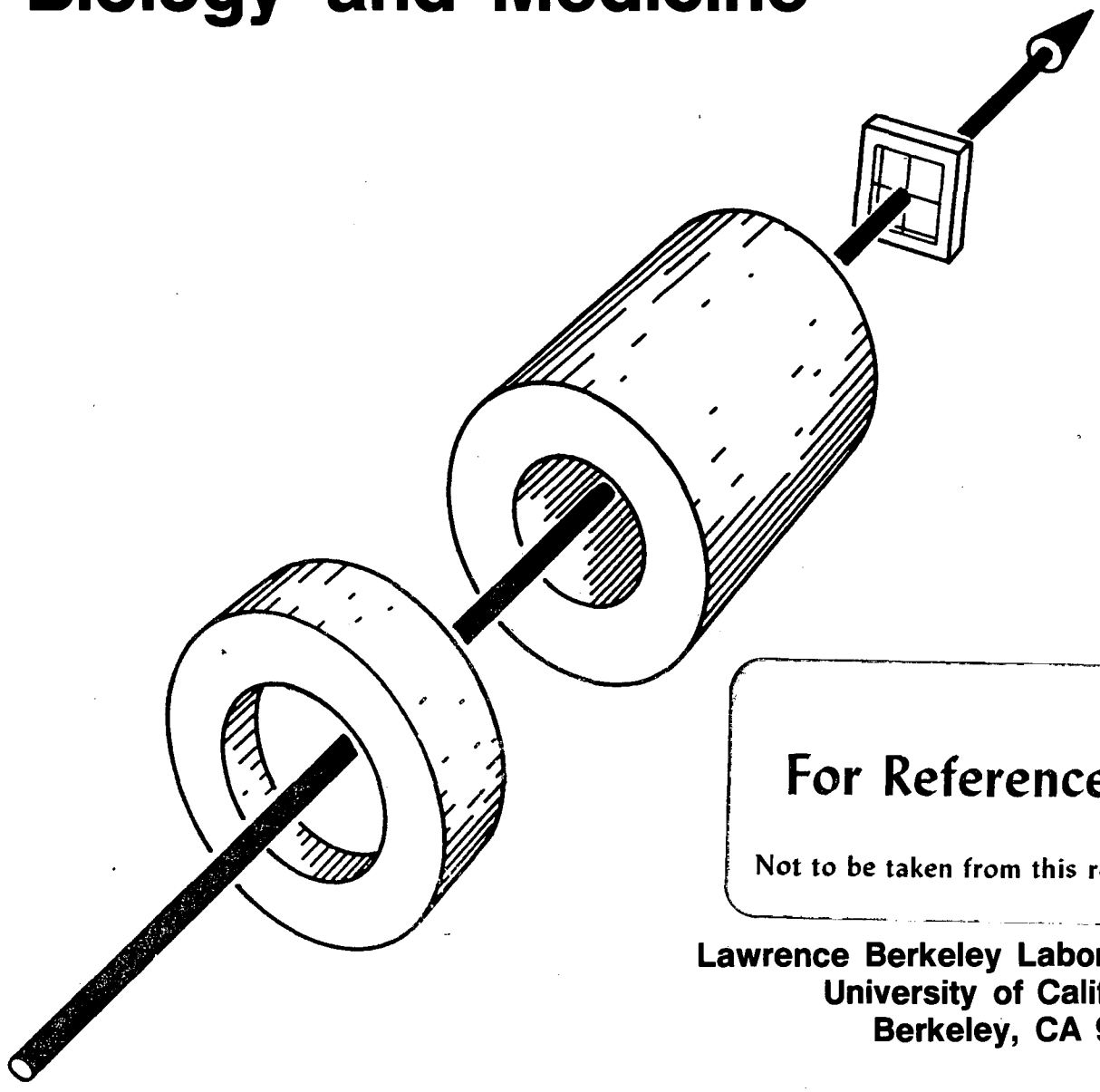
Bevatron/Bevalac User's Handbook:

PUB-101 Rev.
April 1985

Biology and Medicine



Lawrence Berkeley Laboratory
University of California
Berkeley, CA 94720

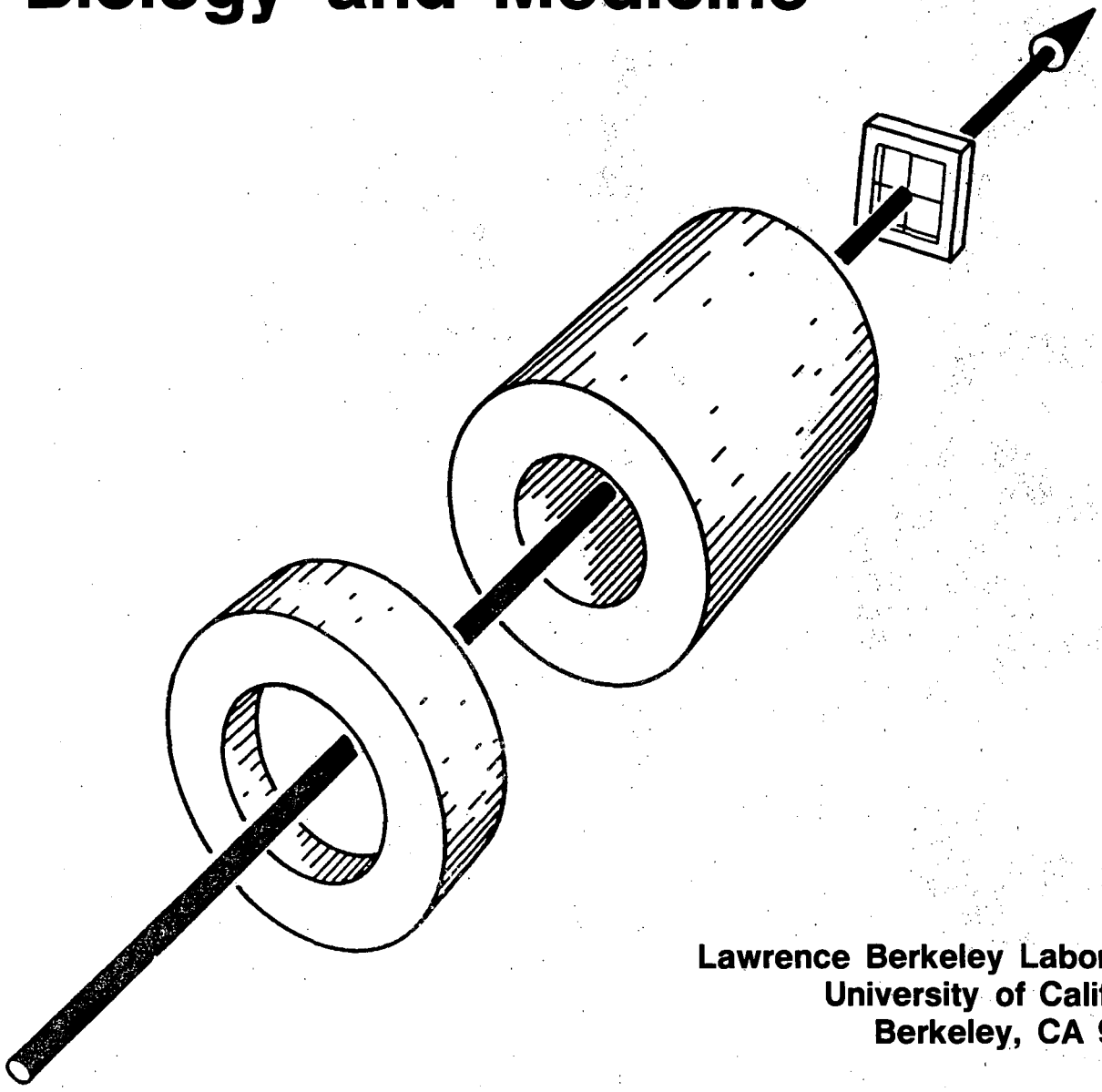
Prepared for the U.S. Department of Energy under Contract No. DE-AC03-76SF00098

