;

1.3.3 Power Supply Overvoltage is detected by the Safety Shutter Controller;

1.3.4 An RF Trip Reachback circuit will dump the x-ray ring if the photon shutter is told to close and does not do so within 2 sec.

Fault logic is implemented redundantly. APPI faults cause the fast-acting Safety Shutters and the photon shutter to close. Faults are latched and must be reset by an NSLS operations coordinator using an interlock reset key.

Faults from other APPI system interlocks which are active in Patient Mode (Scan Switch Interlock, Chair Motion Interlock, Exposure Timer Interlock, Clock Interlock, Logic Interlock) are bypassed when in Set-Up mode. However, the Go/Fault status for these interlocks (non-latched in this mode) continues to be displayed for diagnostic purposes.

### *1.4 Patient Mode*

In Patient Mode it is assumed that a person will be seated in the angiography scan chair and subjected to beam exposure. Normally the Monochromator Room is secured and the front end shutter is opened long before the patient scan so that the monochromator crystals can reach thermal equilibrium in the beam. The closed fast-acting Safety Shutters and photon shutter prevent beam from entering the Angiography Room during this time. The front end shutter cannot be opened from a closed state unless the Monochromator Room photon shutter is closed; once the front end shutter is open, both the photon shutter and the fast-acting Safety Shutters may be opened under APPI supervision.

The fast-acting Safety Shutters are used to control the beam exposure received by the patient during an angiography scan. The shutters are opened and closed at precise times under computer control in relation to the up/down motion and position of the scan chair. The computer-generated shutter open requests are received by the APPI system. The shutters will open only if enabled by the APPI.

Several conditions must be met before the APPI will enable the opening of the fast-acting Safety Shutters:

1.4.1 In Patient Mode the doors to the Fluoroscopy, Reception and Physician Rooms must be closed but not locked with Kirk keys. All Kirk key locks have bolt arrests installed. The doors into the Angiography Room from both the Reception and Fluoroscopy Rooms are locked only from the outside by means of the normal tumbler door locks. That allows immediate egress from the Angiography



Room, but prevents inadvertent entry into the Angiography Room. Redundant door micro-switches sense the closed position. The door between the Physician's Room and the Angiography Room is not locked from either side.

1.4.2 Once the Angiography Room is cleared of personnel by the Responsible Physician, a Search Timer in the Angiography Room must be started with a key available to the Responsible Physician (issued by the NSLS Safety Officer). Following activation of the Search Timer, the room must be cleared and the door to the Physician's Room closed in less than 30 sec. A second keyswitch located on the Physician's Control Panel must then also be turned with the same key to complete the search interlock. The Panel is located just outside the Angiography Room door in the Physician's Room. There is no preset time interval between the two keyswitch actions.

1.4.3 Within 15 sec. after the second keyswitch is activated, the hand-held Scan Switch pushbutton must be pressed and held depressed by the physician for the remainder of the procedure. This action opens the photon shutter and enables the fast-acting Safety Shutters.

1.4.4 The scan chair must be moving faster than a preset speed (to prevent overexposure of the patient). The preset chair speed is authorized by the Responsible Physician.

1.4.5 The Exposure Timer must be active. The Exposure Timer is triggered by the first computer-generated Safety Shutter open request if the Search Timer has terminated and the Scan Switch is on. The timer is non-retriggerable by subsequent shutter open requests until a new scan cycle has been initiated with the keyed Search Timer. The Exposure Timer period sets an overall limit to the time available to perform an angiography scan before the scan sequence must be re-initiated with the Search Timer. The Exposure Timer period is preset to a value authorized by the Responsible Physician and is determined from calculations of worst case exposure.

1.4.6 No APPI faults can be present.

### *1.5 APPI System Faults in Patient Mode*

1.5.1 The Emergency Stop buttons are pressed, even if no scan is in progress. The buttons are located on the Physician's Control Panel (1) and in the Angiography Room (2).

1.5.2 Any of the Angiography Room doors is opened when the fast-acting Safety Shutter is not closed.

1.5.3 The Scan Switch is released when the fast-acting Safety Shutter is not closed.

1.5.4 The scan chair is not moving faster than the preset speed when the fast-acting Safety Shutter is not closed. To avoid a fault, the shutters must be closed during the periods that the chair is slowing down, reversing direction, and speeding up.

1.5.5 The Exposure Timer is not active when the fast-acting Safety Shutter is not closed. To avoid a fault, the angiography scan sequence must be complete before the Exposure Timer times out.

1.5.6 The internal clock for either of the redundant circuit boards in the Digital Panel ceases to function.

1.5.7 The APPI detects an internal logic fault (Section 4.0).

1.5.8 Power Supply Overvoltage is detected in the Safety Shutter Controller.

1.5.9 An RF Trip Reachback circuit will dump the x-ray ring if the photon shutter is told to close and

does not do so within 2 sec.

An APPI fault causes both fast-acting Safety Shutters and the photon shutter to close. Faults are latched and must be reset by an NSLS operations coordinator using an interlock reset key.

### *1.6 APPI Checkout and Authorization*

Before X17B2 is authorized for operation in Patient Mode, the interlocks and APPI will be subjected to inspection and checkout by qualified members of the NSLS safety staff on a schedule to be determined by the proper safety authorities. APPI system checkouts must also occur after any changes have been made to the APPI electronics.

The APPI checkout is performed according to a written test procedure (see Section 6.0 - Appendix) and verifies that all interlock components are physically intact, electrically and mechanically operational, and that the interlock functions according to specification. A full check for redundancy of the APPI fault and operational logic is performed. In addition, more frequent but less complete system checkouts may be required during the course of an angiography experimental run.

The minimum chair speed and Exposure Timer period are specified by the Responsible Physician, and the APPI circuits are adjusted to conform to these specifications. The APPI settings are verified empirically by measuring the chair speed and Exposure Timer period with instruments independent of the APPI.

## 2.0 APPI COMPONENTS

### 2.1 Standard Interlocks

In order to enable the X17B2 beamline, the X17B line must be configured in a specific mode with operational control transferred to the X17B2 control panel. This can only occur when:

- a) the X17 Transport Hutch has been searched and interlocked;
- b) the X17B1 backstop is in the full out position;
- c) the X17B1 hutch has been searched and interlocked;
- d) the X17B lockout key must be inserted and rotated in its Kirk Key Solenoid Release Unit (SRU);
- e) all beamline valves are open and cooling water systems are functional.

A standard NSLS safety system is used to control and safeguard access to the Monochromator Room. The interlock ensures that the front end safety shutter is closed before the door can be unlocked and opened, and that the Monochromator Room has been searched, doors closed and locked before the front end safety shutter can be opened. A further requirement for opening the front end safety shutter is that the photon shutter be closed.

Keys from the doors that are interlocked must be inserted into appropriate Solenoid Release Units (SRU's) before front end safety shutter opening is enabled. The SRU's hold the keys captive while the shutter is open; the door deadbolts hold the keys captive while doors are open. In addition to this mechanical interlock, the interlock system implements a redundant electrical interlock using switches that sense the closed status of doors and shutters (two independent status switches per element).

An interlock fault is generated if the Monochromator Room door status switch indicates "not closed" when the front end safety shutter status switch indicates "not closed". This interlock fault extinguishes stored beam in the NSLS x-ray storage ring. Faults are latched by the X17 interlock system, and must be reset by an NSLS operations coordinator.

An emergency stop button, located in the Monochromator Room, will also dump the x-ray storage ring beam if it is pressed while the front end safety shutter is open. Emergency stop buttons in the Angiography Room(2) as well as on the Physician's Control Panel(1) prevent photon beams from entering the Angiography Room, but do not drop out the storage ring.

### 2.2 APPI Fast-Acting Safety Shutters

Two independently-acting Safety Shutters, when they are closed, prevent radiation from reaching the Angiography Room. Each one is capable of stopping full beam; two are provided to satisfy the requirement for redundancy in radiation safety systems. The shutters are actuated simultaneously.

Each shutter consists of a pair of lead-lined "vaness" that rotate around a horizontal axis that is perpendicular to the incoming beam to produce a "venetian blind" shuttering effect (Fig. 3). That is, beam strikes an upstream vane, then a downstream vane, each at a 45° angle, when the shutter is closed; beam passes unobstructed between the vanes when the shutter is rotated by 45° to its open position.

Each shutter assembly rotates open and closed through the actuation of a pair of spring-loaded rotary solenoids, one solenoid at each end of the assembly. The solenoids must be powered on to open the shutter, and the shutter will close by spring action when power is removed, thus providing fail-safe

operation. Closure time from full open is less than 50 msec once power to the solenoid has been removed. The rapid action of the fast-acting Safety Shutters enables them to be used to precisely control exposure during the angiography scan and to quickly extinguish beam if an unsafe condition is detected by the APPI. (In comparison, it takes somewhat less than 300 msec to extinguish the stored beam in the NSLS x-ray ring after a conventional fault, and more than a second to close the front end safety shutter.)

Closed status for each shutter is detected redundantly by a pair of microswitches. Open status is detected non-redundantly.

The fast-acting Safety Shutter open status is displayed on the Physician's Control Panel, on the APPI Relay Panel, and on the fast-acting Safety Shutter Controller panel.

### *2.3 Scan Chair and Chair Motion Detectors*

To prevent over-exposing the patient to radiation, it is essential that the scan chair be moving up or down at a speed greater than a certain preset value before the fast-acting Safety Shutters are allowed to open. Also, if the shutters are open, they must be made to close if the chair speed should drop below the minimum value. For this reason, the scan chair is equipped with a redundant pair of detectors that sense the speed of up or down motion during a scan.

Each motion detector consists of a rigidly mounted rotary encoder with a small gear mounted on its shaft. As the chair moves up or down, the wheel is turned by a rail attached to the moving chair. The output pulse rate from each encoder is detected by the APPI. The rates from both detectors must exceed a certain preset rate before the APPI permits the fast-acting Safety Shutters to be open. The minimum rate, or, more accurately, the maximum pulse cycle period (in msec), is set redundantly with a pair of thumbwheel switches located behind a locked transparent door on the front panel of the APPI Digital Panel. The minimum rate is authorized by the Responsible Physician.

Circuitry is incorporated to detect changes in chair direction, together with a "chatter filter" that insures that the chair is moving in a single direction at a speed higher than the minimum set value for a preset number of encoder pulse cycles before valid chair motion is indicated. Whereas a number of pulses are required to "fill" the chatter filter counter and establish a valid motion indication, only one over-long pulse cycle or one oppositely phased pulse sequence will reset the counter, yielding a no-motion indication. The chatter filter count for each redundant circuit is preset with board-mounted switches inside the APPI Digital Panel.

### *2.4 Exposure Timer*

The overall time period from the moment the angiography computer issues the first request to open the fast-acting Safety Shutters at the beginning of a sequence of scans to the moment the shutters close for the last time at the end of the last scan in the sequence is limited by the APPI Exposure Timer. The timer is implemented redundantly with the period set to a value authorized by the Responsible Physician. The timer period is determined from calculations of worst case exposure for NSLS beam and angiography scan parameters. The redundant timers are set with a pair of thumbwheel switches located behind a locked transparent door on the front panel of the APPI Digital Panel.

### *2.5 APPI Relay and Digital Panels*

The APPI control and fault logic is implemented within a pair of interconnected chassis. One chassis contains relay circuitry, the other contains solid state (TTL and CMOS) digital circuitry. The Relay and Digital Panels are located in a rack in the X17B2 Control Room. System status is indicated by lights on the front panels of these chassis.

In keeping with NSLS interlock design standards, APPI circuitry is implemented with electromechanical relays wherever possible. Because of the need for fast response times, the chair motion detection circuitry is configured using solid state components, and solid state relays are used in series with the electromechanical relays to interrupt power to the fast-acting Safety Shutter solenoids in case of a chair motion fault (Section 2.3).

System timers and the control/status interface with the angiography computer (Section 4.3) are also implemented in the Digital Panel. Redundancy in the Digital Panel is provided where needed by supplying two independent circuit boards, each with its own isolated power supply, on which parallel-acting redundant circuits can be configured. As a safeguard against unpredictable failure modes of the digital circuitry, a Logic Interlock is provided in the Relay Panel that checks for disagreement between critical signals coming from the redundant digital circuits (Section 4.2.6).

