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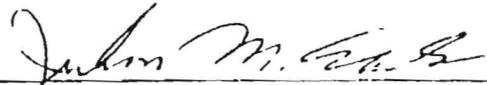
## SAFETY MANUAL

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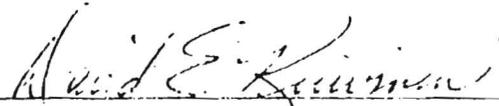
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION  
LEWIS RESEARCH CENTER

SIXTY-NINE INCH CYCLOTRON FACILITY  
SAFETY MANUAL

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## I. INTRODUCTION

### A. Statement of Scope

Section I of this manual defines the purpose of the Cyclotron Safety Manual and the problems toward which it is directed.

Section II defines the circumstances governing and the maximum permissible radiation exposures to which personnel may be subjected.

Section III is a description of the various safety devices which have been incorporated in the operation of the Cyclotron Facility in order to insure personnel safety. These include permissive devices which prohibit operation in an unsafe condition, monitoring devices which permit an indirect evaluation of hazards, warning devices to prevent inadvertent exposure of personnel, and equipment to prevent hazardous situations.

Section IV defines the duties and functions of Cyclotron personnel and procedures for visitors.

Section V sets forth the approved procedures governing the operation and experimental utilization of the Cyclotron Accelerator.

Section VI describes procedures applicable to the Cleveland Clinic Neutron Therapy program.

### B. Purpose

The purpose of this manual is to provide rules and regulations for the protection of personnel against radiation and other hazards arising out of the operation of the NASA Lewis Sixty-nine Inch Cyclotron Facility. The manual may not be circumvented or relaxed in any manner without prior approval by Health Physics and the Area 6 Safety Committee. It is expected, however, that various modifications will occur in the Cyclotron and the equipment described in this manual. Supplements will be added to this manual to describe these changes. Responsibility for the safe operation of the Cyclotron Facility resides with the facility supervisor, who may delegate this responsibility to appropriate personnel in the matters and manners defined herein. This manual provides some operational information but is intended to be definitive only in areas of personnel safety.

### C. Cyclotron Facility

The layout and location of safety devices are shown in Figure 1. The restricted areas to which access is controlled are:

## 1. Radiation Areas

Cyclotron vault, skylight area, hot storage area, hallway connecting skylight area with neutron control room and treatment room. In addition, when valve BV11 is open, the treatment room, magnet house, and the cyclotron mound area enclosed by a security fence.

## 2. Controlled Areas

Hallway between cyclotron control room and skylight area, rear section of equipment room between cyclotron hallway and room 13, room 13, and room 16.

Radiation area means an area, accessible to personnel, in which there exists radiation at such levels that a major portion of the body could receive in any one hour a dose in excess of 5 millirem, or in any 5 consecutive days a dose in excess of 100 millirem.

Controlled area means an area where the primary hazard is more likely to occur from radioactive contamination than from whole body radiation exposure.

## D. Cyclotron Performance Capabilities and Hazards

The cyclotron accelerates protons, deuterons, alpha particles, and  $^3\text{He}$  particles as follows:

<u>Particle</u>	<u>Energy (MEV)</u>	<u>Beam Intensity (uA)</u>
Proton	10-55	50
Deuteron	12-25	50
Alpha	24-55	50
$^3\text{He}$	15-85	50

The intensities given for the beam are for the present estimates based on the experience of users of similar machines. For many applications less intense beams will be required. Beams more intense than approximately two times the quoted currents are probably not possible.

Unless authorized by the facility supervisor, the particle beams are confined to the vacuum pipes and chambers and do not constitute a direct radiation hazard. Secondary production of neutrons and gamma rays constitutes the primary radiation hazard, and most of the provisions of this manual are designed to prevent accidental exposure to this radiation. Radiation levels may be as high as

several hundred R/hour in the cyclotron vault during operation. A lesser hazard results from the production of radioisotopes in the materials of the beam transport system upon which the beam impinges. Most of these materials are chosen to produce only short-lived isotopes, however, this is not always possible. The amounts of direct and residual radioactivity produced in areas outside of the cyclotron vault are approximately an order of magnitude less than those in the vault.

