Crocker Nuclear Laboratory User Radiation Safety Manual
Version: May 28, 2020

The UC Davis Crocker Nuclear Laboratory (CNL) operates a 76-inch cyclotron for research purposes. The purpose of this specification is to outline the basic requirements, personnel responsibilities, and the system for protection of personnel during the operation of the cyclotron.

This manual is intended for users[1] of the North Cave (charged particle beams) and South Cave (neutron beams). All users are expected to familiarize themselves with it. Particular attention should be paid to Section 4 ("Radiation Dosimetry and Dose Limits") and Section 11 ("User Access").

Users should address any questions they have to cyclotron staff prior to signing the required training attestation.

1. Requirements for Use Authorization

All projects involving the use or production of ionizing radiation at CNL must be authorized according to the Radiation Use Authorization Program prior to the commencement of the project. Final authorization of the CNL projects is delegated to the Campus Cyclotron Radiation Use Committee.

2. Procedure for Obtaining a CNL Radiation Use Authorization

A. All proposals for new projects, irradiations, and modifications for existing projects must be presented to the Associate Radiation Safety Officer for the initial review.

B. Each project will be evaluated by the Associate Radiation Safety Officer to assure that the necessary safety precautions are taken into account prior to submission to the campus Radiation Safety Officer and the Campus Cyclotron Radiation Use Committee, when necessary.

Note that there is a blanket authorization for general use of the Radiation Effects Line, so users of this line do not need to obtain individual authorizations.

3. Access to Areas of Crocker Nuclear Laboratory

Controlled Areas:

The following areas are designated controlled areas:

1. Main Vault: cyclotron enclosure.

2. North Cave: charged particle area. The vast majority of users use this area.

[1] In this context, "user" refers to anyone other than cyclotron staff, who are performing work at the cyclotron.

3. South Cave: usually used as an area for users to monitor their exposures in the North Cave; however, it can be interlocked and used for neutron beam.

- This area also included the Eye Therapy Room, which is separately interlocked, and described in a separate document.

3. Tunnel A and B: service areas beneath the cyclotron.

4. Vault Roof: area above the cyclotron, used for storage.

Entrance into controlled areas is restricted to authorized persons, with appropriate dosimetry, as discussed in the next section. With the exception of the North and South Caves, all users must be accompanied by cyclotron staff when entering controlled areas.

4. Radiation Dosimetry and Dose Limits

Radiation dosage is expressed in “gray” or “gad”, where 1 Gray (Gy) is defined as 1 Joule/kilogram of deposited energy and one Rad (R) is .01 Grays. In the context of health effects, we use the units “Sievert” or “rem” (Rad equivalent man), which weight to dose in Gray or Rad, respectively for different types of radiation according to their health impact relative to gamma and beta radiation. At CNL, and in most of the US, rem and millirem (.001 rem) are the most common units, which in most of the rest of the world, sievert (mSv, μSv, etc) are the most common.

To set the scale, the average person in the US receives about 620 mrem/year from a combination of sources including natural radioactive materials, radon, cosmic rays, and medical x-rays. Direct exposure to the proton or neutron beam at CNL would present a serious risk of dangerous radiation exposure; however, we have an interlock system to prevent this from occurring. On the other hand, there is some risk of exposure from “secondary activation”; that is, when samples or items in the room become radioactive from exposure to the beam. As discussed below, we take great steps to minimize this risk, and in fact, the majority of our users receive *no measurable radiation dose above background*.

A. Dosimetry

1. All persons who making unsupervised entry into a control area must register and be issued an appropriate dosimeter before entry is allowed.

2. Upon leaving, the dosimeter will be turned in.

3. During business hours, registration will be done at the Business Office or with the Cyclotron Operator in the Control Room. If entry is allowed through the rear door, registration is the responsibility of whoever granted entrance, or that person must escort the visitor to the Control Room or Business Office for registration.

4. Persons under the age of 18 are not allowed, except those persons under constant supervision of Crocker Nuclear Laboratory staff. Children under the age of 12 will not enter a controlled area.

5. During all other time periods, registration will be done by a Certified Cyclotron Operator or an authorized staff employee.

6. Individuals are groups may access control areas under the direct supervision of cyclotron staff without being issued individual dosimetry. In these cases, a digital dosimeter or dosimeters will be issued to the group, with at least one dosimeter per five people.