### *2.6 Physician's Control Panel with Scan Switch and Emergency Stop Buttons*

An angiography Physician's Control Panel is located just outside the Angiography Room door in the Physician Room. A hand-held pushbutton Scan Switch assembly is attached to the Physician's Control Panel by a short cord. The physician initiates an angiography scan with a search key which activates a keyswitch mounted on the panel. This same key was used in an Angiography Room keyswitch to initiate a search of that room. Use of the key in the Control Panel switch completes the search. Within the ~15 second search period, the physician must depress the Scan Switch button. The physician must keep the Scan Switch button depressed during the entire scan to open the photon shutter and to permit the opening of the fast-acting Safety Shutters by computer command. The short cord enables the physician to move within a limited distance from the Control Panel during the scan. In particular, the physician may move close to the window for observation of the patient. Release of the Scan Switch during the imaging procedure always necessitates a re-enable by the start search key. If the Scan Switch is released while the fast-acting Safety Shutters are open, a latched system fault and closure of the fast-acting Safety Shutters and photon shutter occur. The Safety Officer must reset the system in that case.

Also mounted on the Physician's Control Panel are indicators displaying fast-acting Safety Shutter and APPI system status. A "Radiation Warning" lamp flashes on the panel when the scan cycle is activated by the start-search key, and remains flashing until the sequence is complete (Section 4.1.10). In addition, the Safety Shutter open light is illuminated during those parts of the cycle when the fast-acting Safety Shutters are open.

An Emergency Stop button is mounted on the Physician's Control Panel that will cause a latched system fault and close the fast-acting Safety Shutters and photon shutter when pressed.

### *2.7 Angiography Room Safety System in Set-Up Mode*

When the Angiography Room is configured for angiography operation, but is switched into Set-Up mode, a search must be performed in the room before the photon and fast-acting Safety Shutters can be opened. Details of this mode and the search procedure are given in Section 1.2.

### *2.8 Fast-Acting Safety Shutter Controller and Supply Overvoltage Monitor*

The fast-acting Safety Shutter Controller chassis receives open/close command signals for the two fast-acting Safety Shutters from the APPI Relay Panel and switches power to the shutter solenoids in response.

To open each shutter rapidly against the strong spring force required for fast closure, 50 volts DC is applied momentarily to its solenoid pair. When the shutter is fully open, as detected by an open status switch, the solenoid voltage is dropped to a holding level of 24 volts DC. Because the solenoids can be damaged if 50 volts is applied for more than a few seconds, a timeout circuit is

included for each shutter that automatically cuts all power to its solenoids if the proper open status that switches off the 50 volts is not detected within ~1 second.

Included in the fast-acting Safety Shutter Controller is a redundant Power Supply Overvoltage Interlock that monitors the fast-acting Safety Shutter 50 volt and 24 volt supplies, and also the APPI 24 volt supply. If any of these supplies exceeds its overvoltage trip point (~32 volts for the 24 volt supplies, ~65 volts for the 50 volt supply), a latched Overvoltage Fault will be caused in the Controller, cutting all power to the fast-acting Safety Shutter solenoids. A non-keyed fault reset button is located on the front panel of the fast-acting Safety Shutter Controller. In addition, a latched APPI system fault is generated, requiring a keyed reset by the safety personnel. A rear panel test voltage input jack and selector switch permit testing of the redundant overvoltage monitor circuits.

Front panel indicators for the fast-acting Safety Shutter Controller include shutter open status, open command and 50 volt timer status, power on status for the three monitored power supplies, and Overvoltage Interlock status.

### *2.9 APPI Test Switches*

Several test switches are included in the APPI to facilitate redundancy checking. Most of these are inserted in series with redundant system switches or other components that are activated simultaneously during normal operation and are difficult to manipulate individually for testing purposes. The series type test switches are fail-safe in the sense that they must be closed-circuited for normal operation and leaving one in the open-circuit state simply inhibits one chain of the Safety Shutter open enable logic. Series test switches include:

- a. SS1 and SS2 Open Request Enable/Disable test switches;
- b. Scan Switch A and B Enable/Disable test switches;
- c. Stop Button A and B Enable/Disable test switches;
- d. Chair Motion Detector Encoder Power On/Off test switches;
- e. Digital Panel Clock A and B Enable/Disable test switches.

In addition to the series test switches, parallel test switches have been installed to bypass interlock components that may lead to inconclusive results during testing. The bypass test switches are not inherently fail-safe: leaving one in the bypassed state defeats the safety action of the bypassed component. For this reason, bypass switches are only installed on components that have separate backup counterparts so that a safety interlock is never entirely defeated by leaving a switch in bypass mode (indeed it is the redundant backup feature that leads to inconclusive testing and the need for bypass switches in the first place). Also, the bypass switching is arranged so that the Photon Shutter Open Enable (Section 4.1.4) is inhibited and the shutter is forced to close, and a flashing red light on the front panel of the Relay Panel is activated when any of these switches is in bypass mode.

The APPI bypass switches include (see Section 4.0 for logic specifications):

- a. Safety Shutter 1 Fast Permit Bypass (to bypass Chair Motion Interlock A configured in solid state logic in order to test relay-configured interlock).
- b. Safety Shutter 2 Fast Permit Bypass (to bypass Chair Motion Interlock B configured in solid state logic in order to test relay-configured interlock).

c. Logic Interlock Bypass (so that tests for redundancy in causing shutter closure by manipulation of the Safety Shutter 1 and 2 Open Requests and Fast Permits, and by faulting the chain A and B Exposure Timer and Chair Motion Interlocks, will not also cause shutter closure through the simultaneous generation of Logic Interlock faults).

As a final safeguard against leaving switches in bypass mode, the states of the bypass switches and the functionings of the bypassable components are tested during the APPI Test Procedure (see Section 6.0 - Appendix). The switches are secured behind a locked door at the end of the authorizing procedure.





### 3.0 APPI SHUTTER CONTROL AND INTERLOCKING LOGIC

#### 3.1 Set-Up Mode - Fast Shutters

A simplified logic diagram for the Fast Safety Shutters and Photon Shutter is shown in Figure 4. The logic is shown for Fast Shutter 1(SS1) and the Photon Shutter. The circuit for Fast Shutter 2(SS2) is identical to that for SS1. A description of the logic follows below.

In order for the SS1 to open, SS1 OPEN COMMAND must be true. All inputs to the final AND gate (upper right) must be true. Two of the four conditions are that the SUM GO A and SUM GO B signals be true, indicating that no faults exist. The SUM GO A signal is composed of the state of the DOOR INTERLOCK and the EMERGENCY STOP button not depressed. The SUM GO B signal is a redundant copy of SUM GO A.

The sequence of events is as follows. A standard search of the Angiography Room (also called the B2 Hutch) is done as described in Section 1.0 of the APPI document. At the completion of this procedure the personnel exit the Angiography Room through the PHYSICIAN'S door, closing it behind them. This puts a true condition on the DOOR CLOSED A input to the SS1 OPEN PERMIT AND gate. At this time the SEARCH COMPLETE line (far left) coming from the B2 Hutch Logic is pulled true, triggering the S/R timer. The B2 Hutch Logic also sends a second signal, HUTCH SECURE - B2 to an AND gate (upper left). Since there are no faults, the SUM GO A signal is true, and in addition the doors are closed, resulting in the third true input to the gate. The true output from this gate is fed to a second AND gate. The other input to this gate is the S/R TIMER ON A signal which feeds through the OR gate. The other input to the OR gate is the fed back output of the two input AND gates. This has the effect of latching its own output high, even after the S/R TIMER has turned off.

The S/R TIMER LATCH and the S/R TIMER OFF are sent to yet another AND gate. The output of this gate is one of the inputs to the SCAN SWITCH ON A gate. The second input to the SCAN SWITCH ON A gate, is derived from the pressing of the SCAN SWITCH button, which feeds through the OR gate. Since both inputs are now true, the SCAN SWITCH ON A signal is true and causes the opening of the photon shutter (see lower right). When the Photon Shutter is open, a PHOTON SHUTTER OPEN status signal (upper left) is combined with a fed-back SCAN SWITCH ON A signal to effectively latch up the SCAN SWITCH ON A line, even though the Scan Switch Button may be released. This latching is a major difference between the PATIENT and SET-UP modes.

At this point the SS1 OPEN COMMAND gate is primed and now needs only the SS1 OPEN REQUEST signal from the computer to actually drive the SS1 shutter to the open position. The SS2 drive signal is derived in an identical manner, giving a redundant system for beam control.

#### 3.2 Set-Up Mode - Photon Shutter

The lower right section of Figure 4 shows the logic for the operation of the PHOTON SHUTTER. It is opened by the action of the SCAN SWITCH ON (A & B). These are two of the inputs to the AND gate which drives the OPEN PHOTON SHUTTER line. The other two inputs come from two AND gates. One input to each of these gates is SUM GO A or SUM GO B, indicating that no faults are present in the system (see description of the SUM GO signals in Section 3.1). The other inputs to these gates are fed from an AND/OR gate combination. The AND gate in this group ensures that the Photon Shutter can only be opened when all the FAST SHUTTERS (SS1 & SS2) are closed, which occurs at the start of the imaging process.

Once the PHOTON SHUTTER is open, a signal indicating that it is indeed open is fed through the OR gate. This allows the FAST SHUTTERS to open and close during normal operation without closing the photon shutter during each cycle. Any fault will close the Photon Shutter and

both Fast Shutters. (SS1 & SS2). The normal way to close the PHOTON SHUTTER is to depress the PHOTON SHUTTER CLOSE button located on the B2 HUTCH LOGIC unit. This button is only used in SET-UP mode since the PHOTON SHUTTER is closed by any release of the SCAN SWITCH in PATIENT MODE.

A PHOTON SHUTTER FAULT logic circuit has been added to the standard interlock logic on X17B. If for any reason the PHOTON SHUTTER is told to close (such as an APPI fault) and does not close within 2 seconds, the beam in the ring will be dumped by turning off the ring RF system. This protection essentially "reaches back" into the NSLS acceleration system for personnel protection.

### *3.3 Patient Mode - Fast Shutters*

A simplified logic diagram for the FAST SAFETY SHUTTERS and PHOTON SHUTTER is shown in Figure 5. The logic is shown for FAST SHUTTER 1, (SS1) and the PHOTON SHUTTER. The circuit for FAST SHUTTER 2 (SS2) is identical to that for SS1. A description of the logic follows below.

In order for the SS1 to open, SS1 OPEN COMMAND must be true. All inputs to the final AND gate (upper right) must be true. Two of the six conditions are that the SUM GO A and SUM GO B signals be true, indicating that no faults exist. The SUM GO A signal is composed of the states of the EXPOSURE TIMER INTERLOCK, the LOGIC INTERLOCK, the SCAN SWITCH INTERLOCK and the CHAIR INTERLOCK. The SUM GO B signal is a redundant copy of SUM GO A. These must all be true along with the EMERGENCY STOP button not depressed. The CHAIR INTERLOCK GO A is also fed directly to the final AND gate.

The sequence of events is as follows. The physician searches the Angiography Room and turns his/her key in a START SEARCH key receptacle. He/she then has 30 seconds to exit the room and close the Angiography door in order to successfully complete the search. Closing the door puts a true condition on the DOOR CLOSED input to the SS1 OPEN PERMIT AND gate. He/she then turns the key in the SR TIMER KEYSWITCH on the Physician's Panel, starting the SR TIMER. Before this timer times out (approx. 15 seconds), the SCAN SWITCH BUTTON must be depressed, forcing the SCAN SWITCH ON A line to go true. This line will remain in a true state, even after the SR TIMER times out, provided the SCAN SWITCH BUTTON is held down, by virtue of the feedback through the OR gate.

While the SCAN SWITCH BUTTON is being held down, a computer command is issued for an SS1 OPEN REQUEST which opens the fast-acting Safety Shutters and starts the EXPOSURE TIMER, which is a third condition on the OPEN PERMIT AND gate.

Prior to the issuing of the OPEN REQUEST the patient chair will be in cycles of up and down motion, even though the shutters are not yet open. When the chair is moving at the correct velocity during any part of a cycle, the CHAIR MOTION ON line is held true at the input to the OPEN PERMIT AND gate.

At this point all four inputs to the OPEN PERMIT gate will be true, feeding a true signal to the SS1 OPEN COMMAND gate. A FAST PERMIT SS1 signal derived from the chair motion is also fed to the OPEN COMMAND gate. Thus the SS1 OPEN COMMAND gate is primed and now needs only the SS1 OPEN REQUEST signal from the computer to actually drive the SS1 to the open position. The SS2 drive signal is derived in an identical manner, giving a redundant system for beam control.