The principal electrical hazards are the electrostatic deflector power supply, the RF amplifier power supply, and the various small high-voltage power supplies used in the experimental program.

## II. RADIATION PROTECTION GUIDES

- A. The Radiation Protection Guide (RPG) is defined as "the radiation dose which should not be exceeded without careful consideration of the reason for doing so."

Every effort shall be made to encourage the maintenance of radiation doses as far below this guide as practicable.

- B. The following RPG levels have been derived, in part, from the Nuclear Regulatory Commission Regulations.

1. The RPG in restricted areas for personnel 18 years of age or more is 1.25 rems per calendar quarter or 100 millirems per week.
2. The RPG in restricted areas for personnel under 18 years of age is 125 millirems per calendar quarter or 10 millirems per week.
3. Unbadged visitors are permitted to tour the facility provided they are not likely to receive in any calendar quarter a dose in excess of 312 millirems for persons 18 years of age or more and 62 millirems for persons under 18 years of age.

- C. An experimental participant shall not knowingly permit himself or any person for whom he is responsible to be unnecessarily exposed to radiation from the Cyclotron or radioactive material contained in the Cyclotron Facility or to be exposed in excess of the limits specified in B. Any suspected overexposure, loss, damage, or suspected contamination to individuals or personnel monitoring devices shall be promptly reported to Health Physics and the Area 6 Safety Committee.

- D. When exposure rates in work areas exceed 2 mR/hr, gamma sensitive survey instruments and self-reading pen dosimeters are to be used at all times to keep personnel exposure levels below the limits set forth in B. Typical combinations of dose rate and maximum allowable occupancy time are posted in the control room.

- E. Posting of radiation warning signs shall be done in accordance with Health Physics procedures as stated in the Radiation Protection Program Manual.

- F. Any person who observes an incident involving overexposure of personnel to radiation due to a spill or loss of control of radioactive material shall report the incident by (a) dialing PAX-3190 and (b) notifying the Radiation Safety Officer (PAX-4192 or 8536).

Fires or injuries to personnel in areas where radioactive materials are used shall be reported by dialing PAX or PBX 17. Reporting procedures to be followed after this initial notification are outlined in the Radiation Protection Program Manual, Section V.F., Emergency Procedures. (See Chapter 16, Part A, Lewis Occupational Safety Manual.)

- G. Contamination of work areas, equipment, and protective clothing shall be controlled in accordance with procedures established in the Radiation Protection Program Manual.
- H. Target assemblies and other items to be irradiated which contain radioactive material shall be checked for contamination by Health Physics before being taken into the Cyclotron Facility.

III. SAFETY EQUIPMENT (The locations of the various items listed below are shown on fig.1.)

A. Radiation Monitors

1. Cyclotron Room Monitor

A Tracerlab area monitor gamma detector is located in the Cyclotron room. It is capable of detecting radiation up to the level of 10,000 mr/hr, with a meter readout in the control room. Both the detector and the control room readout are equipped with warning lights which are activated if the radiation level exceeds a preset value.

2. Hallway Monitor

A sensitive Eberline Instrument Corporation beta-gamma thin window Geiger detector is located in the hallway leading from the Cyclotron room area. It produces an audible "click" as well as a metered output having a full-scale sensitivity of 500 CPM. It is used to monitor all personnel and equipment leaving the area.

3. Rear Hall Monitor

A neutron-sensitive monitor is located in the rear hallway, outside of the treatment room. It is capable of measuring radiation levels up to 8 R/hr.

4. Pocket "Beepers"

Pocket-size Geiger counters are provided for personnel entering radiation areas to provide an audible indication of radiation fields. In a 10 mr/hr field, they beep once every ten seconds. Pocket-size Geiger counters are also available which measure accumulated exposure. These counters provide an audible signal for each millirem of gamma exposure.

5. Survey Meters

Gamma and beta sensitive (C.P. and Geiger) radiation survey meters are provided for more accurate area monitoring.