B. Radiation Dose Limits

In accordance with state law, every effort shall be made to maintain radiation doses by humans to levels that are as far below the appropriate regulatory limits as is reasonably achievable (ALARA). As a guide to assist in maintaining radiation doses ALARA, the following UC Davis Administrative Guidelines should not be exceeded.

During a calendar year either 1. or 2. will be in effect - whichever is most limiting.

1. Total Effective Dose Equivalent. 2.5 rem/year (25 mSv).

2. Committed Dose Equivalent to any organ other than the skin of the whole body or the lens of the eye. 25 rem/year (250 mSv)

3. A dose to the lens of the eye. 7.5 rem/year (75 mSv).

4. Shallow dose equivalent to the skin of the whole body. 25 rem/year (250 mSv).

5. Shallow dose equivalent to any extremity. 25 rem/year (250 mSv).

6. The radiation dose to a minor (under 18 years of age) shall be less than 10% of the above guidelines.

At CNL, every effort is made to keep exposures *far* below these limits, and in fact most users do not pick up a measurable dose.

After an exposure, users are not permitted to enter the North Cave until the ambient radiation levels have dropped below 20 mR/hr (see discussion below), after which they will continue to drop quickly.

If users are concerned about radiation exposure, they will be provided with digital dosimeters in addition to their radiation badges. These dosimeters provide instant feedback on radiation exposure. . These dosimeters provide instant feedback on radiation exposure with 0.1 mrem accuracy. In addition, for higher levels of exposure, the CNL staff may recommend ring dosimeters for the person handling the samples.

If proper procedures are followed, exposure to users will generally be kept to less than 1 mrem; however, users should understand that they might be working in areas with ambient exposures as high as 20 mR/hr for brief periods, and may handle samples as high as 50 mR/hr at a foot. If they are not comfortable with this, they should discuss their concerns with the Cyclotron staff.

5. Pickups and Deliveries

Non-Crocker Nuclear Laboratory personnel involved in pick-up and delivery in controlled areas must be registered, issued an appropriate dosimeter, and accompanied by a Crocker Nuclear Laboratory staff employee.

6. Shipment of Radioactive Material from Crocker Nuclear Laboratory

A. Radioactive material will be shipped from Crocker Nuclear Laboratory or UC Davis Environmental Health & Safety, in accordance with all appropriate transportation regulations.

B. Crocker Nuclear Laboratory will obtain from the proposed recipient a copy of recipient's radioactive material license.

C. All radioactive material shipment preparations will be perform only by personnel who have been trained in accordance with 49 CFR, Subpart H.

7. Crocker Nuclear Laboratory Environmental Monitoring

A. TLDs will be used to monitor specific areas within and the areas surrounding the Crocker Nuclear Laboratory to ensure that the radiation dose to members of the general public is kept below 100 mrem per year.

B. Environmental Health and Safety is responsible for the placement, retrieval, and analysis of the results. Any inconsistent or elevated readings shall be reported to the Campus Cyclotron Radiation Use Committee. All dosimetry results and investigations on inconsistent readings will be indefinitely maintained.

8. Responsibilities of Experimenters

Comply with the interlock procedures, safety procedures, and conditions and restrictions outlined in this specification and in the "conditions and restrictions" of the project's Radiation Use Authorization.

9. Cyclotron Interlock System

This section describes the safety interlock system of the cyclotron. User interaction with the interlock system is described in section 11.

A. The UC Davis 76 inch cyclotron uses an interlock system for the protection of personnel and users from direct machine radiation

B. Potentially hazardous areas with regard to direct machine operation consist of the following:

1. Upper and lower cyclotron vaults.

2. The north and south experimental caves.

3. The single access tunnel to the lower vault (tunnel B).

4. The rear confines of tunnel "A" with access openings into both the north and south experimental caves.

5. The eye therapy treatment room.

C. Crocker Nuclear Laboratory adheres to a 100% redundant component interlock philosophy.

D. Two independent parallel interlock chains each contain a switch at each of the above openings. These chains interlock the RF power amplifier plate power supply and the ion source arc power supply in two separate circuits.

E. Accidental exposure by entry into an active area with two interlocks, would require simultaneous failure of at least two components plus misjudgment of the operator and/or person entering the area. Additional protection from acceleration of a residual beam produced with the RF system or the ion source turned "off" is provided by a beam stop (stop 1) at the cyclotron exit which is automatically inserted when any interlocked door is opened.

F. Emergency and Safety Switches

1. Emergency scram or panic buttons are located at the inside of each personnel entrance to the vault and cave areas. Operation of any of these buttons prevents or stops production of the ionized beam.