DISCLAIMER

Bevatron/Bevalac User's Handbook:

PUB-101 Rev.
April 1985

Biology and Medicine



Lawrence Berkeley Laboratory
University of California
Berkeley, CA 94720

Prepared for the U.S. Department of Energy under Contract No. DE-AC03-76SF00098

BEVATRON/BEVALAC USER'S HANDBOOK

BIOLOGY AND MEDICINE

CONTENTS

APPENDICES

INTRODUCTION

The Bevalac Biomedical Facility unites the biological and physical sciences in a joint venture whose ultimate goal is to develop a source of near-relativistic heavy ions for national and international applications to radiation biology, radiation therapy and diagnostic radiology.

Pulsed beams of high LET heavy ions with variable pulse width, frequency, intensity and energy are produced and delivered to the Biomedical Facility by the Bevatron/Bevalac accelerator complex. A sophisticated array of dosimetry equipment under computer control provides accurate determinations of absorbed doses in all regions of the Bragg curve. Depth-dose modifying devices and precise specimen positioning equipment are available. High quality animal housing and tissue culture facilities are convenient to the experimenter.

In many cases the physical plant of a large accelerator like the Bevatron/Bevalac will be foreign to the biomedical researcher. This handbook is designed to provide the user with the relevant information for planning, proposing and executing an experiment here. Most users will find that Sections III, IV and V contain the bulk of the technical information pertinent to them. The first section pertains to necessary administrative details which will also be extremely useful for first-time users. Section II describes SuperHILAC and Bevatron accelerator operation, and is included for completeness.

Handbook revisions will be issued as required to keep users up-to-date on improvements. Your suggestions on how we may refine the handbook and enhance our services will be gratefully appreciated.

I. GENERAL INFORMATION

Lawrence Berkeley Laboratory (LBL) is a national research laboratory operated by the Regents of the University of California under Contract DE-AC03-76SF00098 with the Department of Energy. The Bevatron/Bevalac is operated by the Accelerator and Fusion Research Division of the Lawrence Berkeley Laboratory. Research at the Bevatron/Bevalac is conducted by both staff and guest scientists whose research proposals have been reviewed and approved by an international advisory panel.

The Biology and Medicine Division appoints a scientific director for the biomedical program at the Bevatron/Bevalac. E. John Ainsworth presently holds this position. A scientific director for the nuclear science program at each accelerator is appointed by the LBL Nuclear Science Division to provide leadership for the research on the floor and to coordinate long-term improvements. Howel G. Pugh and Richard M. Diamond presently hold these positions at the Bevalac and SuperHILAC, respectively.

A. ACCELERATOR RESEARCH COORDINATION OFFICE

The Accelerator Research Coordination Office (ARC Office) is designed to streamline communications with research proposers and to coordinate all services for experimenters at the Bevatron/Bevalac and the SuperHILAC. In addition to this Bevatron/Bevalac User's Handbook for Biology and Medicine, there are separate handbooks for the nuclear science users at the Bevatron/Bevalac and the SuperHILAC. All these handbooks are available from the ARC Office.

Research proposals should be submitted to the ARC Office. The staff biology physicist in the ARC Office is the coordinator of Bevalac Biomedical research operations, and questions regarding any phase of an experiment, from

conception to execution, should be directed to him/her. Office staff will handle business and administrative details for guest experimenters. The following section describes procedures which must be followed by guest experimenters.

Before each experimental run, the ARC Office must be consulted regarding the status of the machine and the experiment. Also, the ARC Office should be informed regarding the success of experiments and ways in which research can be conducted more effectively.

There is a reference library in the ARC Office of reprints and/or preprints of reports and publications of work done at the Bevatron/Bevalac. Additions to this library are welcome at all times. When sending publications to the ARC Office, please make reference to the specific experiment number that was assigned to the experiment.

Maps of Berkeley and LBL are included in Appendix B; additional copies are available from the ARC Office.

The ARC Office is located just inside the front door of the Bevatron. The mailing address is:

Accelerator Research Coordination Office
Building 51, Room 208
Lawrence Berkeley Laboratory
1 Cyclotron Road
Berkeley, California 94720
415-486-5185 or FTS 451-5185

B. IDENTIFICATION CARDS, FILM BADGES, PARKING PASSES, PATENT AGREEMENT

Each guest experimenter must comply with DOE requirements and complete a Participating Guest Information form, a Guest Patent Agreement and a Medical Information for Participating Guest form before his/her scheduled experiment is to start. A copy of each form may be found in Appendix C for your information. The quickest way to satisfy these requirements is to call or write to the ARC Office as soon as you know the dates that you will be coming for your experiment so that the forms can be mailed to you and completed prior to your visit to LBL. The forms can then be mailed back to the ARC Office if there is sufficient time, or hand carried to the ARC Office upon your arrival. In either case, your first stop at LBL will be the ARC Office to check in. After a brief review of the guest forms and a few instructions, your next stop will be the Pass Office in Building 90 where a picture will be taken and an identification badge will be made for you.

Please have your automobile license number with you if you wish a parking pass to gain entry into LBL with your car for the duration of your stay. However, because it is virtually impossible to park your car at LBL during the weekday daytime hours because of the limited number of parking spaces, we recommend that you take the LBL shuttle buses. They operate between the hours of 6:30 a.m. and 6:50 p.m, Mondays through Fridays. The shuttle bus routes and schedules are shown in Appendix B.

It is essential that you have a film badge during your stay. If you do not have one, apply for one through the ARC Office. If you have a film or thermoluminescent detector (TLD) provided by your home institution, please bring it with you.

C. FOREIGN VISITORS

If there are any foreign nationals to be included in your visiting group at Berkeley, LBL's Foreign Visitors Unit can provide the necessary visa documentation. Please allow at least 30 days for this visa process for all foreign nationals, except Indian nationals and Soviet Bloc visitors. For Indian nationals, the Department of Energy requires LBL to have prior approval, which takes 30 days in addition to the visa documentation time. For Soviet Bloc visitors, allow 3 to 4 months for DOE approval in addition to the visa documentation time.