B. Interlocks and Warning Devices

1. Power Off and Beam Safe Controls

A BEAM SAFE switch located in the treatment room locks all beam stops closed so that no beam can enter the treatment

room. Large knob push buttons are located in the Cyclotron room and equipment room to permit emergency shutdown of the Cyclotron. The BEAM SAFE button located in the Cyclotron room disables the Cyclotron ion source so that no beam can be accelerated.

The POWER OFF buttons, located in the Cyclotron room and equipment room, disable the Master Power Switch so that no part of the Cyclotron can be operated with the exception of the vacuum system. BEAM SAFE switches and buttons and POWER OFF buttons must be reset in the same physical location where they were originally tripped, before operation can continue.

## 2. Cyclotron Vault Gate and Water Door

A gate and a water-filled shielding door across the entrance to the Cyclotron room prevent accidental radiation exposure due to unauthorized entry while the Cyclotron is in operation. When either the gate or water door is open, electrical interlocks permit either the RF system or the ion source to be operated, but not both simultaneously. A bell rings automatically in the Cyclotron room when the gate is closed to warn personnel that the interlocks no longer inhibit the acceleration of beam. Opening either the water door or the gate while beam is being accelerated will interrupt operation.

## 3. Fire Door Interlock

A limit switch on the fire door located outside the treatment room hallway is designed to prevent accidental exposure of personnel to radiation. If either BV21 or BV11 is open (implying that beam may be delivered to either the treatment room or the hot storage area), it will be impossible to open the beam shutter unless the fire door is reset. Reset requires that the door be closed and that one of the reset buttons (one located on each side of the door) be pushed following the closing. Opening the door while the shutter is open will cause the shutter to close.

## 4. Magnet House Interlock

The entrance to the magnet house (located above the treatment room) is equipped with a limit switch, such that when the door is opened, it will be impossible to open the beam shutters. If they are already open, they will be closed automatically by the opening of this door. The interlock does not function if valve BV11 is closed, thereby prohibiting the delivery of beam to the treatment room.

#### 5. Neutron Control Room Door Interlock

A limit switch on the neutron control room shielding door prevents opening any beam stop unless the neutron control room door is closed. Opening the door while the beam stops are open will cause the beam stops to close.

#### 6. Hallway Electric Eye

An electric eye located just outside the Cyclotron control room door, prohibits or interrupts delivery of beam to the hot storage-skylight area unless properly set. The interlock, once broken by the interruption of the light beam, will not permit the delivery of beam to be resumed until the reset button, located next to the light source for the eye, has been pressed. This interlock is not functional unless the vacuum system is so configured (BV21 open) that delivery of beam to these areas is possible.

#### 7. Magnet House Electric Eye

An electric eye located at the entrance to the shielding maze outside of the magnet house will inhibit or interrupt delivery of beam to the treatment room unless properly set. The interlock, once broken by interruption of the light beam will not permit delivery to be resumed until a reset button, located next to the eye, has been pressed. Again, this interlock is not functional unless BV11 is open.

#### 8. Audible Signals

All interlocked areas (magnet house, treatment room, skylight hot storage, Cyclotron room) are equipped with a warning bell which sounds when the last link in the interlock chain is completed and the delivery of beam to that area is permitted.

#### 9. Beam Shutters

Beam shutters are water-cooled, metal gates that interrupt the beam path. One is located just outside the Cyclotron and prevents beam from entering any part of the beam transport system. Two other shutters are located in those beam lines which lead to the treatment room (one in the vertical line, one in the horizontal line).

## 10. Status Lights

Lighted signs are located outside the Cyclotron entrance as well as in the Cyclotron room. These signs warn personnel of the main magnet status and the beam status so that proper precautions can be taken.

A lighted sign ("AREA SECURE") just outside the fire door informs personnel that the fire door interlock has been reset. A second sign at this point ("HIGH RADIATION AREA") is lighted if beam is being delivered to the treatment room.

A sign ("AREA SECURE") in the treatment room is lighted when all interlocks are set so that delivery of beam to the treatment room is possible. A second sign ("BEAM ON") is lighted when beam is being delivered.