2. As an added safety precaution, all hydraulic doors can be opened from the inside of the vault and caves by opening the accordion safety gate.

3. Safety buttons are also located at strategic positions within the same areas. All of the safety buttons must be operating in order to secure a specific area (vault or cave) for bombardment.

G. Indicator Lights

1. Lights are mounted above or near each entrance to a potentially hazardous area as well as in select locations, to indicate machine operational status.

2. Yellow lights indicate the area is open or all safety buttons have not been set up. They indicate a non-operative condition for the production of ionized beam but do not indicate the presence of residual activity.

3. Red lights above the vault doors and beside the lower vault entrance indicate that the cyclotron main magnet is on. Flashing red lights mounted on the magnet yoke give the same indication.

4. Flashing magenta lights at each entrance indicate that the cyclotron is operating and bombardment may be occurring in the area. The significance of each light is inscribed on it and is quite legible when the light is in operation.

H. Sonic Warning Devices

1. Two primary sonic devices are employed to provide a warning of impending machine operation and as an indication of operation.

2. One is a Klaxon type signal that is audible in all hazardous areas. It is initiated automatically by completing the final operation to bring the machine on and lasts three seconds. A time-delay period of 30 seconds occurs before the contact for the power amplifier power supply or ion source arc power supply actually closes. Such a delay is designed to allow time for emergency action by anyone who is trapped in a bombardment area.

3. Closure of the interlocked contactor will coincide with the initiation, in the main bay, of a chime signal of approximately three second intervals that persists while the machine is in operation.

I. Only one beam line to a cave can be used. The channel selector logic is designed so that only one beam line (normally blocked by a beam plug) can be open at a time. A selection of a different beam line requires closure and automatically closes any previously selected line.

J. Beam plugs are interlocked to prevent opening of another beam line into a non-interlocked area. Breaking the interlock to an area with an open beam plug will automatically close that beam plug.

K. The beam line selector logic operates in conjunction with the door safety chain interlocks so as to allow access to any experimental caves, when beam is on in the main vault and all the beam plugs are closed.

L. Selection of a target line into the north cave allows access to the south cave and vice versa.

M. The entrance door to the Eye Therapy Room as well as the water door between the North and South caves is interlocked to respective beam plugs.

10. Communications

A. A paging and talk-back system is installed for communication between the control room and experimental caves.

B. Mounted in the rear control racks and beside each door to a hazardous area are meters that indicate the radiation level in the area. Logic is incorporated in the safety system so that the radiation warning light and horn in the area will respond if any interlock is broken while radiation exceeds a preset level.

11. User Access

This section describes interlocking and accessing the North Cave, which users generally carry out themselves, unsupervised.

Interlocking and accessing the South Cave will be performed by cyclotron staff at the request of the users.

A. Securing the North Cave.

1. Beginning at the time the first safety button in the cave is depressed, a pre-set maximum time interval is allowed for setting up all the remaining safety buttons, if there is more than one, and securing the entrance to the areas.

2. If the time required for complete operation is exceeded, the total sequence of securing the area must be repeated.

3. Additionally, the time interval limit and safety button positions are used to force a physical search for personnel in the area within a limited time period before securing the area. The search and securing of an area may be done by one person provided that he/she locks the entrance gate to prevent access of personnel during the search procedure.

B. Accessing the North Cave after Exposure

1. Researchers who wish to access the North Cave after exposing their sample should inform the Cyclotron Operators via the intercom system. The operators will inform them when they have disabled the beam.

2. Researchers should verify that the light over the rolling door displays "OK".

3. Researchers should not enter the area until the left of the door reads less than .02 R/hr (20 mR/hr).

4. Researchers should check their sample with the digital survey meter at a distance of 1 foot (30 cm). If it reads greater than 10 mR/hr, they should use gloves to handle it. If it reads greater than 20 mR/hr, they should consult with the Cyclotron staff before proceeding.

User Check List

1. Did you CHECK-IN with the Cyclotron Operator?

2. Do you have your dosimetry BADGE?

3. Did you put your PARKING PERMIT in your car? Be sure you are parked in designated space marked RADIATION EFFECTS.

4. Did you verify that you are not bringing food or drinks into the radiation area?

5. Your 8 hour day starts at 8:00am and ends at 4:00pm which includes one hour for tuning plus seven hours of beam time.

6. Long pants and closed-toed shoes are required for your safety.

7. PLEASE TURN IN your dosimetry badge at the end of your stay.