Foreign Visitors Unit can provide visitor guides to the Bay Area. Temporary housing can be arranged through the Housing Office on the University of California campus. You may avail yourself of their services by contacting them directly. The address and telephone number is:

Faculty/Staff Housing
University of California
2401 Bowditch Street
Berkeley, California 94720
415-642-0667 or 415-642-3642

D. FINANCIAL ARRANGEMENTS FOR LBL SERVICES

Once a proposal has been accepted, the guest user should arrange for his/her home institution to establish an expense account with LBL.

This account can be used to cover such services as the following:

a. miscellaneous LBL storeroom materials and supplies,

b. purchase of materials,

c. design and fabrication of specialized equipment by the LBL shops,

d. graphic arts and copying services,

e. special telephone service, and

f. data reduction and computer use at the LBL computer center.

Guest users generally are charged at the same rates for these services as are LBL users. The rates include LBL overhead costs. Total charges for specific services may depend in part upon the degree of collaboration with LBL research groups. Estimates for the services desired, including a reasonable allowance for contingency, should be made in order to prepare a purchase order, which should contain the following information:

a. Description of services, such as general supplies and services required from LBL in support of Experiment _____ (Use assigned proposal number).

b. Term of the order consistent with expectations of stay at LBL.

c. Approximate dollar amount. Not-to-exceed amounts are not acceptable. Estimated amounts can be augmented easily.

d. Names of participating personnel who may incur and approve costs against the account. A principal investigator should be identified as being responsible to see that the dollar amount and time limit of the order are not exceeded.

e. Acknowledgment such as the following to satisfy the LBL's contractual obligation: "It is understood that all work hereunder is to be performed in accordance with the terms and conditions of Contract No. DE-AC03-76SF00098 between DOE and the Regents of the University of California. No other terms or conditions shall apply unless specifically agreed upon in writing by the University."

f. A check from your home institution for $300.00 or more to cover initial expenses.

Purchase orders and any questions regarding them should be addressed to:

Lawrence Berkeley Laboratory
Business Services
B90F, Room 101
Berkeley, CA 94720
415-486-4121 or FTS 451-4121

E. BEVALAC USERS' ASSOCIATION

The Bevalac Physical Sciences Users' Association is an organization of active scientists and engineers with a special interest in the Bevatron/Bevalac and its research program. The purpose of this association is to provide a formal channel for the exchange of information among scientists interested in the Bevalac and between these scientists and the Bevatron/Bevalac program advisory committees (PACs). The Association also provides a means for offering advice and counsel to the Bevalac management on operating policy and facilities. The membership is open to practicing scientists and engineers who will be added to the roster upon receipt of a written request, or upon submission of a nuclear science experiment proposal to the ARC Office. The Association Charter and other information may be obtained from the ARC Office, Lawrence Berkeley Laboratory, Building 51, Room 208, 1 Cyclotron Road, Berkeley, CA 94720.

F. INITIATING A BEVATRON/BEVALAC PROPOSAL

Proposals for Bevatron/Bevalac experiments are reviewed by one of two program advisory committees. Each committee, one for nuclear science and one for biology and medicine, recommends to the LBL Director which of the proposals should be approved and for how many hours of beam time.

BEVATRON/BEVALAC PROGRAM ADVISORY COMMITTEE
BIOMEDICAL PANEL

Dr. E. John Ainsworth (Executive Secretary)
Lawrence Berkeley Laboratory
Bldg. 74, Rm. 255
Berkeley, CA 94720
Commercial: 415-486-5394

Dr. Malcolm A. Bagshaw
Department of Radiology
Stanford University Medical Center
Stanford, CA 94305
Commercial: 415-497-5650

Prof. Kelly H. Clifton
Prof. of Human Oncology & Radiology
Wisconsin Clinical Cancer Center
University of Wisconsin
Dept. of Human Oncology
Radiobiology Section
600 Highland Ave.
Madison, WI 53792
Commercial: 608-263-5342

Dr. Ralph E. Durand
The Johns Hopkins Oncology Center
Radiology Laboratory
600 North Wolfe Street
Baltimore, MD 21205
FTS: 202-955-8777

Dr. John T. Lyman
Lawrence Berkeley Laboratory
Biology and Medicine Division
Berkeley, CA 94720
FTS: 415-451-5814

Prof. Paul W. Todd
Dept. of Biophysics
The Pennsylvania State University
University Park, PA 16802
FTS: 814-865-0242

The committee considers proposals at formal meetings, presently held twice a year.

An announcement is sent to all experimenters approximately two months prior to each formal meeting of the PAC. The deadline for submission of a proposal for consideration at an upcoming Bevalac Biomedical PAC meeting is four weeks prior to that meeting. However, proposals may be submitted at any time for the subsequent meeting.

A proposal is essential for a new project or for an existing approved request where the experimental objectives have been largely reoriented.

An extension request is appropriate where the beam time allocated was not sufficient to satisfactorily complete the originally specified experimental objectives.

Small amounts of discretionary beam time may be requested from the Scientific Director, E. J. Ainsworth, to complete experiments or to initiate pilot experiments to generate data to be included in a future proposal.

Copies of the proposal forms will be found in Appendix C (original and requests for extension). (NOTE: Running and tune-up time requests on all Bevatron/Bevalac proposals should be presented in hours rather than shifts.) Proposals should be sent to the ARC Office, Lawrence Berkeley Laboratory, Building 51, Room 208, Berkeley, CA 94720.

A summary of past Bevatron/Bevalac proposals together with a current schedule of accepted proposals can be obtained from the ARC Office.

Some research time at the Bevatron/Bevalac is scheduled for parasitic operation. The general definition of a parasitic experiment is one that requires a negligible amount of beam, equipment, and manpower. In addition, it must not interfere with the primary operations schedule. It is difficult to mount a full-fledged experiment parasitically, but it is frequently possible

for a scheduled primary experiment to obtain beam in a parasitic mode for tuning or calibration purposes. Such parasitic beam may well be very different in ion, energy, and intensity from that desired in the main experiment, but will be very useful to the investigator(s) just prior to the start of a scheduled run. Parasitic time may be charged against approved experimental time depending upon the circumstances. If in doubt, it is best to determine in advance whether you will be charged for parasitic time.

Requests for parasitic beam time that fit the requirements cited above should be submitted to the Bevatron/Bevalac operations staff through the ARC Office.

G. PROTECTION OF HUMAN SUBJECTS

Experiments involving human subjects in any way, including the investigator as a subject, must be reviewed and approved by the UC Berkeley Committee for Protection of Human Subjects. To avoid delays, this approval should be sought at the time your proposal is being prepared. Information on how to submit requests for approval can be found in Appendix C.

H. SCHEDULE

After an experiment is approved by the LBL Director, it is integrated into the Bevatron/Bevalac research schedule at the earliest practical date. Precise scheduling of shifts is accomplished through communications between the experimenter and staff biology physicist, Ext. 5575.