A BEAM ON light is located on the Cyclotron control console, indicating that beam is being accelerated.

## C. Miscellaneous Safety Equipment

### 1. Intercom

#### a. Area Intercom

The area intercom is operative at all times, providing voice communication between the Cyclotron vault and the control room. The system consists of a "PAGE" channel, which provides telephone-to-loudspeaker communications, and five "IC" channels which provide telephone-to-telephone communications.

#### b. Neutron Control Room Intercom

A separate intercom system provides communication between the Cyclotron control room and the neutron control room, as well as between the neutron control room and the treatment room.

### 2. Fire Extinguishers

Fire extinguishers are placed in a number of locations (see fig.1) throughout the area. These locations are marked with signs. The condition and location of the extinguishers are checked weekly.

3. Cyclotron Vault Ventilation System

The Cyclotron room ventilation system is separate from that of the rest of the building. There is an inlet fan and an exhaust fan. The exhaust fan has a rated capacity of 5000 CFM. Normal operation is with the exhaust fan only.

4. Treatment Room Ventilation System

The treatment room has a separate explosion-proof exhaust system having a capacity of 2280 CFM. It is used continuously in normal operation.

5. Vacuum Cleaners

In the event that work must be done in the interior of the Cyclotron, a large vacuum cleaner is used to prevent radioactive dust from contaminating the Cyclotron vault. The exhaust of the vacuum cleaner is discharged to the outside after passing through an absolute filter.

6. First Aid Kit

A first aid kit is provided in the equipment room.

7. Scott Air Packs

Two units are provided for emergency situations involving a contaminated or poisonous atmosphere. One is placed in the hallway opposite the control room. The second unit is located in the hallway outside room 18. Packs will be inspected monthly for operating condition by the Material Development Service Section.

8. A Hot Storage Area

Ten caves equipped with three-inch lead doors are mounted in the wall of this area for the storage of items activated by the Cyclotron beam.

D. High Voltage Equipment

1. Electrostatic Deflector Power Supply

The deflector power supply furnished 140 KV at 15 MA. It is mounted on top of the Cyclotron yoke and is completely enclosed

in a steel tank, prohibiting access to the interior of the supply.

## 2. RF Power Supply and Amplifiers

The RF amplifier power supply furnished 17.5 KV at 30 amps. This supply is enclosed in a steel cabinet protected by a Kirk-Interlock System. The amplifiers themselves are located in the Cyclotron vault and are contained in boxes with microswitch-interlocked doors. Failure to close either of the doors disables the RF system and triggers an alarm light in the control room.

#### IV. DUTIES AND FUNCTIONS OF PERSONNEL

##### A. Facility Supervisor

The Facility Supervisor is in charge of the Cyclotron facility operation and sets the limits within which the accelerator may be operated. All exceptions must receive his prior approval. For brevity, the term Facility Supervisor will herein designate Dr. J. W. Blue or his alternate. At present F. R. Kebberly is designated as his alternate. The duties of the Facility Supervisor include:

1. Selection and supervision of the training of operators.
2. Certification of qualified operators.
3. Approval of work schedule for each shift.
4. Authorization of Cyclotron experimental programs and designation of personnel having the status of experimental participants.
5. Conduct periodic reviews and reevaluation of operational knowledge of experimental participants.
6. Prior authorization, as a necessary condition for action, of all proposed exceptions to normal operating procedures.
7. Authorization to run a beam in air.
8. Authorization to operate with personnel occupying a radiation area.
9. Authorization to operate with a malfunctioning or bypassed safety device. This authorization requires concurrence of Health Physics.

##### B. Operator

An OPERATOR is assigned for each working shift by the Facility Supervisor and has responsibility for ensuring the safe and proper usage of the Cyclotron and associated equipment. The duties of the operator are:

1. Provide for the personal safety of all experimental participants and visitors.
2. Assure proper operation of the accelerator and all associated equipment.