### 3.4 Patient Mode - Photon Shutter

The lower right section of Figure 5 shows the logic for the operation of the PHOTON SHUTTER. It is basically opened and closed by the action of the SCAN SWITCH ON (A & B). These are two of the inputs to the AND gate which drives the OPEN PHOTON SHUTTER line. The other two inputs come from two AND gates. One input to each of these gates is SUM GO A or SUM GO B, indicating that no faults are present in the system (see description of the SUM GO signals in Section 3.3). The other inputs to these gates are fed from an AND/OR gate combination. The AND gate in this group ensures that the PHOTON SHUTTER can only be opened when all the FAST SHUTTERS (SS1 & SS2) are closed, which occurs at the start of the imaging process. Once the PHOTON SHUTTER is open, a signal indicating that it is indeed open is fed through the OR gate. This allows the FAST SHUTTERS to open and close during normal operation without closing the PHOTON SHUTTER during each cycle. Release of the SCAN SWITCH or any fault will close the Photon Shutter and both Fast Shutters (SS1 & SS2).

A PHOTON SHUTTER FAULT logic circuit has been added to the standard interlock logic on X17B. If for any reason the PHOTON SHUTTER is told to close (such as an APPI fault) and does not close within 2 seconds, the beam in the ring will be dumped by turning off the ring RF system. This protection essentially "reaches back" into the NLS acceleration system for personnel protection.

Note that there is only one PHOTON SHUTTER, and the circuits for the photon shutter explained above are not duplicated.



## 4.0 APPI CONTROL AND FAULT LOGIC SPECIFICATIONS

Principal control and fault logic specifications for the APPI system are given below:

### 4.1 APPI Control Logic

#### 4.1.1 Safety Shutter Open Command (SS Op Cmd), redundant Safety Shutters 1 and 2 (SS1 and SS2)

$$\text{SS Op Cmd}(1,2) = \text{SS Open Request}(1,2) \text{ AND } \text{SS Open Enable}(A,B) \\ \text{AND } [\text{Chair Intlk Go}(A,B) \text{ OR } \text{Set-Up Mode}(A,B)] \\ \text{AND } \text{SS Fast Permit}(1,2)$$
$$\text{SS Close Cmd} = \overline{\text{SS Op Cmd}}$$

Note: In addition to APPI Op Cmd, Power Supply Overvoltage Intlk in Safety Shutter Controller must be in Go state to energize shutter solenoids.

SS Open Request generated by angiography control computer.

#### 4.1.2 Safety Shutter Open Permit (SS Op Perm) and Enable, redundant

$$\text{SS Op Perm}(A,B) = \text{Doors Closed}(A,B) \text{ AND } \text{Scan Switch On}(A,B) \text{ AND} \\ [\text{Set-Up Mode}(A,B) \text{ OR } (\text{Exposure Timer On}(A,B) \text{ AND} \\ \text{Chair Motion On}(A,B))] \text{ AND} \\ \text{Lamp Buss OK}$$
$$\text{SS Open Enable}(A,B) = \text{SS Op Perm}(A,B) \text{ AND } \text{Sum Go A}(A,B) \text{ AND} \\ \text{Sum Go B}(A,B)$$

#### 4.1.3 Safety Shutter Fast Permit (SS Fast Perm), redundant

$$\text{SS Fast Perm}(1,2) = \text{Set-Up Mode}(A,B) \text{ OR } [(\text{Chair Motion On}(A,B) \text{ OR} \\ \text{SS1\&2 Closed}(A,B)) \text{ AND } \text{Clock Intlk Go}(A,B)]$$

Note: SS Fast Permit logic is implemented in Digital Panel and utilizes solid state relays in Relay Panel. Response time = ~1 msec.

#### 4.1.4 Photon Shutter Open Enable (PS Op En), redundant

$$\text{PS Op En}(A,B) = [(\text{SS1 Closed A\&B} \text{ AND } \text{SS2 Closed A\&B}) \text{ OR } \text{PS Open}] \\ \text{AND } \text{Lamp Buss Go} \text{ AND } \text{Logic or Fast Intlk Unbypassed} \\ \text{AND } \text{Summary Go}(A,B)$$

#### 4.1.5 Search Timer

**Start Search Timer = Summary Go A&B AND [(Patient Mode AND Physician's Control Pan Keysw)**

**Stop Search Timer = Time-out OR Summary Fault A OR Summary Fault B**

#### 4.1.6 Scan Switch (Scan Sw), redundant

##### a. Patient Mode

**Scan Sw Enable(A,B) = Search Timer On(A,B) OR Scan Sw On(A,B)**

**Scan Sw On = Scan Sw Enable(A,B) AND Scan Sw pressed(A,B)**

##### b. Set-Up Mode

**Scan Sw Enable(A,B) = Angiography Room Searched(A,B)**

**Scan Sw On(A,B) = Scan Sw Enable(A,B) AND [Scan Sw(A,B) [Scan Sw(A,B) momentary on OR (Scan Sw On(A,B) AND Photon Shutter Open(A,B))]**

#### 4.1.7 Angiography Room Searched (Srch OK) and Search Latch, redundant

**Search Latch On(A,B) = Set-Up Mode(A,B) AND Summary Go(A,B) AND B2 Hutch Secure(A,B) AND Doors Closed(A,B) AND [Search Timer On(A,B) OR Search Latch On(A,B)]**

**Srch OK(A,B) = Search Latch On(A,B) AND Search Timer Off(A,B)**

**4.1.8 Exposure Timer (Exp Timer, Patient Mode only), redundant**

**Exp Timer On(A,B) = Exp Timer triggered(A,B) AND Exp Timer not  
timed out(A,B) AND Patient Mode(A,B)**

**Exp Timer Off(A,B) = Exp Timer timed out(A,B) OR Set-Up Mode(A,B)**

**Exp Timer Trigger(A,B) = SS Open Request(1,2) AND Exp Timer Trigger  
Enable(A,B)**

**Trigger Enable(A,B) = Scan Sw On(A,B) AND Search Timer Off AND Exp  
Timer Trig Latch On(A,B)**

**Trig Latch Set(A,B) = Search Timer On AND Trig Latch Not Reset(A,B)**

**Trig Latch Reset(A,B) = Sum Go A&B OR Set-Up Mode A&B OR Exp Timer  
On(A,B) OR [Scan Sw A&B Not On(A,B)  
AND Search Timer Off]**

**4.1.9 Chair Motion On, redundant**

**Chair Motion On(A,B) = time period between pulses coming from chair motion sensors (A,B) must be  
less than the preset period, corresponding to a minimum chair speed**

**AND**

**the chair must be moving in the same direction as determined by direction  
change sensing circuits (A,B)**

**FOR**

**a preset number of pulse cycle periods as determined by the setting of the  
Chatter Filter (A,B) - Section 2.3**

**4.1.10 Radiation Warning Light (Rad Warn On, flashing, Patient mode)**

**Rad Warn On = Sum Go A&B AND [Exp Timer B Trig Latch On OR  
(Scan Sw A&B On AND Exp Timer B On)]**

**4.1.11 Logic or Fast Interlock Bypass**

**Logic or Fast Intlk Bypass = Logic Intlk Bypass Sw On OR  
Fast Permit 1 Bypass SW On OR  
Fast Permit 2 Bypass Sw On**

**Note: See Section 2.9 for description of bypass switches.**

#### 4.1.12 Patient/Set-Up Mode (Pat/Set-Up Mode), redundant

Patient Mode(A,B) = Pat Mode Keyed On(A,B) OR [Pat Mode(A,B) AND Search Timer On(A,B)]

Set-Up Mode(A,B) =  $\overline{\text{Patient Mode(A,B)}}$

Note: The Patient Mode logic prevents key-switching to Set-Up mode if the Search Timer is on. Without this precaution it would be possible to open Safety Shutters without chair motion, etc., if a Patient Mode scan was key-started by the physician and if the APPI was then switched to Set-Up mode before the Search timeout. Switching from Patient to Set-Up mode during a scan after the Search timeout will close and inhibit opening of the Safety Shutters until an Angiography Room search sequence is performed (Section 1.2).

#### 4.2 APPI System Go/Fault Logic

All APPI system Go/Fault logic is implemented redundantly (Chains A and B). Interlock faults are latched unless they are bypassed by switching to Set-Up mode, in which case the faults are indicated but not latched and do not cause a system summary fault. Latched faults must be reset by an NSLS Operations Coordinator using the reset key.

An interlock Fault is the logical inverse of its Go condition:

Fault =  $\overline{\text{Go}}$

##### 4.2.1 Stop Button Interlock

Stop Button Intlk Go(A,B) = Stop Button(A,B), 2 each, not pressed

##### 4.2.2 Angiography Room Door Interlock

Angiography Room Door Intlk Go(A,B) = Doors Closed(A,B) OR [SS1 Closed(A,B) AND SS2 Closed(A,B)]

##### 4.2.3 Scan Switch Interlock

Scan Sw Intlk Go(A,B) = Scan Sw On(A,B) OR [SS1 Closed(A,B) AND SS2 Closed(A,B)]

Note: Scan Switch Interlock is bypassed in Set-Up mode.

##### 4.2.4 Chair Interlock

Chair Intlk Go(A,B) = Chair Motion On(A,B) OR [SS1 Closed(A,B) AND SS2 Closed(A,B)]

Note: The Chair Motion Interlock is implemented with solid state logic in the Digital Panel as part of the shutter Fast Permit (Section 4.1.3), and with relay logic in the Relay Panel. Chair Motion Interlock is bypassed in Set-Up mode.



#### 4.2.5 Exposure Timer Interlock

Exp Timer Intlk Go(A,B) = Exp Timer On(A,B) OR [SS1 Closed(A,B) AND SS2 Closed(A,B)]

Note: Exposure Timer Interlock is bypassed in Set-Up mode.

#### 4.2.6 Logic Interlock(Digital Panel logic check; Logic Interlock has redundant relays following the non- redundant logic given below)

Logic Intlk Go(A,B) = [(SS1 Fast Perm On AND SS2 Fast Perm On) OR  
(SS1 Fast Perm Off AND SS2 Fast Perm Off)]  
AND  
[Chair Motion On A AND Chair Motion On B) OR  
(Chair Motion Off A AND Chair Motion Off B)]  
AND  
[Exp Timer On A AND Exp Timer On B) OR  
(Exp Timer Off A AND Exp Timer Off B)]  
AND  
[SS1 Open Request AND SS2 Open Request) OR  
(SS1 Close Request AND SS2 Close Request)]

Note: Logic Interlock is bypassed in Set-Up mode.

#### 4.2.7 Power Supply Overvoltage Interlock

Overvoltage Intlk Go(A,B) = Shutter Controller 50V < -65V AND  
Shutter Controller 24V < -32V AND  
APPI Relay Panel 24V < -32V

Note: Overvoltage Interlock faults are also latched on the front panel of the Safety Shutter Controller.

#### 4.2.8 Summary Interlock Go (Sum Go A & B)

Sum Go(A,B) = Overvoltage Intlk Go(A,B) AND Stop Button Intlk  
Go(A,B) AND Door Intlk Go(A,B) AND  
[Set-Up Mode(A,B) OR (Scan Sw Intlk Go(A,B) AND Chair  
Intlk Go(A,B) AND Exp Timer Intlk Go(A,B) AND Logic Intlk Go(A,B))]

#### 4.2.9 Clock Interlock

Clock Intlk Go(A,B) = Clock On(A,B)

Note: This interlock is implemented in the Digital Panel and is part of the Fast Permit (Section 4.1.3). The interlock is bypassed in Set-Up mode.

In addition to the above redundant interlocks, a non-redundant, non-latched Lamp Buss Interlock is implemented in the APPI. The Lamp Buss interlock ensures that one or more of the steering diodes used to direct power from the Lamp Test Buss to system interlock and status indicator lights is not short circuited. Such a short could put power on the Lamp Buss when it was not intended. A Lamp Buss Fault causes the Safety Shutters and Photon Shutter to close.

#### 4.2.10 Lamp Buss Interlock, non-redundant

Lamp Buss Intlk Fault = Lamp Test button not pushed AND +24V power on Lamp Test Buss

#### 4.3 APPI Computer Interface

The angiography computer monitors APPI system status and transmits the request to open Safety Shutters via a CAMAC digital input/output register (Kinetic Systems IGOR 3060) that interfaces directly to the APPI Digital Panel. Monitored status includes:

- 4.3.1 Angiography Room doors closed status;
- 4.3.2 Photon shutter opened and closed status;
- 4.3.3 Safety Shutter Open Enable;
- 4.3.4 Safety Shutters 1 and 2 open and closed status;
- 4.3.5 Scan Switch on AND Search Timer off (OK to begin scan);
- 4.3.6 Summary Interlock Go/Fault status;
- 4.3.7 Patient/Set-Up mode.

#### ACKNOWLEDGEMENTS

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At the NSLS, contributions to the design and implementation of the APPI system came from R. Best, W. Case, T. Dickinson, M. Hughes, and T. Monahan.