Standard operation for the Bevatron/Bevalac includes about seven months of running per year, concentrated in autumn and spring. Short shutdowns during these periods are scheduled for holidays, necessary maintenance, and routine access to the accelerator. The most frequent of these occur on

Mondays for eight hours for routine maintenance and access. Otherwise, the Bevatron/Bevalac operates 24 hours a day for its nuclear science and biomedical researchers.

Specific operating programs for the Bevatron/Bevalac are developed during weekly meetings of the Accelerator Staff Scheduling Committee and are generated at least two months in advance of the actual running period. Experimenters may usually expect to have at least two months notice of their approximate running date on the accelerator (the date will be correct within a week or so). As the time draws near, the user will be given a more specific date for operation of the experiment.

The regular accelerator schedule has the following general structure:

Monday: Maintenance and studies

Tuesday through Friday, day shift: Radiotherapy and shared biology.

Nights and weekends: Nuclear Science except as specifically scheduled for Biomedical research, which amounts to about five shifts per month on the average.

These are the normal operating conditions. The schedule may be modified to accommodate special runs such as development of new beams.

Budget-related shutdowns of the experimental program are scheduled during the year as required. During these periods, machine development (on a limited basis) and maintenance programs are conducted.

Beginning in April 1985, a new day-to-day operating schedule will be in effect. This change is brought about by the availability of the upgraded Bevatron local injector to supply therapy beams, and the recently achieved capability of the Bevatron to change operating modes very quickly, changing from a particular ion, intensity, energy, and beam line to a second ion, intensity, energy, and beam line in a minute or less. Because the therapy

program needs only five minutes per half hour of beam time during the day, it will be virtually transparent to the other ongoing programs. The revised schedule is structured as follows:

BEVATRON/BEVALAC

Weekly Operation Pattern

	Mon	Tue	Wed	Thu	Fri	Sat	Sun
0000							
OWL	Res	Tune	Res	Studies	Res	Res	Res
0800							
DAY	Maint	Res+ Rx	Res+ Rx	Res+ Rx	Res+ Rx	Res	Res
1600							
SWING	Tune	Res	Studies	Res	Res	Res	Res
2400							

	Shifts
Res = Research	15
Rx = Therapy	1
Studies	2
Tune	2
Maintenance	1
	21

I. FACILITIES AND SERVICES AVAILABLE TO EXPERIMENTERS

A number of facilities and services are provided at the Bevatron/Bevalac to aid experimenters in the design, construction, setup, and operation of their experiments. The ARC Office staff will put the experimenter in contact with the Bevatron Operations and Engineering groups to assist in the design and layout of experiments. This may include providing layout drawings and the surveying and alignment of experimental equipment during the installation of the experiment. The Engineering and Coordination groups also help the experimenters in the design and installation of their equipment and advise with regard to safety requirements. Setup and removal of the experiment is performed by the Bevatron staff in conjunction with the engineers and experimenters. In addition, the Bevatron Operations and LBL support groups also provide the following services and support items on a basis consistent with available LBL facilities and effort.

1. Maintenance and operation of the beam transport system to the experimental area, including vacuum pipes, standard mass slits, standard separators, beam diagnostics, etc.

2. Biomedical irradiation caves and preparation rooms, complete with equipment as described in Section II, Biomedical Facility.

3. Ac and dc power.

4. De-ionized water and compressed air. Instrument quality air may be provided, if necessary.

5. Reasonable quantities of liquid hydrogen and inexpensive bottled gases, such as nitrogen, oxygen, and carbon dioxide.

6. Assistance in repair and maintenance of electronics, as available. (It would be helpful to have schematic diagrams of any electronic gear that might need servicing.)

7. Assistance in unloading trucks or vans and temporary storage of equipment.

8. Bevatron shop facilities for small construction jobs and emergency repair work.

1. Shop Facilities

In addition to the services listed above, LBL mechanical and electrical shop facilities are available to visiting investigators for the design, fabrication, repair and rebuilding of experimental apparatus. Visiting groups normally are encouraged to use shop facilities at their own institutions because the time required there may be substantially shorter than at LBL, where shops typically are committed heavily to LBL work requests. For apparatus that needs repair or remodeling during the time an experiment is running, every effort will be made to expedite the work, consistent with the shop load and experimental priorities. The ARC Office staff can determine the availability of shop and engineering services and initiate contacts for work to be done. Charges for engineering and shop services will be billed at prevailing LBL rates to the user's established account.

J. BEVATRON/BEVALAC BIOMEDICAL FACILITY OPERATIONS STAFF

Many of the people named below will be involved in your experiment planning and operation and can be contacted for assistance. General questions, should be referred to the ARC Office.

		LBL Ext.
Biomedical Scientific Director	John Ainsworth	5394
Chief, Bevalac/SuperHILAC Operations	Jose Alonso	5575
Biomed-Accelerator Division Coord.	Bill Chu	5831
Staff Biology Physicist Dosimetry, Experimental Design, Scheduling, Laboratory Support	Bernhard Ludewigt	5575 or 5831
Electronics Engineering	Mark Nyman	6471
Mechanical Support, Localization, Immobilization	Bob Walton Charlie Pascale	5372 5467
Electronics Support	Frank Upham	5838
Computer Support, Software	Maury McEvoy R. P. Singh	6411 6411
Animal Support	Bob Springsteen	5221
Dosimetry Consultation	John Lyman	5814
Radiation Control	Pierre La Plant	5575
Electronics Coordination	Ron Stratdner	5831
Safety	Ken Biscay Pierre La Plant	5575 5575
ARC Office	Fred Lothrop	5185
Therapy Physicist	Tim Renner	5831

K. BEVATRON SAFETY REQUIREMENTS

Each experimental installation at the Bevatron/Bevalac is reviewed for compliance with safety standards from both radiation and occupational hazard aspects. Safety procedures and policies for the Bevatron/Bevalac area are contained in Operational Safety Procedures: Bevatron/Bevalac Building 51 Complex, BRSP/WE and Rules and Procedures for the Design and Operation of Hazardous Research Equipment, Pub-3001. These policies and procedures apply to anyone doing work in the area, including user groups, and it is expected that they will be familiar to all. Copies of the safety manual are available from Pierre La Plant, Radiation Control Officer for the Bevatron/Bevalac, Building 64, Room 206. The documents deal primarily with radiation hazards and installation procedures and requirements for hazardous materials and research equipment likely to be used here. Liquid hydrogen targets, high pressure Cerenkov counters, and high voltages on spark chambers must be designed and installed properly. Policies and procedures for the use of nonradioactive hazardous materials (flammable fluids, toxic substances, gases, etc.), as well as electrical safety, are detailed in the manuals. Experimental setups must be designed and built to conform to these LBL standards. Guidelines from OSHA are followed as closely as possible.

Potential radiation hazards at the Bevatron/Bevalac are dealt with by Pierre La Plant, Ext. 5575, who operates within the appropriate guidelines set forth in 1969 by Subcommittee N43-4 of the American National Standards Institute and published in NBS Handbook 107, June 1970.