3. Conduct a personal check of the Cyclotron vault prior to securing the vault, with the exceptions listed in Section V-C.
4. Be responsible for security of the high-voltage permissive key against unauthorized use.
5. Be present during accelerator operation.
6. Authorize accelerator operation only when all normal operating equipment is performing properly unless Facility Supervisor makes an exception.
7. Inform all experimental participants of unauthorized activities and report repeated violators to the Facility Supervisor.
8. Supervise maintenance of operation logbook.
9. Inform all experimental participants of changes in normal operating procedure.
10. Instruct maintenance and repair personnel with regard to personnel safety.
11. Record the names and/or sponsor (in the case of large groups) of all visitors in the operational logbook.

#### C. Experimental Participants

The term EXPERIMENTAL PARTICIPANT applies to all of the following personnel when they participate in the operation or experimental utilization of the Cyclotron: Facility Supervisor, operator, operator trainee, experimental user, and repair and maintenance personnel. The following regulations will apply to all experimental participants.

1. One member of the crew must remain at the control console at all times during Cyclotron operation. For repairs in the Cyclotron vault, with the machine in operation, at least two persons are required to be present in the vault.
2. For simple adjustments or observations, only one person is required to be present in the vault provided another is at the Cyclotron control console and in voice communication.
3. Pocket dosimeters and film badges are to be worn at all times in radiation areas.
4. Pocket dosimeter readings must be recorded on the log sheets provided by Health Physics at least daily when used; before and after recharging; after every exposure that produces a detectable change.

5. The operator is in charge of personnel and accelerator safety and must be obeyed in such matters.
6. Equipment is to be used in the manner for which it was intended. This includes a specific prohibition of using personnel safety interlock devices as operational controls.
7. Unauthorized tampering with safety or operational equipment is prohibited. Repairs or modifications of the Cyclotron may only be made by personnel designated by the Facility Supervisor. At present this consists of the Cyclotron operators and Cyclotron mechanics.
8. Malfunction of any normal operational equipment is to be reported immediately to the operator.
9. Visitors must be referred to the operator for assignment of an escort, before entry to the Cyclotron restricted areas is permitted.
10. All equipment and material which is to be transferred from restricted areas (Radiation and Controlled Areas) to unrestricted areas shall be checked for radiation and contamination by Health Physics. Materials transferred from radiation areas to controlled areas shall be checked with area monitors either by Cyclotron personnel or by Health Physics.
11. During operation or standby condition, clearance must be obtained from the operator prior to entry into radiation areas.
12. Shipments of radioactive materials shall be reviewed and approved by Health Physics for compliance with applicable Government regulations. A record of each review shall be filed in the Health Physics office.
13. Equipment stored in the accelerator vault must be primarily intended for use in that area.
14. Food and drink may be consumed only in the control room portion of the Cyclotron Facility. Radioactive contaminated materials may not be taken into the control room.
15. When dose rates in work areas exceed 2 mr/hr, gamma-sensitive survey instruments will be used at all times, and self-reading pen dosimeters will be read frequently to keep exposure below the permissible level.
16. High-voltage terminals in the oscillator cabinet, oscillator power supply cabinet, or Cyclotron vacuum tank must be grounded before entry or inspection.

17. Occupancy of areas which have been contamination posted is prohibited until entry is authorized by HP.
18. Use of shoe covers and protective clothing is required for entry into contamination-posted areas. Eating, drinking, and smoking are not allowed in these areas.

#### D. Visitors

The term VISITOR includes all Lewis and non-Lewis personnel whose normal job assignment does not permit sufficient familiarity with the operation of the Cyclotron that they may be classified as experimental participants. Visitors' conduct and safety are the responsibility of the operator for the entire duration of their visit. He must also provide a badged escort for entry into a radiation area. Requirements for a visitor are as follows:

1. Visitors must be escorted in the restricted areas by an experimental participant at all times.
2. Visitors must receive clearance from the operator before entering the hall-skylight area. The entrances to this area are posted. Visitors may enter these areas without escort, but only after the restricted areas have been pointed out to them by the operator.
3. Unbadged visitors are permitted to tour the facility provided they are not likely to receive in any calendar quarter a dose in excess of the value given in II.B.3.
4. The escort will be responsible for assuring that the visitor's maximum radiation exposure does not exceed allowable limits.
5. Visitors will be required to wear shoe covers when permitted to enter areas of contamination posted by Health Physics.