## **5.0 FIGURES**

5.1 NSLS Experimental Floor with SMERF Highlighted

5.2 Synchrotron Medical Research Facility (SMERF) in Detail

5.3 APPI Safety Shutter Sketch

5.4 APPI Logic Diagram - Set-Up Mode

5.5 APPI Logic Diagram - Patient Mode



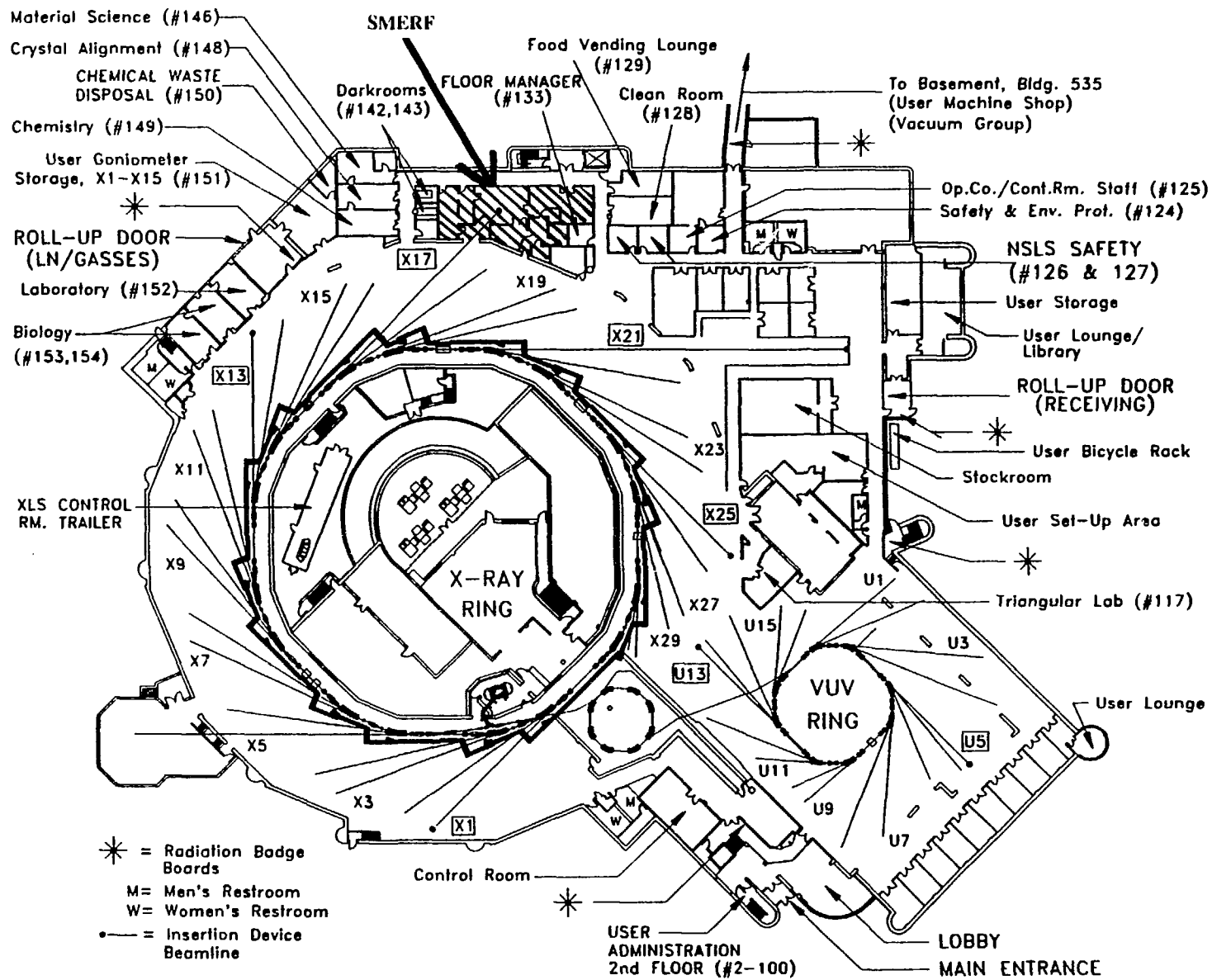
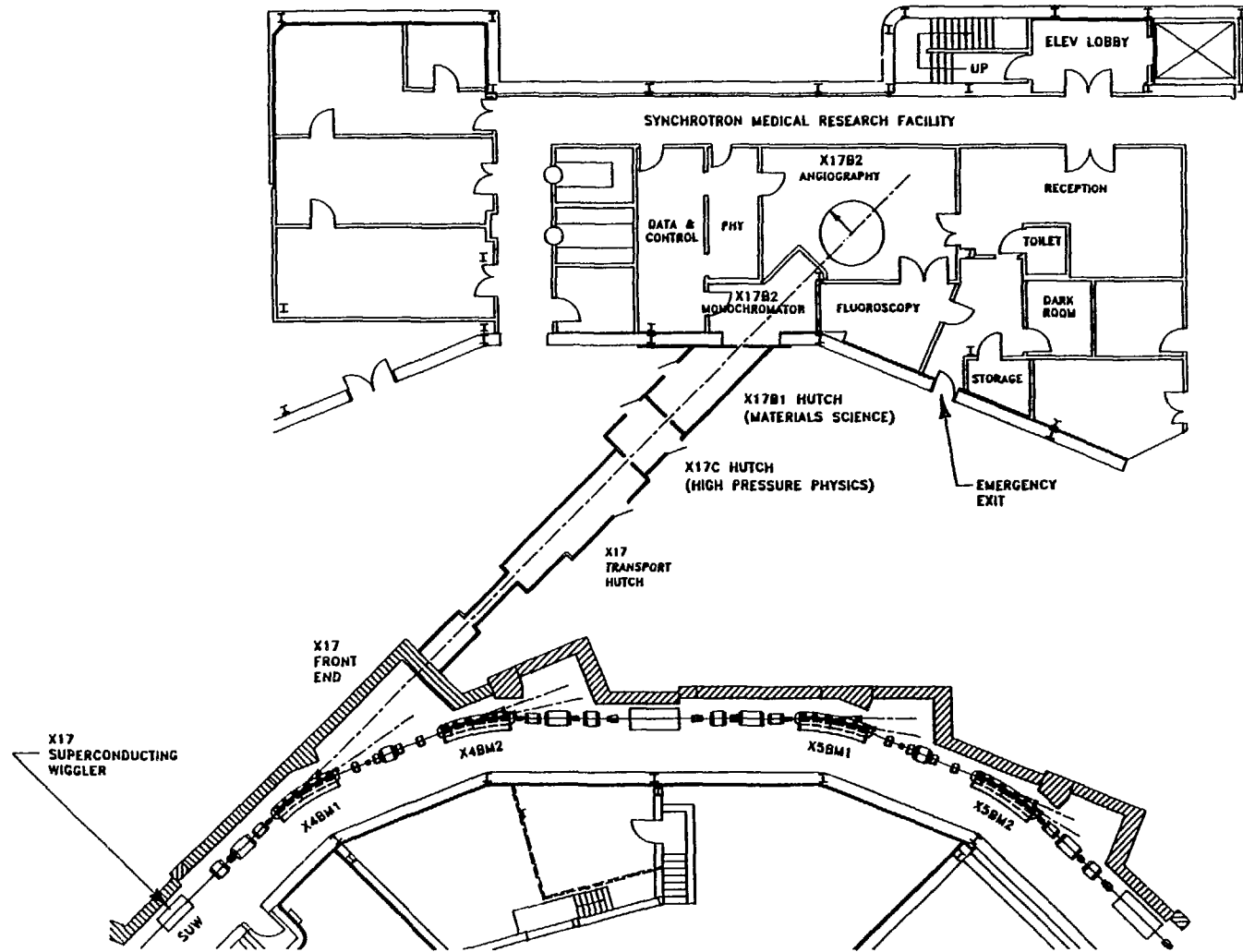


Figure 1. NSLS Experimental Floor with SMERF Highlighted.



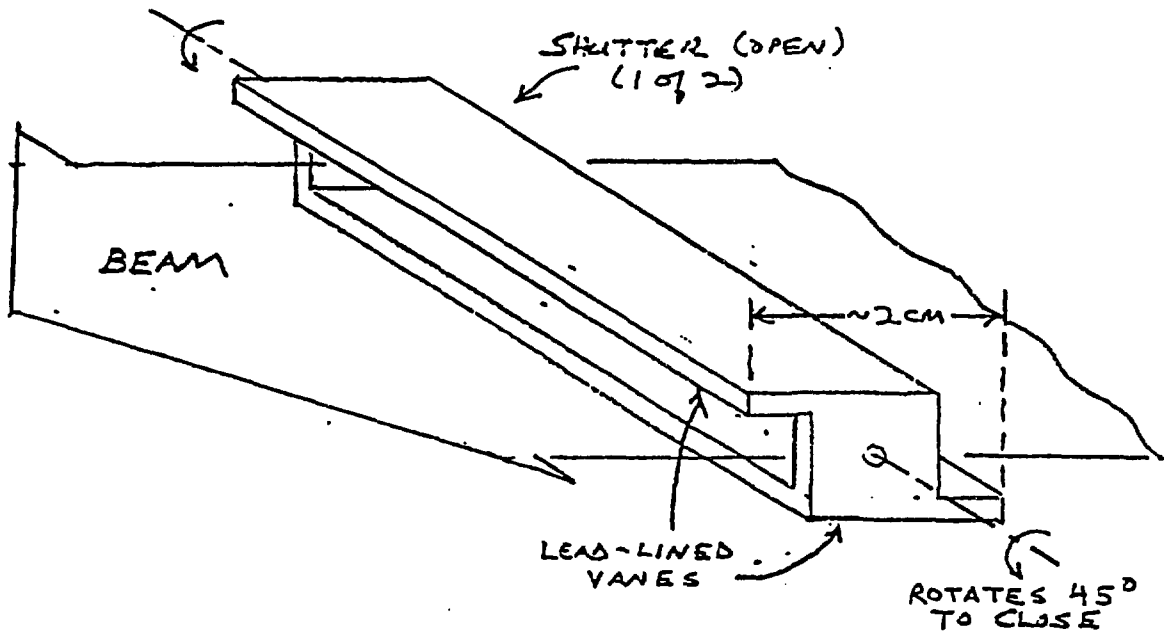


SCALE .055" = 1'2"

Figure 2. Synchrotron Medical Research Facility (SMERF) in Detail.