Safety instructions relating to specific beam programs, the handling of radionuclides and other matters are published in reports listed near the end of this section.

1. Radionuclide Sources

All LBL source users, including guests, are responsible for the safe use, location, and condition of sources at all times. Each source user is still responsible if he lends his source to someone else. Environmental Health and Safety Operations (EH&S) is responsible for the issuance and accountability of "HC" numbered radioactive sources, and has the authority to enforce the sealed radioactive source control regulations. EH&S has a variety of sources available for counter calibrations, simulations, etc. These sources will be lent only to LBL employees, so if you have need of a source please ask your LBL contact or collaborator to obtain one.

A representative of the EH&S Group is resident at each of the accelerators and will be glad to be of service to your group. At the Bevatron/Bevalac and SuperHILAC, see Ken Biscay, Ext. 5575. Jim Haley in Building 75B, Ext. 5251, has LBL-wide responsibility for radionuclide safety.

Employees or guests who plan to work with radioisotopes must review their intended operation with the EH&S representative for their area before starting any of the work.

2. Transportation of Radioactive Materials (Shipment of Radioisotopes from LBL)

Removal of radioactive materials from LBL will not be permitted unless written authorization is obtained from the Director's Office. Radioactive materials include anything that emits measurable radiation of alphas, betas, or gammas.

Application for authorization will be made by the EH&S group after it receives your Hazardous Material Request for Shipment, Form RL-3634, which you must fill out if you intend to have radioactive material moved from LBL. [See article 4.312 of the LBL Health and Safety Regulations, LBL-2077 (revised 1/5/76)]. At the proper time, after authorization is obtained, EH&S will pick up your material, pack it, and send it to the destination you have specified.

3. Shipment of Sources to LBL

If you intend to ship a radioactive source from your home institution to LBL you must contact the health and safety group at your institution and ask them to make arrangements with EH&S at LBL for the proper transportation of your material. All incoming shipments are to be routed through EH&S. They will inspect the package for proper shipping requirements and possible damage, and then deliver it to the area you have specified. Shipment here includes any method of bringing the material into the laboratory. Packages are to be addressed as follows, or taken to Earl Hart immediately upon arrival:

Earl E. Hart
Lawrence Berkeley Laboratory
Bldg. 75, Rm. 107
Berkeley, CA 94720
Re: Bevalac Experiment # ___

4. Shipment of Sources Within LBL

Inter-building transfer of radioactive material or equipment must be done by the Environmental Health and Safety (EH&S) Transportation Group.

5. Storage of Sources at LBL

Environmental Health and Safety (EH&S) is responsible for proper storage of any radioactive source. Sources not in use must be stored in a locked container or storage area approved by EH&S for that type of source.

Each container and storage area must be marked with the sign:

CAUTION == RADIOACTIVE MATERIAL

6. Purchase of Sources

Sources may be bought by experimenters through Ray Aune, Ext. 5251. The buyer need not be an LBL employee, but must show need for a source. Used sources are available from LBL stock, and new sources will be bought from outside vendors if needed.

SAFETY GUIDELINES AND POLICY PUBLICATIONS

BRRS/WE-100	Program for Control of Radiation Hazards Caused by Bevatron/Bevalac Beam Induced Residual Activity.
BRSP/WE-200	The Bevatron Synchrotron Radiation Safety Program (Part of Bev-802 revised).
BRSP/WE-310	Preliminary Instructions for Apprentice Users and Operators, Bevatron/Bevalac Nuclear Science Beams.
BRSP/WE 321	Preliminary Instructions to Users of Radionuclide Sources at LBL Accelerator Beam Sites.
BRSP/WE-400	Technique in Radiation Safeguard to be Used with Bevatron/Bevalac External Beams (Part of Bev-865 revised).
BRSP/WE-420	External Primary Beam Radiation Safety System Specifying Operating Procedures (Bev-846 revised).
BRSP/WE-600	Bevatron/Bevalac Experimenter Beams Radiation Safety Programs.
BRSP/WE-620	Instructions for Using Personnel Radiation Systems at the Bevatron (Bev-845 revised).
BRSP/WE-800	Bevalac Biomedical Beam Safety - Group Responsibility.
BRSP/WE-850	Bevalac Biomedical Beam Enclosure Radiation Safety Programs.
Bev-496	Liquid Hydrogen, Propane, Other Inflammable Fluids, and High Pressure Gases at the Bevatron and 184-Inch Cyclotron.

Bev-509	Check List for Flammable Fluid and High Pressure Equipment Operation at the Bevatron.
Bev-709	Electrical Safety Rules for High Voltage Equipment.
Pub-3000	Health and Safety Manual, Lawrence Berkeley Laboratory
Pub-3001	Rules & Procedures for the Design & Operation of Hazardous Research Equipment

L. SAFETY PROCEDURES IN THE BIOMEDICAL AREA

These LBL procedures are applicable to activities in the laboratories associated with the Biology and Medicine Division in Donner Laboratory and other buildings of LBL. The intent is to provide information on safe handling of biological specimens and animals. Additional guidelines and procedures pertain to experiments with human subjects are available from the LBL Human Use Committee (Room 468, Donner Laboratory).

1. Inexperienced or new workers should be instructed as to potential dangers and hazards in the laboratory where they will be employed. This includes chemicals, equipment, and procedures.

2. No food or liquids are to be stored or consumed in working areas with biological samples or where tests are being performed. This includes refrigerator space. Smoking is permitted only in designated areas. (See LBL Administrative Memo-Policy and Procedure dated June 1, 1983, Vol. IX-No.18 at end of this section.)

3. Laboratory coats should be worn when performing experiments and when working with patients.

4. Safety glasses must be worn when working with acids, cleaning solutions, boiling reagents, glass tubing, etc.

5. Hands should be washed before and after each experiment, each patient, and before coffee breaks or eating. Use disinfectant if working with contaminated material. Avoid touching telephones before washing hands.

6. When finished: Work area must be cleared of debris and cleaned thoroughly to prevent contamination with other experiments.

7. Rubber or plastic gloves must be worn when handling any infectious tissues or infected specimens and radioactive materials. Open wounds or cuts should be covered with band-aids or finger cots before starting any procedures.

8. Mouth suction tubing should be kept in the lab coat pocket by each individual and never left on a table or a bench. Mouth suction tubing should not be shared.

9. Sterile technique should be used for all skin punctures (finger, vein, artery, sternal, etc.). Cleanse the area by rubbing with gauze saturated with choice of disinfectant (alcohol, Merthiolate, etc.).

10. Water, acid, or any spilled solution should be wiped up immediately. Spilled material containing pathogenic organisms must be wiped up immediately and the area disinfected with 5% pheno or appropriate disinfectant. Table tops and all working areas must be wiped carefully with a disinfectant solution after working with infectious material. When using radioisotopes, toxic materials, etc., waxed paper is to be taped over the working area (absorbent paper with waxed backing).

11. Eppendorf pipette (used for micropipetting) or a pipette filler (sometimes called a Propipette) must be used when working with infectious, corrosive, toxic, unknown, radioactive, or sterile liquids.