## V. NORMAL OPERATING PROCEDURES

### A. Cyclotron Startup after Prolonged (Overnight) Shutdown

1. Operator inspects the log of the previous day for any malfunctions of the Cyclotron or safety equipment. Startup must stop if there are any safety malfunctions or serious machine malfunctions unless approval has been given by the facility supervisor.
2. Dosimeter and film badges must be worn.
3. Two operators or an operator and an experimental participant must be in the control room before beginning operations.
4. One or both operators will enter the Cyclotron vault, visually inspect for any obvious malfunctions, clear areas of personnel, secure the interlocked gate, and close the radiation shielding door unless frequent entry into the vault is planned.
5. Operator returns to the console and starts the normal starting sequence as specified in the Cyclotron manual.

### B. Cyclotron Startup after Short Shutdown (Less than Overnight)

Procedure is the same as A., if there has been a crew change since previous operation. Step 1 may be omitted if there has not been a crew change.

### C. Standby and Startup from Standby Condition

STANDBY is defined as that state in which most filaments and the main magnet are on, but no beam is accelerated. It is usually used to allow minor repairs or adjustments to be made in the Cyclotron vault. For purposes of safety, standby also requires that the control console remain manned by an operator. Operation reverts to shutdown if this is not observed.

1. If the Cyclotron vault has not been breached, operation may be started immediately.
2. Entry into the vault by experimental participants during standby is allowed only upon the explicit approval of the operator.
3. Startup after entry into the vault is as follows:

- a. Experimental participant who has entered the vault surveys area for unauthorized personnel and clears area if necessary.
- b. He secures interlocked gate and shielding door and immediately reports to the console.
- c. Normal operation is continued.

#### D. Operation with a Bypassed Safety Interlock

1. Authorization to operate with a bypassed safety interlock must be given by the Facility Supervisor and Health Physics before proceeding.
2. Circumstances of a bypassed interlock must be noted in the operational log and shall reflect the current status of the equipment at all times.
3. Operation with an interlock bypassed should be treated as an exceptional situation and, therefore, added precaution taken. Each electric eye or door equipped with an interlock shall be conspicuously posted with a warning sign which indicates the interlock has been bypassed.
4. Bypassed interlocks must be restored to their normal condition as soon as the immediate circumstance requiring their disenabement is no longer present.
5. Bypassed safety interlocks must be restored to their normal condition when the accelerator is shut down at the end of a shift.
6. In the situation in which accelerator operation spans two shifts without shutdown, the procedure outlined above must be followed as if a new situation requiring interlock bypass had been encountered except that the bypass connections do not have to be physically removed.

#### E. Overnight (or longer) Shutdown

1. De-energize accelerator.
2. Perform procedures for support equipment as appropriate to shutdown period.
3. Clear vault of all personnel and close vault gate and shielding door.
4. Remove (if applicable) safety interlock bypass connections.

F. Operation With Only an Operator Present

A single operator may operate the Cyclotron during periods other than normal business hours.

After operation of the Cyclotron has started, this operator may enter the Cyclotron for inspection purposes only.

## VI. NEUTRON THERAPY PROGRAM

### A. General

All participants in the neutron therapy program being carried out in conjunction with the Cleveland Clinic will abide by the safety regulations and guidelines set forth in this manual.

### B. Operating Procedures

Detailed descriptions of the therapy control system and procedure for proper operation of the system are documented in a neutron therapy operations manual which will be available in the neutron control room.

### C. Cleveland Clinic Personnel

Regular participants in the program (therapists, nurses, clinical physicists, technicians) will be considered "EXPERIMENTAL PARTICIPANTS" (Section IV.C of this manual) and will be subject to all the regulations described for such personnel, with the exception of their own personnel radiation monitoring, which shall be the responsibility of the Cleveland Clinic rather than Lewis Research Center.