FRONT VIEW

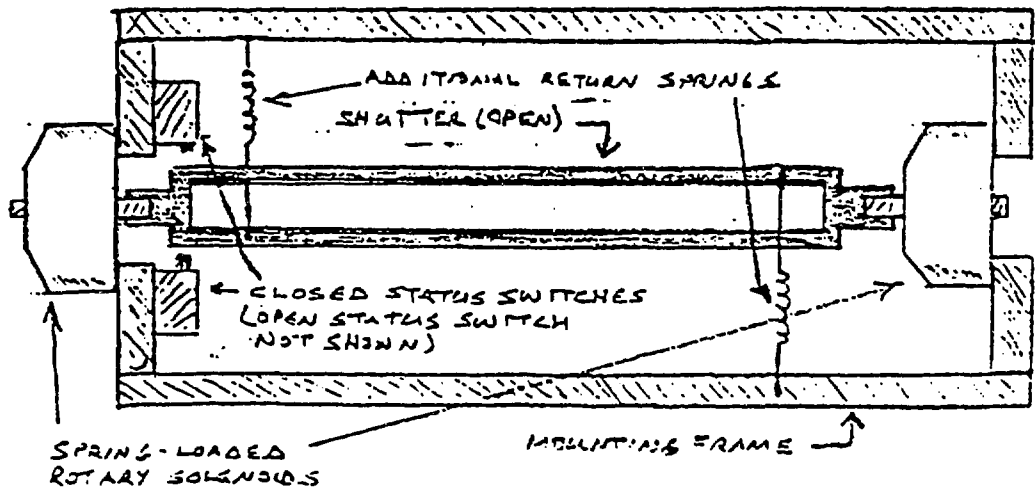
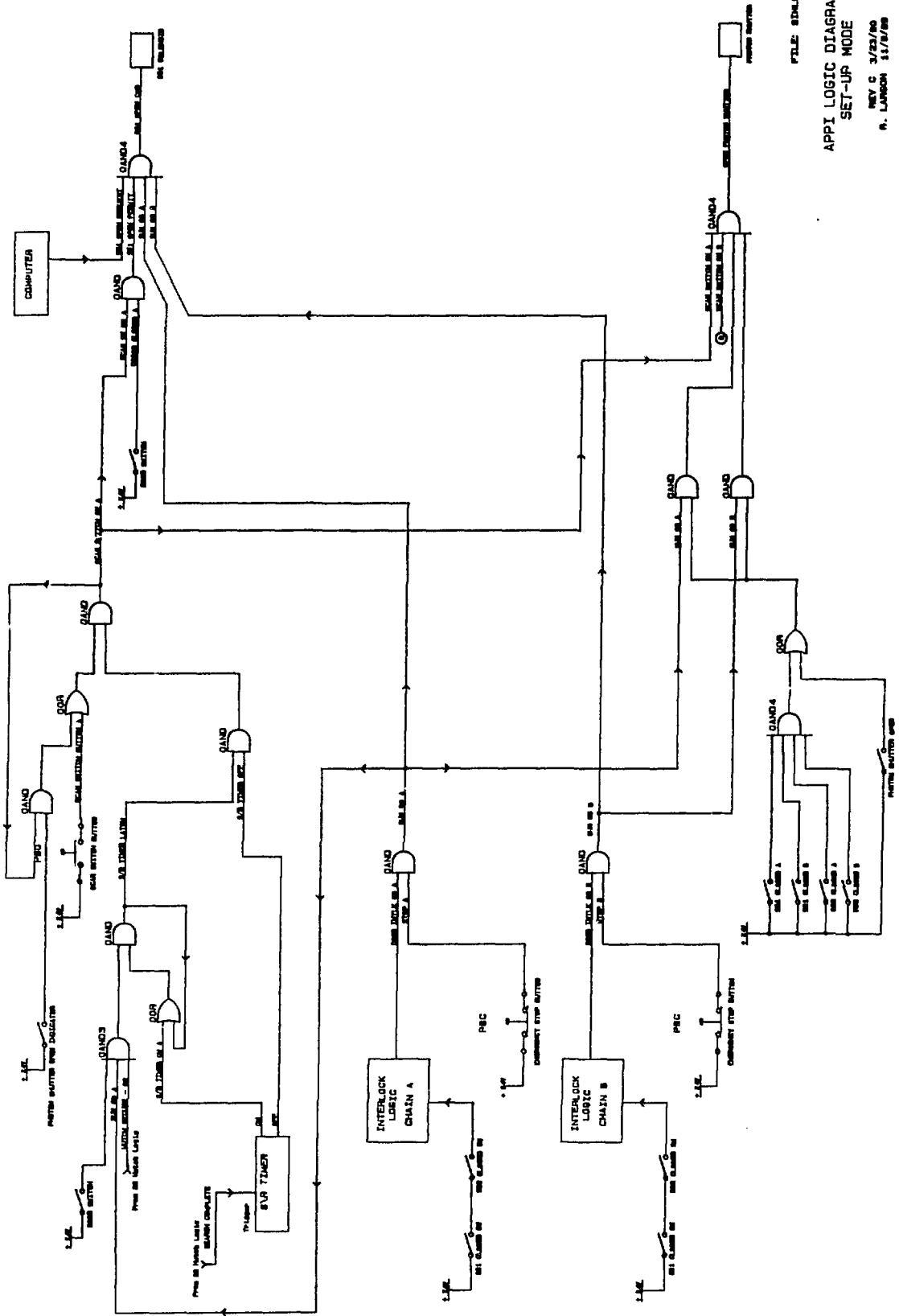


Figure 3. APPI Safety Shutter Sketch.





FILE: SDH43C3  
 APPI LOGIC DIAGRAM  
 SET-UP MODE  
 REV C 3/23/80  
 R. LARSON 11/8/80  
 MAR 2 1980

Figure 4. APPI Logic Diagram - Set-Up Mode.



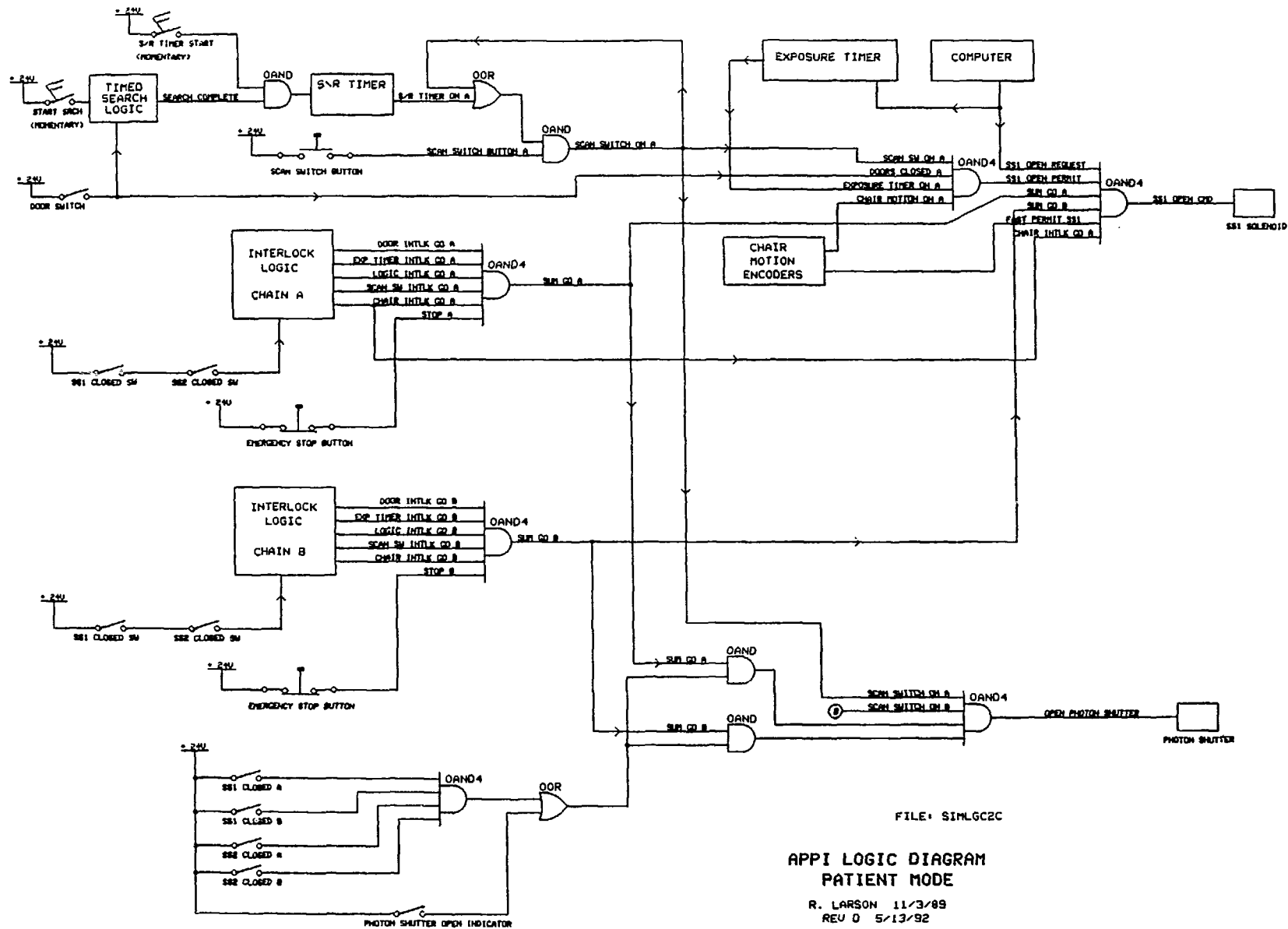


Figure 5. APPI Logic Diagram - Patient Mode.



## **6.0 APPENDIX**

- 6.1 APPI Test Procedures for Set-Up and Patient Modes
- 6.2 APPI X17 Beamline Connection Diagram (SLS-61.75-1-4-A)
- 6.3 APPI Relay Panel Wiring Diagram (SLS-61.62-1-4-B; 3 sheets)
- 6.4 Digital Panel - Logic Board A Wiring Diagram (SLS-61.72-1-4-A)
- 6.5 Digital Panel - Logic Board B Wiring Diagram (SLS-61.73-1-4-A)
- 6.6 APPI Digital Panel - I/O Interface Boards A&B (SLS-61.74-1-4-A)
- 6.7 APPI Digital Panel Wiring Diagram (SLS-61.84-1-4-A)
- 6.8 APPI Chair Motion Detector - Line Drivers (SLS-61.85-1-3-A)
- 6.9 APPI Safety Shutter Controller & Overvoltage Monitor (SLS-61.65-1-4-A)

**Note:** Diagrams 6.2 through 6.9 are not included in this document due to the lack of space. Copies of these diagrams may be obtained from the NSLS Design Group.

SET-UP MODE

APPI TEST PROCEDURE

Rev P 1/30/91

Date \_\_\_\_\_  
Test personnel \_\_\_\_\_

1. Before starting this test, the source of radiation must be locked out.

X-RAY RING LOCKED OUT AND TAGGED \_\_\_\_\_  
OR  
X-17 BEAMLINE LOCKED OUT AND TAGGED \_\_\_\_\_

In the following tests, shutter status lights on APPI panels are used to indicate shutter position. Step 14. verifies that these indicators are accurate.

PREPARATION:

- A. Use key to switch to SETUP MODE \_\_\_\_\_
- B. Reset if any faults are latched. \_\_\_\_\_
- C. Do a lamp test on all three panels \_\_\_\_\_

2. Kirk lock Reception Room and Fluoroscopy Room doors. Search room, turning physicians key in check station adjacent to the Reception Room door. Close the physicians door and Kirk lock. Press the external check station push button. Transfer Kirk keys, insert and turn key in the SRU.

Turn START SCAN keyswitch on the operators panel.  
SEARCH TIMER light on APPI panel does not light \_\_\_\_\_

3. Close all (3) doors, but do not search hutch. Send a SHUTTER OPEN REQUEST. Fast Shutters do not open 1\_\_\_ 2\_\_\_  
Shutter OPEN REQUEST lights on APPI panel come on 1\_\_\_ 2\_\_\_

4. Leave SHUTTER OPEN REQUEST signal active. Push SCAN SWITCH. Fast Shutters do not open 1\_\_\_ 2\_\_\_

NOTE: Through step 11., be prepared for multiple observations during a limited time.

5. Kirk lock Reception Room and Fluoroscopy Room doors. Search hutch. [Standard search procedure covered on other form.] Put Kirk Keys in transfer unit and put transfer key into SRU, but do not activate. (Do not rotate final key) Push SCAN SWITCH while sonolert is sounding. Fast Shutters do not open 1\_\_\_ 2\_\_\_  
Scan switch does not latch \_\_\_\_\_  
S/R timer does not go on \_\_\_\_\_

6. After sonolert stops push SCAN SWITCH. Scan switch does not latch \_\_\_\_\_  
Fast Shutters do not open 1\_\_\_ 2\_\_\_



7. Deactivate SHUTTER OPEN REQUEST. Search hutch, complete Kirk Key sequence, turning transfer key in SRU. Press SCAN SWITCH while sonolert sounding.

Activate SHUTTER OPEN REQUEST. Scan switch does not latch \_\_\_\_\_  
Deactivate SHUTTER OPEN REQUEST. Fast Shutters do not open 1 \_\_\_ 2 \_\_\_

8. After sonolert stops, push SCAN SWITCH until Photon Shutter is open, then release:

Scan switch does latch \_\_\_\_\_  
Photon shutter opens \_\_\_\_\_  
Fast Shutters do not open 1 \_\_\_ 2 \_\_\_  
SRU light goes out \_\_\_\_\_

9. Activate SHUTTER OPEN REQUEST. Fast shutters open 1 \_\_\_ 2 \_\_\_

10. Deactivate SHUTTER OPEN REQUEST. Photon shutter remains open \_\_\_\_\_  
Fast shutters close 1 \_\_\_ 2 \_\_\_

11. Remove the cover on the Fast Shutters enclosure in the Monochromator Room.

Observe that the FAST SHUTTER 1 CLOSED light is on \_\_\_\_\_  
Manually rotate Fast Shutter 1 slightly.  
FAST SHUTTER 1 CLOSED light goes out \_\_\_\_\_

Continue rotation of Fast Shutter 1 until it is fully open.  
FAST SHUTTER 1 OPEN light goes on \_\_\_\_\_  
Release Fast Shutter 1.

Observe that the FAST SHUTTER 2 CLOSED light is on \_\_\_\_\_  
Manually rotate Fast Shutter 2 slightly.  
FAST SHUTTER 2 CLOSED light goes out \_\_\_\_\_

Continue rotation of Fast Shutter 2 until it is fully open.  
FAST SHUTTER 2 OPEN light goes on \_\_\_\_\_  
Release Fast Shutter 2.

Replace the cover on the Fast Shutters enclosure. \_\_\_\_\_

INTERLOCK FAULT CHECKS

STOP BUTTONS

Open the ANGIOGRAPHY ROOM.