12. All serologic, volumetric, or blood cell pipettes should be placed in a container with water and/or disinfectant immediately after use. Hemocytometers and coverslips must be washed with distilled water and 70% alcohol immediately after use. Dry gently with a soft cloth, being careful to not rub the ruled portion.

13. A hood must be used when working with toxic or poisonous compounds, in particular those capable of liberating poisonous gases or fumes by addition of acid (e.g., KCN used in hemoglobin solutions).

14. Culture media, pathogenic material, and specimens must be autoclaved before discarding.

15. The following items must be disposed of as soon as possible, and not be permitted to lie around the laboratory: excess or nearly decayed radioactive materials, test specimens, waste and soiled papers, sheets, towels, etc., broken glassware, specimen containers, wet mounted or unfixed slides, and reagents.

16. All tissues, specimens, radioactive materials, toxins, poisonous compounds, unknowns, old chemicals, alcohols, etc., should be disposed of as follows:

    a. Water-soluble chemicals such as acids or alcohols: flush down the drains with plenty of water.

    b. Flammables: organic waste disposal can (do not mix flammables and acids).

c. Stock dry or liquid chemicals: (large amounts) given to EH&S Department for disposal.

d. Solid non-poisonous chemicals: usual waste containers.

e. Tissues and dead animals: frozen and disposed of by EH&S Department.

f. All questionable items: contact EH&S Department for regulations (a disposal service is available on request).

g. Do not keep ether or dioxane over six months.

h. Radioactive material: radioactive waste container.

17. Special ventilation is required to remove animal odors.

18. Research involving laboratory animals is governed by extensive Federal regulations and corresponding divisional and LBL-wide rules. Investigators using animals must familiarize themselves with these procedures. There are hygiene and personnel safety factors involved; some of the important ones are set forth below.

    a. All animals should be provided with comfortable and clean housing. For example, rat cage bedding should be changed twice each week, mouse cage bedding should be changed once each week.

    b. As a general rule surgical procedures, injections, and bleeding of animals should be carried out with the same sterile techniques as used with humans. All major operative procedures should be conducted under full anesthesia and all animals at all times should be handled and treated with care. No large animal may be left unattended unless properly caged.

    c. Autopsies should be performed as soon after death as possible, especially if bacteriological examination is required.

LAWRENCE BERKELEY LABORATORY
ADMINISTRATIVE MEMO

POLICY AND PROCEDURE

JUNE 1, 1983 Volume IX - No. 18

SMOKING POLICY FOR THE LAWRENCE BERKELEY LABORATORY

On April 1, 1977 the California Clean Air Act* became operative. In accord with this act the Lawrence Berkeley Laboratory issued Policy and Procedure Volume III - No. 7 (April 6, 1977) which stated the LBL policy with regard to smoking in Laboratory facilities.

The policy is hereby restated:

Smoking is not permitted in:

a. Building 50 Auditorium.
b. Laboratory and Division libraries.
c. Restrooms.
d. Elevators and Stairways.
e. Cafeteria, except in special areas provided for smokers.
f. Laboratory shuttle buses.
g. Meeting rooms, if any occupant objects.
h. Medical Services - Building 26, Waiting Rooms and Treatment Rooms.
i. Posted Areas.

Smoking is acceptable in:

a. Hallways, where receptacles have been provided and no contrary instructions have been posted.

b. Open office space, private offices, and laboratories, only if all occupants are in accord.

Please note that smoking is NOT permitted in offices, meeting rooms or laboratories unless all occupants are in accord.

Walter D. Hartsough
Associate Director
Engineering and Technical
Service Division

WDH/amd

* Chapter 10.8, Division 20, Health and Safety Code

II. BEVALAC OPERATIONS

A. HISTORY OF THE BEVALAC

The history of accelerated heavy-ion beams goes back beyond the very beginning of cyclotron development with E. O. Lawrence. As early as 1940 C^{6+} was accelerated to a total energy of 50 MeV in the 37-Inch Cyclotron. The first heavy-ion-induced nuclear reactions were produced in 1950, again with C^{6+}, at 120 MeV in the 60-Inch Cyclotron.

Several research groups at LBL had been interested in a high energy accelerator of medium heavy ions throughout the 1960s. However, scarce funding and a lack of interest at that time by the user community in general prevented the realization of this heavy-ion capability until the 1970s.

In 1971 a novel means of obtaining heavy-ion beams in the billion electron volt range was suggested by Al Ghiorso et al. The idea simply was to combine the newly refurbished SuperHILAC as an injector with the Bevatron to produce multi-GeV ions from protons to uranium. Preliminary biomedical, physics, and chemistry experiments were very encouraging, and the Bevalac was funded by the Atomic Energy Commission (AEC) in 1972. A transferline was constructed down the hillside connecting the two accelerators, and by the fall of 1974 SuperHILAC beams of carbon, neon, and argon had been injected into the Bevatron and accelerated to 2 GeV/amu.

Improvements to the Bevalac system continue to increase its operational efficiency. The ion energies and intensities produced here are presently unavailable at any other accelerator complex in the world.

B. DESCRIPTION OF THE BEVATRON/BEVALAC AND SUPERHILAC

An overall view of the Bevatron/Bevalac is shown in Fig. II-1. Beam formation begins in one of four injectors, three at the SuperHILAC (ADAM, ABEL, and EVE) and one at the Bevatron. When accelerating SuperHILAC-initiated beams, we use the term Bevalac to describe the combined operation.

1. SuperHILAC

a. Injectors

EVE is an air-insulated 850-kV Cockroft-Walton injector designed to produce beams of ions from helium to argon. Currently it is used mostly for neon and carbon beams. In addition to mass limits, this injector ionizes only gaseous elements or compounds.

ADAM is a pressurized 2.5-MV modified Cockroft-Walton ("Dynamitron") most useful for ions beams of elements between argon and xenon. It contains a sputtering feature in its source so that metallic elements may be ionized directly.

ABEL is a compounded injector comprising a 750-kV Cockroft-Walton ion source pre-injector and a Wideroe linear accelerator. Its capability extends from argon through uranium, and it is especially useful for heavy metallic elements.

All three injectors operate with Penning ion gauge (PIG) sources.

b. Linac

The SuperHILAC accelerates beam in two distinct stages by means of two Alvarez-type linac sections. These are separated by a stripper foil to deliver higher charge-to-mass state ions into the second tank. The ion beam leaves the SuperHILAC at an energy of 8.5

MeV/amu, and is transported 500 feet through an elevation drop of 148 feet, to the Bevatron injector line. Beam steering and focusing is achieved with conventional dipole and quadrupole magnets, with segmented Faraday cups as total beam current and spatial monitors.