### D. Visitors

Visitors escorted by Cleveland Clinic personnel shall be subject to all the regulations described in Section IV.D of this manual.

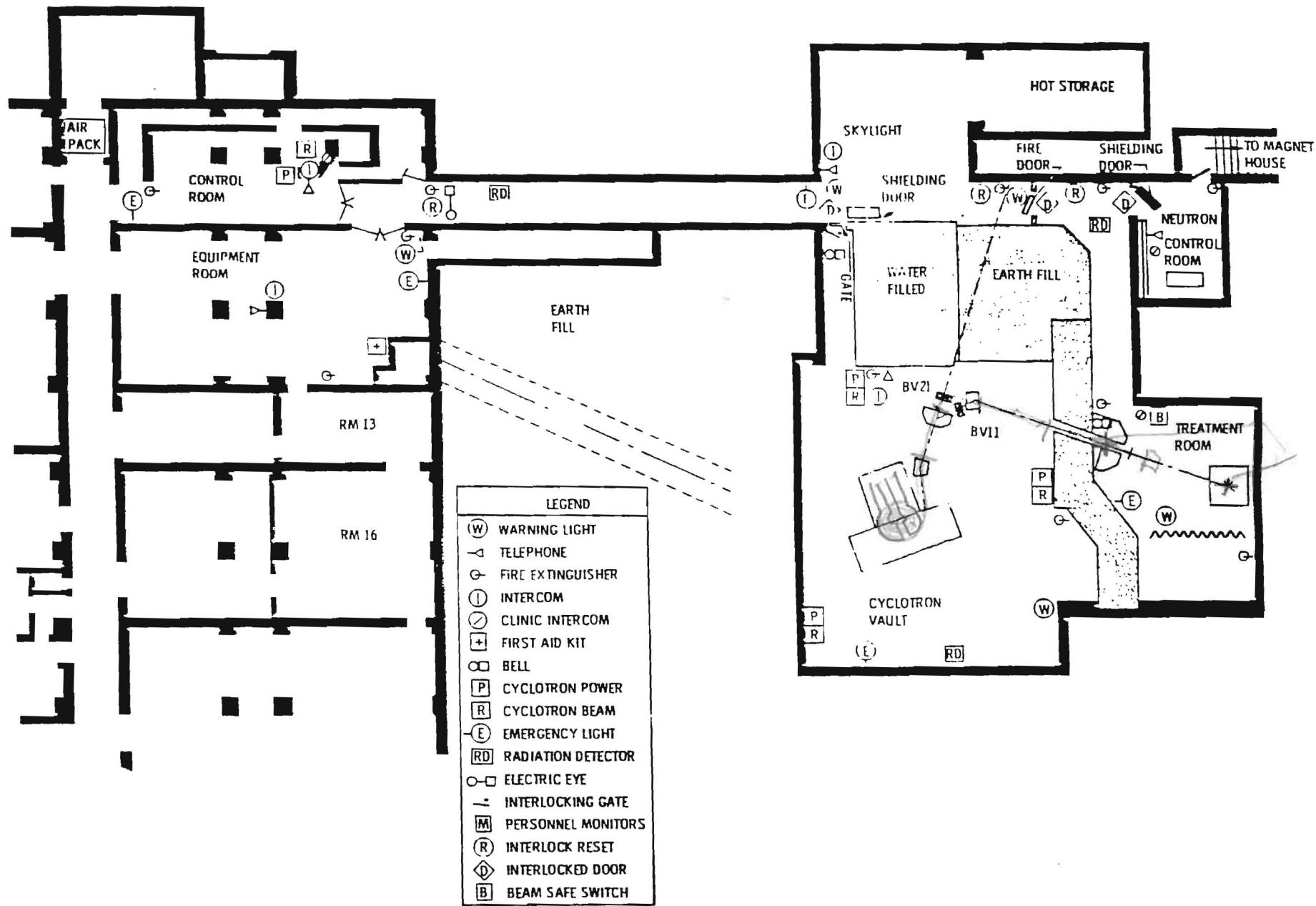


Figure 1. - Cyclotron Safety Manual.