Note: RESET after each fault.

12. Press each STOP button in turn. Stop button fault (1) \_\_\_\_\_  
Summary fault A \_\_\_\_\_ B \_\_\_\_\_
- Stop button fault (2) \_\_\_\_\_  
Summary fault A \_\_\_\_\_ B \_\_\_\_\_
- Operators panel Stop button fault (3) \_\_\_\_\_  
Summary fault A \_\_\_\_\_ B \_\_\_\_\_
13. Reset EMERGENCY STOP fault at B2 logic unit but do not reset fault at APPI panel. Do complete search with Kirk Key sequence. Scan switch does not operate \_\_\_\_\_
14. Reset faults. Do complete search as above, push STOP button. Stop button fault light goes on \_\_\_\_\_
15. Activate SHUTTER OPEN REQUEST Fast Shutters do not open 1 \_\_\_\_\_ 2 \_\_\_\_\_  
Deactivate SHUTTER OPEN request.
16. Reset faults. Do complete search with Kirk Key sequence. Press SCAN SWITCH until Photon Shutter opens, then release: SCAN SWITCH does operate and latch \_\_\_\_\_
- Activate SHUTTER OPEN REQUEST Fast Shutters do open 1 \_\_\_\_\_ 2 \_\_\_\_\_
- Press STOP button on operators panel: Fast Shutters close 1 \_\_\_\_\_ 2 \_\_\_\_\_
- Photon shutter closes \_\_\_\_\_  
Stop button fault light goes on \_\_\_\_\_
- Reset faults. Deactivate SHUTTER OPEN request.
17. Throw STOP BUTTON A test switch to test position. Photon shutter enable light goes out \_\_\_\_\_  
STOP BUTTON INTERLOCK GO A goes out \_\_\_\_\_  
STOP BUTTON FAULT goes on \_\_\_\_\_  
SUMMARY FAULT A goes on \_\_\_\_\_  
SUMMARY GO B remains lit \_\_\_\_\_
- Return test switch A to the active position. Reset fault.

18. Throw STOP BUTTON B test switch to test position.

Photon shutter enable light goes out	_____
STOP BUTTON INTERLOCK GO B goes out	_____
STOP BUTTON FAULT goes on	_____
SUMMARY FAULT B goes on	_____
SUMMARY GO A remains lit	_____

Return test switch B to the active position. Reset fault.

DOORS

19. Place switch holders on appropriate door switches (4 for each door section). Place latch device on door lock so key can be removed. Search hutch. Complete Kirk Key sequence. Push SCAN switch. Activate SHUTTER OPEN REQUEST. Remove switch holder from APPI switch 1. Observe indicator lights and check off. Remove switch holder from HUTCH LOGIC door switch 1 to drop search relays; then replace all holders to prepare for next switch test. Repeat this sequence for each No. 1 switch.

APPI Door Switch 1	PHYS	RECEP MAIN	RECEP AUX	FLOUR MAIN	FLOUR AUX
Fast Shutter 1 closes	_____	_____	_____	_____	_____
Fast Shutter 2 closes	_____	_____	_____	_____	_____
Photon Shutter closes	_____	_____	_____	_____	_____
Scan Switch A deactivates	_____	_____	_____	_____	_____
Door fault lights	_____	_____	_____	_____	_____
Summary Fault A lights	_____	_____	_____	_____	_____

20. Repeat 19. for Door switch 2.

APPI Door Switch 2	PHYS	RECEP MAIN	RECEP AUX	FLOUR MAIN	FLOUR AUX
Fast Shutter 1 closes	_____	_____	_____	_____	_____
Fast Shutter 2 closes	_____	_____	_____	_____	_____
Photon Shutter closes	_____	_____	_____	_____	_____
Scan Switch B deactivates	_____	_____	_____	_____	_____
Door fault lights	_____	_____	_____	_____	_____
Summary Fault B lights	_____	_____	_____	_____	_____

Remove all doorswitch holders. Check operation of all four switches on each door. Open each door slowly and listen for a distinct click for each switch.

APPI doorswitch 1	_____	_____	_____	_____	_____
APPI doorswitch 2	_____	_____	_____	_____	_____
Hutch logic doorswitch 1	_____	_____	_____	_____	_____
Hutch logic doorswitch 2	_____	_____	_____	_____	_____

AUXILIARY TEST SWITCHES

21. Throw the SS1 OPEN REQUEST test switch to the test position. Do the entire system operation sequence, including pressing the SCAN SWITCH. Activate a SHUTTER OPEN REQUEST via the computer.

Fast Shutter 1 does not open \_\_\_\_\_  
 Fast Shutter 2 does not open \_\_\_\_\_

Deactivate the SHUTTER OPEN REQUEST.

Return the SS1 OPEN REQUEST test switch to the normal active position. Throw the SS2 OPEN REQUEST switch to the test position. Activate a SHUTTER OPEN REQUEST via the computer.

Fast Shutter 1 does open \_\_\_\_\_  
 Fast Shutter 2 does not open \_\_\_\_\_

Deactivate the SHUTTER OPEN REQUEST.

Return all switches to the normal active position.

22. Throw the SCAN SWITCH A test switch to the test position. Close the Photon Shutter. Press the Scan Switch. Activate a SHUTTER OPEN REQUEST via the computer.

Scan switch A does not operate \_\_\_\_\_  
 Scan switch B does operate \_\_\_\_\_  
 Fast Shutter 1 does not open \_\_\_\_\_  
 Fast Shutter 2 opens \_\_\_\_\_

Deactivate the SHUTTER OPEN REQUEST.

Return the SCAN SWITCH A test switch to the normal active position. Press the CLOSE PHOTON SHUTTER button.

Throw the SCAN SWITCH B test switch to the test position. Press and HOLD DOWN the Scan Switch. Activate a SHUTTER OPEN REQUEST via the computer.

Scan switch A does operate \_\_\_\_\_  
 Scan switch B does not operate \_\_\_\_\_  
 Fast Shutter 1 opens \_\_\_\_\_  
 Fast Shutter 2 does not open \_\_\_\_\_

Deactivate the SHUTTER OPEN REQUEST.

Return the SCAN SWITCH B test switch to the normal active position.

23. Return all test switches to the active mode:

On the RELAY PANEL:

SS1 FAST PERMIT BYPASS \_\_\_\_\_  
SS2 FAST PERMIT BYPASS \_\_\_\_\_  
SCAN SWITCH A \_\_\_\_\_  
SCAN SWITCH B \_\_\_\_\_  
STOP BUTTON A \_\_\_\_\_  
STOP BUTTON B \_\_\_\_\_  
SS1 OPEN REQUEST \_\_\_\_\_  
SS2 OPEN REQUEST \_\_\_\_\_  
LOGIC INTLK BYPASS \_\_\_\_\_

On the DIGITAL PANEL:

CLOCK FAULT A \_\_\_\_\_  
CLOCK FAULT B \_\_\_\_\_

On the CHAIR:

ENCODER A \_\_\_\_\_  
ENCODER B \_\_\_\_\_

#### TEST OF REACHBACK FEATURE (Set-up Mode)

### CAUTION !!

During this portion of the test it is necessary to enable beamline X-1

NO SWITCH HOLDERS OR OTHER BYPASSES MAY BE USED DURING THIS PART OF THE TEST, SINCE IT WOULD BE POSSIBLE TO BRING BEAM INTO THE AREA.

It is possible to do the test without opening the X-17B safety shutter. However, if the shutter is opened, beam will come into the angiography area, and the x-ray ring will trip when the test is conducted.

24. If X-17B1 cannot be made safe for beam (missing shielding etc) then the test may be conducted only if the x-ray ring has been tagged off as when regular beamline interlock tests are done.

X-ray ring interlock is tagged off \_\_\_\_\_

OR

X-17B is safe for beam \_\_\_\_\_

25. Verify that all door switch holders have been removed and switches tested for proper function. (step 18 above) \_\_\_\_\_  
Verify that all test switches are returned to the active mode. (step 21 above) \_\_\_\_\_

26. Search and secure the Transport hutch. Make sure that the backstop in the B1 hutch is in the out-of-beam position. Search and secure the B1 hutch. Put X-17B1-B2 "on line" (lockout key in place and CRSC keys enabled). Open monochromator hutch. Send an observer with a radio to the front end disconnect panel at the sawtooth. Verify that the "beamline secure" indicator lights for X-17B1 are out. \_\_\_\_\_

27. Close the air supply valve for the photon shutter. Search the mono hutch. The beamline secure lights come on (one light comes on when the door is closed, the other comes on when the warning is complete). \_\_\_\_\_

28. Search and secure the Angiography Room, complete the Kirk Key transfer. Press the SCAN SWITCH. \_\_\_\_\_

29. Press the PHOTON SHUTTER CLOSE button on the X17B2 logic unit, while announcing this on the radio. Photon Shutter does open \_\_\_\_\_

At the Front End: The top "beamline secure" light goes out within two seconds of pressing the button \_\_\_\_\_

At the Logic Unit: Photon shutter "closed" indicator light does not come on \_\_\_\_\_

PHOTON SHUTTER FAIL light comes on on logic unit \_\_\_\_\_

30. Open the Monochromator room and turn on the air supply. \_\_\_\_\_

Reset the PHOTON SHUTTER FAIL on the X17B2 logic unit. Photon Shutter does close \_\_\_\_\_

PHOTON SHUTTER FAIL does not reset w/o SOR key \_\_\_\_\_

31. Search the Monochromator room and Angiography room. Exercise the PHOTON SHUTTER by doing a search and pressing the SCAN SWITCH and the PHOTON SHUTTER BUTTON. \_\_\_\_\_

Photon Shutter does open \_\_\_\_\_

Photon Shutter does close \_\_\_\_\_

PHOTON SHUTTER FAIL light does not come on \_\_\_\_\_

Beamline secure light does not trip \_\_\_\_\_

This completes the test of the Interlock Reach Back feature in Set-Up Mode.

PATIENT MODE

APPI TEST PROCEDURE

Rev R 1/30/91

Date \_\_\_\_\_  
Test personnel \_\_\_\_\_  
\_\_\_\_\_

- 1. Before starting this test, the source of radiation must be locked out. X-RAY RING LOCKED OUT AND TAGGED \_\_\_\_\_  
OR  
X-17 B BEAMLINE LOCKED OUT AND TAGGED \_\_\_\_\_

In the following tests, shutter status lights on APPI panels are used to indicate shutter position. Step 12. verifies that these indicators are accurate.

PREPARATION:

- A. Use key to switch to PATIENT MODE. \_\_\_\_\_
- B. Reset if any faults are latched. \_\_\_\_\_
- C. Do a lamp test on all three panels \_\_\_\_\_

- 2. Kirk lock Reception Room and Fluoroscopy Room doors. Search hutch, pressing check station buttons and closing Physicians door. Complete the search and Kirk Key sequence as for SET-UP mode. After the sonolert stops sounding, observe the SEARCH TIMER light.  
SEARCH TIMER light on APPI panel does not light \_\_\_\_\_

Send a SHUTTER OPEN REQUEST using the computer program, IGT.  
SHUTTER OPEN REQUEST lights on APPI panel come on 1\_\_\_ 2\_\_\_  
Fast Shutters do not open 1\_\_\_ 2\_\_\_

Leave the SHUTTER OPEN REQUEST active. Push the SCAN SWITCH.  
SCAN SWITCH does not latch \_\_\_\_\_  
Photon Shutter does not open \_\_\_\_\_  
Fast Shutters do not open 1\_\_\_ 2\_\_\_

Deactivate the SHUTTER OPEN REQUEST. (IGT)

- 3. Remove Kirk Keys and unlock all three doors. Close but do not lock the Reception and Fluoroscopy Room doors. Exit the Angiography Room by the Physician's door, and close but do not lock. Turn the START SEARCH keyswitch on the operators panel.  
SEARCH TIMER light does NOT come on \_\_\_\_\_

Press the SCAN SWITCH.  
SCAN SWITCH ACTIVE does NOT come on A\_\_\_ B\_\_\_  
Photon Shutter does NOT open \_\_\_\_\_  
Send a SHUTTER OPEN REQUEST. Fast Shutters do not open 1\_\_\_ 2\_\_\_

Deactivate the SHUTTER OPEN REQUEST.

4. Enter the Angiography Room and turn the key in the Physicians check station adjacent to the Reception Room door. Leave the room, and immediately turn the key in the operators panel. (Within 30 sec). Do not close the door.

SEARCH TIMER light does not come on \_\_\_\_\_

Press the SCAN SWITCH.

SCAN SWITCH ACTIVE does NOT come on A\_\_\_ B\_\_\_

4a. Enter the Angiography Room and turn the key in the Physicians check station. Start timing with a stop watch. After 30 seconds, close the door.