2. Bevatron

a. Injector

The Bevatron's local injector is being modified to produce intense beams of ions through silicon, and maybe as high as argon. A new structure called an RFQ (radio-frequency quadrupole) linac will do the initial acceleration from an ion source operating at about 50 kV. The RFQ will feed the Alvarez-type linac already in place and the output energy will be 5 MeV/nucleon.

b. Synchrotron

The Bevatron is a weak-focusing synchrotron composed of four quadrant magnets of 15 m radius, separated by 6-m-long straight sections . Injection occurs in the East straight section, the acceleration electrode is in the North, and extraction magnets are in the East and South. The extracted beam leaves the ring through the West straight section. Injection takes place over many turns within a 500-μs interval, filling the vacuum ring completely.

Toward the end of the injection pulse, the rf accelerating voltage is turned on. Not quite half of the injected beam is captured in a phase stable region. The frequency of the rf is programmed to maintain an essentially constant radius in the rising magnetic guide field as the ions gain energy. The magnetic guide field is flat-topped at a predetermined value to give the desired ion energy.

The radial and vertical widths of the beam are determined essentially by the amplitudes of the betatron oscillations. The injected beam is about 25 cm vertically by 100 cm radially. At 12 kilogauss, the beam is damped to about 4.6 cm by 18 cm. At 4 kilogauss, the beam is damped to 8.8 by 35 cm. The larger dimensions reduce extraction efficiency.

Beam exits from the Bevatron by resonant extraction. Horizontal betatron oscillations are driven to perturb the beam orbit until the ion path crosses two septum bending magnets, first in the East and then the South straight sections. The second magnet's field deflects the beam so that it leaves the Bevatron ring in the vicinity of the West straight section, and enters into an ion-optical transport system which directs the beam to any of several destinations. The external particle beam (EPB) system and experimental areas are described in the next sections.

The pulse rate varies from 10 per minute to 15 per minute, the faster rate for lower final beam energies.

c. Computer Control

A major aspect of Bevatron/Bevalac versatility is the ability to shift rapidly from one operating mode to another, both at the SuperHILAC and the Bevatron. This has been accomplished through the installation of virtually identical data-processing and control systems at the two accelerators. For each system the architecture is that of a central processor (ModComp IV) communicating with several peripheral processors (ModComp II's) that perform the actual machine control tasks. The central units supply stored information to the

peripheral ones as needed, and also serve as the point of operator access to the system. In addition, the central processors may be be linked with other computer facilities within LBL.

d. Computer Controlled Time-Sharing

The SuperHILAC operates at 36 pulses per second, each pulse about 4 ms long. Since the Bevatron's pulse rate is much slower (10 to 15 pulses per minute), experiments can be run simultaneously at the two accelerators, even in the Bevalac mode, by directing one or two pulses per second of SuperHILAC beam down the transferline. The bulk of SuperHILAC beam remains for that facility's experimental program.

In fact, by means of the computer control system at the SuperHILAC, different ions can be accepted from each injector on alternate pulses. Routine beam combinations are neon or argon from ADAM and krypton, xenon, or gold from ABEL, with a few pulses of one beam diverted to the Bevalac transferline.

C. BEVATRON/BEVALAC EXTRACTED BEAM INTENSITIES

Table II-1 that follows the extracted beam intensities for Bevatron/Bevalac operation. The maximum kinetic energy for protons is 4.88 GeV and for heavy ions 2.1 GeV per nucleon. Beam intensities are dependent on the source injector and the particle.

Table II-1. Bevalac Heavy Particle Inventory, October 1983.

Ion	Atomic weight, A	Atomic charge, Z	Acceleration charge	Kinetic energy, MeV/n 12.575 kG	2.8 kG	Typical intensity at F1
Carbon	12	6	6	2100	200	5×10^9
Oxygen	16	8	8	2100	200	5×10^9
Neon	20	10	10	2100	200	2×10^9
Silicon	28	14	14	2100	200	5×10^8
Argon	40	18	13	1160	90	1×10^9
			18	1820	164	2×10^8
Iron	56	26	17	1050	78	
			24	1700	150	1×10^8
			26	1900	174	2×10^7
Zinc*	64	30	18	937	59	1×10^4
Krypton	84	36	22	840	59	
			33	1510	127	3×10^5
Niobium	93	41	(23)24	820	57	1×10^6
			35	1430	118	
Xenon	136	54	45	1190	92	3×10^6
Lanthanum	139	57	29	590	38	8×10^7
			48	1260	100	1×10^6
Gold	197	79	35	450	28	1×10^7
			61	1080	81	
Uranium	238	92	38	378	22	
			68	960	70	2×10^5

*Record of a single instance; optimization will improve intensity dramatically

D. PULSING CAPABILITIES

The Bevatron power supply has the capability of providing a wide variety of pulse modes to suit specific experimental requirements. One of the most common modes furnishes a two-second flat-top at a field strength of 12.5 kilogauss, with a 10 pulse per second repetition rate. Virtually a continuous selection of field strengths is available, up to a maximum of about 12.5 kilogauss, under normal circumstances, at discrete increments of repetition rates, 8.7, 9.3, 10.0, 10.9, 12.0, 13.5, and 15 pulses per minute. Flat-top lengths are continuously variable from about 500 ms to 2 s., depending on flat-top field. Limitations on the possible pulse modes are (a) power supply capability, which is limited to 5.5 MW, and (b) limits on speed variations of the two synchronized motor generator sets used for power conversion.

Figure II-2 shows the range of flat-top lengths available at various field strengths for the available pulse rates. The graph should be taken only as a guide for specific operation. Requested parameters will be used as input data for the computer program that governs the power supply. The mode that most closely approaches the request will be used. Detailed information on magnet pulse modes may be obtained from Robert Frias, Ext. 5831.

E. BEAM SPILL METHODS

Essentially all experiments are now done in external beam channels, and the spill methods used are those that excite particle oscillations required for the resonant extraction system described the next section. There are two spill methods available. They are achieved with the spiller magnet either on (long spill) or off (ramp spill).

When the long spill method is used, S1, a winding on the East plunging mechanism, is turned on and controls the rate at which beam is delivered from its circulation to the external beam channel. The current is comprised of two components, a ramp signal that establishes an approximate rate of spill, and a feedback signal that maintains the spill at the desired rate. The feedback is derived from either a thin scintillator-photomultiplier or a thin water Cerenkov counter detector in the external beam channel. The choice of detectors is determined by the velocity of the particle and the intensity of the beam.

This method is useful with the rf voltage either on or off. Normally the rf is off and fine structure of the beam (40-ns bunches at 400-650 ns period) is eliminated.

Beam spills generally will have low frequency modulation induced by ripple in power supply components. Dominant frequencies are approximately 60, 180, 360, 720, and 1440 Hz. The low frequency amplitudes will be small due to the spill circuit feedback action, but the higher frequency structure, resulting in part from long (1-2 ms) excitation times of some particles in the resonant process may be troublesome.

The ramp spill is with the spiller off. Excitation of the resonance is accomplished by either of two methods, each of which moves the circulating beam radially into the region of resonance excitation. The first method employs a controlled increase in the frequency of the accelerating voltage, requiring the rf system to be on, and full rf structure will appear on the spill. The second method employs a modulation of the magnetic guide field to bring the beam to resonance, and does not require the rf system to be on. Spill lengths are limited to about 500 ms, but there is no rf structure.