READY light does not come on \_\_\_\_\_

Turn the key in the operators panel.

SEARCH TIMER light does not come on \_\_\_\_\_

Press the SCAN SWITCH.

SCAN SWITCH ACTIVE does NOT come on A\_\_\_ B\_\_\_

5. Enter the Angiography Room and turn the key in the Physicians check station adjacent to the Reception Room door. Leave the room and close the door. Turn the key in the operators panel.

SEARCH TIMER light does come on \_\_\_\_\_

Press and hold the SCAN SWITCH during the SEARCH TIMER ON cycle.

SCAN SWITCH ACTIVE does come on A\_\_\_ B\_\_\_

Photon Shutter does open \_\_\_\_\_

Send a SHUTTER OPEN REQUEST.

Fast Shutters do not open 1\_\_\_ 2\_\_\_

Release the SCAN SWITCH.

PHOTON SHUTTER closes \_\_\_\_\_

Again press the SCAN SWITCH.

SCAN SWITCH ACTIVE does not come on A\_\_\_ B\_\_\_

PHOTON SHUTTER does not open \_\_\_\_\_

Fast Shutters do not open 1\_\_\_ 2\_\_\_

Deactivate SHUTTER OPEN REQUEST.

NOTE: SET CHAIR MOTION TO 12 cm/sec, 5 cycles via the computer, using program CH2.

6. Do NOT activate the START SEARCH keyswitch. Start a chair cycle (via computer system - CH2) so that the motion light comes on and off, and SHUTTER OPEN REQUESTs are issued. Observe during the MOTION ON part of the cycle, when the SHUTTER OPEN REQUEST is also on:

Fast Shutters do not open 1\_\_\_ 2\_\_\_

Press and hold the SCAN SWITCH through one complete cycle of the chair.

SHUTTER OPEN REQUEST goes on and off 1\_\_\_ 2\_\_\_

Photon Shutter does not open \_\_\_\_\_

Fast Shutters do not open 1\_\_\_ 2\_\_\_

Release the SCAN SWITCH.



7. Do a complete search. Start the SEARCH TIMER from the operators panel. Start the chair motion for 5 cycles. Press the SCAN SWITCH, while the chair motion is on.

SHUTTER OPEN REQUEST goes on and off \_\_\_\_\_

Photon Shutter does open \_\_\_\_\_

Fast Shutters do open 1\_\_\_\_ 2\_\_\_\_

Release the SCAN SWITCH when the Fast Shutters are closed.

8. Run the chair motion without SHUTTER OPEN REQUESTS. (Use program CHO) Do a complete search. Start the SEARCH TIMER from the operators panel. Push and hold the SCAN SWITCH DURING the SEARCH TIMER cycle. No SHUTTER OPEN REQUESTS occur 1\_\_\_\_ 2\_\_\_\_

Photon Shutter does open \_\_\_\_\_

Exposure timer does not go on \_\_\_\_\_

Fast Shutters do not open 1\_\_\_\_ 2\_\_\_\_

Release the SCAN SWITCH.

9. Stop the chair motion for this step. Do a complete search. Start the SEARCH TIMER from the operators panel. Push and hold the SCAN SWITCH DURING the SEARCH TIMER cycle. Activate the SHUTTER OPEN REQUEST. (IGT)

SHUTTER OPEN REQUEST does come on \_\_\_\_\_

Photon Shutter does open \_\_\_\_\_

Exposure timer does go on \_\_\_\_\_

Fast Shutters do not open 1\_\_\_\_ 2\_\_\_\_

Release the SCAN SWITCH.

Photon Shutter closes \_\_\_\_\_

10. Re-start the chair motion with SHUTTER OPEN REQUESTS. (CH2). Do a complete search. Start the SEARCH TIMER from the operators panel. Open the Physicians door. Push and hold the SCAN SWITCH DURING the SEARCH TIMER cycle.

Photon Shutter does open \_\_\_\_\_

Exposure timer does go on after a SHUTTER OPEN REQUEST \_\_\_\_\_

Fast Shutters do not open 1\_\_\_\_ 2\_\_\_\_

Release the SCAN SWITCH.

11. Do a complete search. Start the chair motion. (CH2) Start the SEARCH TIMER from the operators panel. Push and hold the SCAN SWITCH DURING the SEARCH TIMER cycle. Observe the EXPOSURE TIMER when the first SHUTTER OPEN REQUEST occurs:

Photon Shutter opens \_\_\_\_\_  
Exposure timer does go on \_\_\_\_\_  
Fast Shutters open 1\_\_\_\_2\_\_\_\_

Release the SCAN SWITCH while the Shutters are in the CLOSED part of the cycle.

Photon Shutter closes \_\_\_\_\_  
Fast Shutters stay closed on the next cycle 1\_\_\_\_2\_\_\_\_  
Once again push the SCAN SWITCH.

Photon Shutter does not open \_\_\_\_\_  
Fast Shutters do not open 1\_\_\_\_2\_\_\_\_

Release the SCAN SWITCH.

12. Remove the cover on the Fast Shutters enclosure in the Monochromator Room.

Observe that the FAST SHUTTER 1 CLOSED light is on \_\_\_\_\_

Manually rotate Fast Shutter 1 slightly.

FAST SHUTTER 1 CLOSED light goes out \_\_\_\_\_

Continue rotation of Fast Shutter 1 until it is fully open.

FAST SHUTTER 1 OPEN light goes on \_\_\_\_\_

Release Fast Shutter 1.

Observe that the FAST SHUTTER 2 CLOSED light is on \_\_\_\_\_

Manually rotate Fast Shutter 2 slightly.

FAST SHUTTER 2 CLOSED light goes out \_\_\_\_\_

Continue rotation of Fast Shutter 2 until it is fully open.

FAST SHUTTER 2 OPEN light goes on \_\_\_\_\_

Release Fast Shutter 2.

Observe that the FAST SHUTTER 2 CLOSED light is on \_\_\_\_\_

Replace the cover on the Fast Shutters enclosure. \_\_\_\_\_

## INTERLOCK FAULT CHECKS

### STOP BUTTONS

Open the ANGIOGRAPHY ROOM.

Note: RESET after each fault at the APPI panel and at the HUTCH LOGIC PANEL, unless noted differently.

13. Press each STOP button in turn.

Stop button fault (1) \_\_\_\_\_  
Summary fault A \_\_\_\_\_ B \_\_\_\_\_  
Hutch Logic Emerg. Stop fault \_\_\_\_\_

Stop button fault (2) \_\_\_\_\_  
Summary fault A \_\_\_\_\_ B \_\_\_\_\_  
Hutch Logic Emerg. Stop fault \_\_\_\_\_

Operators panel Stop button fault (3) \_\_\_\_\_  
Summary fault A \_\_\_\_\_ B \_\_\_\_\_

Do not reset this fault.

14. Do NOT reset the fault at the APPI panel. Do a complete search. Turn the SEARCH START keyswitch, then press the SCAN SWITCH.

Search Timer does not operate \_\_\_\_\_  
Scan switch does not operate \_\_\_\_\_

15. Reset faults. Do a complete search. Start the S/R timer. (SEARCH TIMER) Push STOP button after S/R timer starts.

S/R timer terminates \_\_\_\_\_

Stop button fault \_\_\_\_\_  
Summary fault A \_\_\_\_\_ B \_\_\_\_\_

Do NOT reset these faults.

16. Activate SHUTTER OPEN REQUEST. (IGT)

SHUTTER OPEN REQUEST comes on 1 \_\_\_\_\_ 2 \_\_\_\_\_

Fast Shutters do not open 1 \_\_\_\_\_ 2 \_\_\_\_\_

Deactivate SHUTTER OPEN request.

Reset faults.

17 Do complete operational sequence with the chair in motion, and the SHUTTER OPEN REQUEST active. Observe during the OPEN REQUEST part of the cycle:

Fast Shutters do open 1\_\_\_ 2\_\_\_  
Press STOP button on operators panel:  
Fast Shutters close 1\_\_\_ 2\_\_\_  
Photon shutter closes \_\_\_\_\_  
Stop button fault \_\_\_\_\_  
Summary fault A\_\_\_ B\_\_\_

Reset faults. Deactivate chair motion and SHUTTER OPEN request.

18. Throw STOP BUTTON A test switch to test position.  
Photon shutter enable light goes out \_\_\_\_\_  
STOP BUTTON INTERLOCK GO A goes out \_\_\_\_\_  
STOP BUTTON FAULT goes on \_\_\_\_\_  
SUMMARY FAULT A goes on \_\_\_\_\_  
SUMMARY GO B remains green \_\_\_\_\_

Return test switch A to the active position. Reset fault.

19. Throw STOP BUTTON B test switch to test position.  
Photon shutter enable light goes out \_\_\_\_\_  
STOP BUTTON INTERLOCK GO B goes out \_\_\_\_\_  
STOP BUTTON FAULT goes on \_\_\_\_\_  
SUMMARY FAULT B goes on \_\_\_\_\_  
SUMMARY GO A remains green \_\_\_\_\_

Return test switch B to the active position. Reset fault.

## INTERLOCK FAULT CHECKS

### DOORS

20. Place switch holders on appropriate door switches (4 for each door section). Do complete operational sequence with the chair in motion, (CH2) and the SHUTTER OPEN REQUEST active. During a part of the cycle when the Fast Shutters are OPEN, remove switch holder from APPI switch 1. Observe indicator lights and check off. Replace all holders and RESET FAULTS to prepare for next switch test. Repeat this sequence for each No. 1 switch.

APPI Door Switch 1	PHYS	RECEP MAIN	RECEP AUX	FLOUR MAIN	FLOUR AUX
Fast Shutter 1 closes	_____	_____	_____	_____	_____
Fast Shutter 2 closes	_____	_____	_____	_____	_____
Photon Shutter closes	_____	_____	_____	_____	_____
Door fault lights	_____	_____	_____	_____	_____
Summary Fault A lights	_____	_____	_____	_____	_____

21. Repeat 19. for Door switch 2.

APPI Door Switch 2	PHYS	RECEP MAIN	RECEP AUX	FLOUR MAIN	FLOUR AUX
Fast Shutter 1 closes	_____	_____	_____	_____	_____
Fast Shutter 2 closes	_____	_____	_____	_____	_____
Photon Shutter closes	_____	_____	_____	_____	_____
Door fault lights	_____	_____	_____	_____	_____
Summary Fault B lights	_____	_____	_____	_____	_____

Remove all doorswitch holders. Check operation of all four switches on each door. Open each door slowly and listen for a distinct click for each switch.

APPI doorswitch 1	_____	_____	_____	_____	_____
APPI doorswitch 2	_____	_____	_____	_____	_____
Hutch logic doorswitch 1	_____	_____	_____	_____	_____
Hutch logic doorswitch 2	_____	_____	_____	_____	_____

### INTERLOCK FAULT CHECKS

#### SEQUENCE FAULTS

Reset faults, and close all doors.

22. Do a complete search. Start the S/R timer from the operators panel. Push and hold the SCAN SWITCH DURING the S/R timer cycle. Start the chair motion/SHUTTER OPEN REQUEST cycle (computer program CH2). Release the SCAN SWITCH when the shutters are open.

Fast Shutters close 1 \_\_\_ 2 \_\_\_  
 Summary fault A \_\_\_ B \_\_\_  
 Scan switch fault \_\_\_\_\_

Reset faults.

23. Set the chair motion speed for 12 cm/s, and the pulse width thumbwheels on the digital panel for 4. Do a complete search.

Start the S/R timer from the operators panel. Push and hold the SCAN SWITCH during the S/R timer cycle. Start the chair motion/SHUTTER OPEN REQUEST cycle. When the shutters are open, quickly turn thumbwheel A to 2:

Fast Shutters close 1 \_\_\_ 2 \_\_\_  
 Chair motion fault \_\_\_\_\_  
 Summary fault A \_\_\_ B \_\_\_  
 Logic fault \_\_\_\_\_  
 Fast Permit SS1 light goes out \_\_\_\_\_  
 Chair Intlk fault A \_\_\_\_\_

Fast Shutters remain closed on subsequent cycles 1 \_\_\_ 2 \_\_\_  
 Reset faults and reset thumbwheel A to 4.

24. Repeat 23., but with thumbwheel switch B.

Fast Shutters close 1 \_\_\_ 2 \_\_\_

Chair motion fault \_\_\_\_\_

Summary fault A \_\_\_ B \_\_\_

Logic fault \_\_\_\_\_

Fast Permit SS2 light goes out \_\_\_\_\_

Chair Intlk fault B \_\_\_\_\_

Fast Shutters remain closed on subsequent cycles 1 \_\_\_ 2 \_\_\_

Reset faults and reset thumbwheel B to 10.

NOTE: In steps 25 and 26, if the Exposure Timer times out when the shutters are not open, no Exposure Timer fault will occur.

The thumbwheel must be changed slightly and the test repeated.

25. Set Exposure timer A to 11 seconds and Exposure timer B to 21 seconds. Repeat scan cycle as above except hold the SCAN SWITCH until the exposure timer times out.

Fast Shutters close 1 \_\_\_ 2 \_\_\_

EXPOSURE TIMER ON A goes out \_\_\_\_\_

EXPOSURE TIMER ON B stays on several seconds longer \_\_\_\_\_

Exposure Timer fault \_\_\_\_\_

Summary fault A \_\_\_ B \_\_\_

Logic fault \_\_\_\_\_

26. Repeat 25., but with Exposure timer A at 21 seconds and Exposure timer B at 11 seconds.

Fast Shutters close 1 \_\_\_ 2 \_\_\_

EXPOSURE TIMER ON B goes out \_\_\_\_\_

EXPOSURE TIMER ON A stays on several seconds longer \_\_\_\_\_

Exposure Timer fault \_\_\_\_\_

Summary fault A \_\_\_ B \_\_\_

Logic fault \_\_\_\_\_

27. With the Exposure Timer thumbwheels set to the same time (e.g. 14 seconds) run through the system sequence, but hold the Scan Switch on until the Exposure Timer times out. If it times out when the Fast Shutters are CLOSED, change the timers and repeat the entire sequence until the Exposure Timer times out when the Fast Shutters are OPEN. Time with a stop watch.

Exposure Timer times out when SS1 & SS2 are OPEN \_\_\_\_\_

Photon Shutter closes \_\_\_\_\_

Fast Shutters close 1 \_\_\_ 2 \_\_\_

Exposure Timer fault \_\_\_\_\_

Summary fault A \_\_\_ B \_\_\_

Time in seconds equals thumbwheel setting \_\_\_\_\_

28. Set Exposure Timer thumbwheels to the same time, but one or two seconds different from step 27, so time out occurs when the Fast Shutters are NOT open. Change and repeat sequence until this is achieved. Hold Scan Switch on until the Exposure Timer times out. Time with a stop watch.

Photon Shutter does not close \_\_\_\_\_  
Fast Shutters do not open on subsequent cycles 1\_\_\_\_2\_\_\_\_  
Time in seconds equals thumbwheel setting\_\_\_\_\_

#### AUXILIARY TEST SWITCHES

29. Throw the Logic Interlock Bypass switch to TEST. Throw the SS1 OPEN REQUEST test switch to the test position. Do the entire system operation sequence (CH2) including pressing the SCAN SWITCH.

Photon Shutter does not open \_\_\_\_\_  
Fast Shutter 1 does not open \_\_\_\_\_  
Fast Shutter 2 does open \_\_\_\_\_

Return the SS1 OPEN REQUEST test switch to the normal active position.

30. Repeat 29., except use the SS2 OPEN REQUEST switch.

Photon Shutter does not open \_\_\_\_\_  
Fast Shutter 1 does open \_\_\_\_\_  
Fast Shutter 2 does not open \_\_\_\_\_

Return all switches to the normal active position.

31. Throw the Logic Interlock Bypass switch to the Active position. Set the SS1 OPEN REQUEST switch to test. Send a SHUTTER OPEN REQUEST. (IGT)

SS1 OPEN REQUEST does not light \_\_\_\_\_  
SS2 OPEN REQUEST does light \_\_\_\_\_  
Logic fault \_\_\_\_\_  
Summary fault A\_\_\_\_B\_\_\_\_

Deactivate request, reset faults.

32. Repeat 31., but with SS2 OPEN REQUEST test switch.

SS1 OPEN REQUEST does light \_\_\_\_\_  
SS2 OPEN REQUEST does not light \_\_\_\_\_  
Logic fault \_\_\_\_\_  
Summary fault A\_\_\_\_B\_\_\_\_

Return all test switches to the active position.



33. Throw the SCAN SWITCH A test switch to the test position.

Do the entire system operation sequence, including pressing the SCAN SWITCH.

Photon Shutter does not operate \_\_\_\_\_  
Scan switch A does not operate \_\_\_\_\_  
Scan switch B does operate \_\_\_\_\_

Return the SCAN SWITCH A test switch to the active position.

34. Repeat 33., except throw the SCAN SWITCH B test switch to the test position.

Photon Shutter does not operate \_\_\_\_\_  
Scan switch A does operate \_\_\_\_\_  
Scan switch B does not operate \_\_\_\_\_

Return the SCAN SWITCH B test switch to the active position.

35. Throw the CLOCK FAULT A test switch to the test position.

Fast Permit SS1 light goes out \_\_\_\_\_  
Logic Intlk fault \_\_\_\_\_  
Summary Fault A \_\_\_\_\_ B \_\_\_\_\_  
Clock Fault A \_\_\_\_\_

Return the CLOCK FAULT A switch to the active position.

36. Throw the Logic Interlock Bypass switch to the test position. Do an operational sequence. One person observes the SS lights, while the other throws the CLOCK FAULT A switch to the test position WHILE THE SHUTTERS ARE OPEN.

FAST PERMIT 1 light goes out \_\_\_\_\_  
SS1 closes immediately \_\_\_\_\_  
SS2 continues to cycle \_\_\_\_\_  
Clock fault A \_\_\_\_\_

Reset faults.

Return the CLOCK FAULT A switch to the active position.

37. Repeat 35., except throw the CLOCK FAULT B test switch to the test position.

Fast Permit SS2 light goes out \_\_\_\_\_  
Logic Intlk fault \_\_\_\_\_  
Summary Fault A \_\_\_\_\_ B \_\_\_\_\_  
Clock Fault B \_\_\_\_\_

Return the CLOCK FAULT B switch to the active position.

38. Repeat 36., but with CLOCK FAULT B switch.

FAST PERMIT 2 light goes out \_\_\_\_\_  
SS2 closes immediately \_\_\_\_\_  
SS1 continues to cycle \_\_\_\_\_  
Clock fault B \_\_\_\_\_

Reset faults, return all switches to active positions.

39. Throw the ENCODER DISABLE A test switch to the test position.

Throw the LOGIC INTERLOCK BYPASS switch to the test position.

Close the door. Do a complete operational sequence.

Chair motion fault \_\_\_\_\_  
Chair Intlk fault A \_\_\_\_\_  
Fast Permit SS1 lamp goes out \_\_\_\_\_  
Summary fault A \_\_\_\_\_

Return the ENCODER DISABLE A test switch to the active position.

40. Repeat 39., but for the ENCODER DISABLE B switch.

Chair Motion fault \_\_\_\_\_  
Chair Intlk fault B \_\_\_\_\_  
Fast Permit SS2 lamp goes out \_\_\_\_\_  
Summary fault B \_\_\_\_\_

Return the ENCODER DISABLE B test switch to the active position.

41. Throw the FAST PERMIT SS1 test switch to the test position. Set the chair motion speed for 12 cm/s, and the pulse width thumbwheels on the digital panel for 4. Do a complete operational sequence. When the shutters are open, quickly turn thumbwheel A to 2:

Fast Shutters close 1 \_\_\_ 2 \_\_\_  
Chair motion fault \_\_\_\_\_  
Summary fault A \_\_\_\_\_  
Logic fault does not light \_\_\_\_\_  
Fast Permit SS1 light stays on \_\_\_\_\_  
Chair Interlock fault A \_\_\_\_\_

Return the FAST PERMIT SS1 switch to the active position. Reset faults and reset thumbwheel A to 4.

42. Throw the FAST PERMIT SS2 test switch to the test position. Repeat 41. sequence. When the shutters are open, quickly turn thumbwheel B to 2:

Fast Shutters close 1   2    
Chair motion fault             
SUMMARY FAULT B             
Logic fault does not light             
Fast Permit SS2 light stays on             
Chair Interlock fault B           

Return the FAST PERMIT SS2 switch to the active position. Reset  
faults and reset thumbwheel B to 12.

43. Leave the LOGIC INTERLOCK BYPASS switch in the test position. Set Exposure timer A to 11 seconds and Exposure timer B to 21 seconds. Repeat the complete scan cycle, except hold the SCAN SWITCH until the exposure timer times out.

Exposure Timer fault             
SUMMARY FAULT A             
SUMMARY GO B remains green           

Reset faults.

44. Leave the Logic Interlock Bypass switch in the test position. Set Exposure timer A to 21 seconds and Exposure timer B to 11 seconds. Repeat scan cycle as above except hold the SCAN SWITCH until the exposure timer times out.

Exposure Timer fault             
SUMMARY FAULT B             
SUMMARY GO A remains green           

Return the LOGIC INTERLOCK BYPASS switch to the active position.

45. Set the thumbwheel switches to the nominal positions:

Exposure Timer A - 25        B - 25         
Chair Motion A - 12        B - 12

46. Return all test switches to the active mode:

On the RELAY PANEL:

STOP BUTTON A \_\_\_\_\_  
STOP BUTTON B \_\_\_\_\_  
LOGIC INTERLOCK BYPASS \_\_\_\_\_  
SS1 OPEN REQUEST \_\_\_\_\_  
SS2 OPEN REQUEST \_\_\_\_\_  
SS1 FAST PERMIT BYPASS \_\_\_\_\_  
SS2 FAST PERMIT BYPASS \_\_\_\_\_  
SCAN SWITCH A \_\_\_\_\_  
SCAN SWITCH B \_\_\_\_\_

On the DIGITAL PANEL:

CLOCK FAULT A \_\_\_\_\_  
CLOCK FAULT B \_\_\_\_\_

On the CHAIR:

ENCODER A \_\_\_\_\_  
ENCODER B \_\_\_\_\_

TEST OF REACHBACK FEATURE (Patient Mode)

CAUTION !!

During this portion of the test it is necessary to enable beamline X-17B.

NO SWITCH HOLDERS OR OTHER BYPASSES MAY BE USED DURING THIS PART OF THE TEST, SINCE IT WOULD BE POSSIBLE TO BRING BEAM INTO THE AREA. It is possible to do the test without opening the X-17B safety shutter. However, if the shutter is opened, beam will come into the angiography area, and the x-ray ring will trip when the test is conducted.

47. If X-17B1 cannot be made safe for beam (missing shielding etc) then the test may be conducted only if the x-ray ring has been tagged off as when regular beamline interlock tests are done.

X-ray ring interlock is tagged off \_\_\_\_\_

OR

X-17B is safe for beam \_\_\_\_\_

48. Verify that all door switch holders have been removed and switches tested for proper function. (step 21 above)

Verify that all test switches are returned to the active mode. \_\_\_\_\_  
(step 46 above) \_\_\_\_\_

49. Search and secure the Transport hutch. Make sure that the backstop in the B1 hutch is in the out-of-beam position. Search and secure the B1 hutch. Put X-17B1-B2 "on line" (lockout key in place and CRSC keys enabled). Open monochromator hutch. Send an observer with a radio to the front end disconnect panel at the sawtooth. Verify that the "beamline secure" indicator lights for X-17B1 are out. \_\_\_\_\_

50. Close the air supply valve for the photon shutter. Search the mono hutch. The beamline secure lights come on (one light comes on when the door is closed, the other comes on when the warning is complete). \_\_\_\_\_

51. Search the Angiography Room, using the physician's key and closing the doors. Do not lock the doors or do the Kirk Key transfer. Complete the search with the physician's key at the operator's panel. Press and hold the SCAN SWITCH.

Photon Shutter does open \_\_\_\_\_

52. Release the SCAN SWITCH, while announcing this on the radio.  
At the Front End:

The top "beamline secure" light goes out within two seconds of releasing the switch \_\_\_\_\_

At the Logic Unit:

Photon shutter "closed" indicator light does not come on \_\_\_\_\_

PHOTON SHUTTER FAIL light comes on on logic unit \_\_\_\_\_

53. Open the Monochromator room and turn on the air supply.

Photon Shutter does close \_\_\_\_\_

Reset the PHOTON SHUTTER FAIL on the X17B2 logic unit.

PHOTON SHUTTER FAIL does not reset w/o SOR key \_\_\_\_\_

54. Search the Monochromator room and Angiography room. Exercise the PHOTON SHUTTER by pressing and releasing the SCAN SWITCH.

Photon Shutter does open \_\_\_\_\_

Photon Shutter does close \_\_\_\_\_

PHOTON SHUTTER FAIL light does not come on \_\_\_\_\_

Beamline secure light does not trip \_\_\_\_\_

This completes the test of the Interlock Reach Back feature in Patient Mode.