F. PARTICLE EXTRACTION

Circulating beam is spilled by means of a resonant extraction system and provides a spill length of up to 1500 ms per Bevatron pulse. Resonant extraction is the term used to describe the process of inducing horizontal betatron oscillations in the circulating beam.

The 2/3 integral radial betatron resonance is driven with an azimuthally lumped perturbation such that a controlled growth of the radial betatron amplitude can be achieved. The perturbation is designed as an integral part of the M1 magnet. The thin septum of the M1 dipole magnet is placed at a radial position relative to the closed orbit R_o where the growth per resonant period (three turns) is adequate to ensure good extraction efficiency. Given the septum thickness t and the growth g, then in linear approximation the extraction efficiency becomes:

$$u = \frac{g - t}{g} \qquad \frac{0.85 - 0.15}{0.85} = 80\%$$

Figure II-3 shows a single particle on six turns prior to extraction. On the seventh turn, after jumping the septum of M1, the particle is deflected into septum magnet M2 with a larger septum, and a stronger dipole field that in turn deflects it clear of the main guide field. M1 and M2 are plunged magnets, kept well clear of the beam during acceleration, and brought close to the beam only during extraction.

The presentation of the trajectories in Figure II-3 is qualitative but is descriptive for the whole accelerator. A correct presentation for a single point in the East straight section is given in Figure II-4, a diagram of the betatron phase space indicating the transverse radial position and angle of extracted particles.

A stable fix point of the motion in phase space is the closed orbit R_o, which is the origin of the coordinate system in Figure II-4. A stable fix point is characterized by the elliptical motion of neighboring points in phase space. A particle originating in A will appear on subsequent turns in B, C, and then A again as it passes the East. A, B, and C are called the unstable fix points, and the line between them the separatrix. Inside the separatrix is the original undisturbed beam. Note that only the particle in the unstable fix point has exactly the average tune of 2/3.

After emerging from the unstable fix points, an unstable particle will progress along the dotted lines that branch out to larger amplitudes. The last six turns prior to extraction are labeled 1 - 6, as in Figure II-3.

The motion indicated by the phase diagram shown in Figure II-4 is a consequence of a properly shaped guide field (pole-face winding) and an appropriate field-perturbation. The perturbation has a time-independent part (P1), which establishes the unstable fix points at the start of extraction.

Ideally no beam is spilled with P1 alone. There is also a time-dependent perturbation (S1) which is part of a closed loop. A sensing device in the external beam will activate S1, and S1 in turn will shrink the stable area at the required spill rate.

At guide field levels above 12 kilogauss, 80% of a well-tuned internal beam will pass the M1 septum.

The vertical emittance will be unaffected by the extraction process. Hence in linear approximation it can be calcuated to be

$$E_v = \frac{a_v^2 \nu_v}{R_o} \quad 26 \times 10^{-3} \quad \text{(cm rad)}$$

where

a_v	= 1.5 in. (3.75 cm)	vertical betatron amplitude
ν	= 0.91	vertical betatron frequency
R_o	= 602 in. (1500 cm)	closed orbit at extraction

The vertical amplitude is limited by the aperture of the M1 magnet. The beam size at the F1 focus for high-intensity or low-energy beams will be about 1.1 inches high.

The radial emittance, being recreated in the resonant process, is strongly dependent on extraction parameters. Emittance values should not exceed 5×10^{-3} (cm rad) and can be as small as 1×10^{-3} (cm rad) for 90% of the beam.

G. EXTERNAL PARTICLE BEAM SYSTEM

The external particle beam (EPB) system at the Bevatron/Bevalac, introduced in 1963 for proton beams, has evolved into an extremely versatile, flexible operation for heavy ions as well as protons. Use of targets inside the Bevatron ring was completely overshadowed by the EPB even before the advent of heavy-ion research.

The present external beam facilities include three main channels branching from one extraction point at the West straight section of the accelerator to provide particle beams to as many as ten different experimental setups, of which one or two will be taking beam at any one time. In addition to the three main channels (EPB I, EPB II and the Septum Channel), the Bevalac Biomedical Facility has two standard beam lines branching from EPB II.

The EPB shielding, in general, allows beam levels in each channel of no more than about 1×10^{12} particles per pulse.

Most experiments on the floor in the past two years have made use of the direct primary beam in their beam lines, and the concept of specific target stations for each of the channels is academic. However, the optics of the EPB do predict spot sizes at certain points in each of the channels. The most useful points are named F3 in Channel I and the Septum Channel, and F2 in Channel II. At these points the dimensions of the beam are approximately 1/16 in. vertically by 1/8 in. horizontally (FWHM) for full energy beams. Since beam emittances are poorer for lower energy beams, spot sizes will be larger.

Vernier steering magnets provide for the final beam positioning at the foci. Some of these magnets rotate about the beam axis such that the beam may be deflected in any direction transverse to the beam axis. Beam positioning and focusing at intensities above 10^{10} charges are monitored by plastic scintillators which can be inserted at the various foci. Continuous monitoring is provided by counter telescopes viewing the targets and by secondary emission monitors (SEM) in the EPB channels.

Multiwire proportional chambers have been installed at appropriate stations throughout the EPB system. These chambers are used for beam monitoring and positioning at low intensities, from about 10^5 charges on up.

These 34 x 34 wire chambers are monitored in the main control room, but access to the display output is available upon request in any experimental control station. In addition, the portability of the chambers allows for relocation or insertion of special chambers to suit individual experimenter needs for beam monitoring.

H. MACHINE PARAMETERS

The following values associated with mass and energy were used in calculating the Bevatron/Bevalac parameters; m is the mass in kilograms or MeV; M is the ratio of the mass of the atom or ion to one-twelfth the mass of the carbon-12 atom; p is a subscript to indicate the quantity per atomic mass unit (amu).

Proton: m_p = 938.2796 MeV

amu: m = 931.5016 MeV

The above values are from LBL Particle Properties, 1974 edition. The ratios of masses (M) for various isotopes were taken from the Chart of Nuclides, Knolls Atomic Power Laboratory, 11th edition, Revised to April 1972.

From the above sources, we have the following basic constants:

Proton: m_p = 938.2796 MeV
M = 1.007276

amu: m = 931.5016 MeV
M = 1.00000

Electron: m_e = 0.511 MeV
M = 549×10^{-6}

Values of charge (Z), M, and Z/M for various isotopes are tabulated in Table II-2. The values for Bevatron/Bevalac kinetic energy, rigidity and radiofrequency as a function of magnetic field markers are given in Table II-3. Detailed tables of these parameters are available in the Main Control Room (MCR).

The values used in calculating Table II-3 are the atomic mass of one and one-twelfth the carbon atom (931.5016 MeV) and the Z/M ratio for the various ions. The values tabulated under amu were calculated for carbon-12 and in

general apply to all ions where the Z/M ratio is approximately 1/2. For ions where Z/M is not 1/2, special tables have been calculated using the Z/M for the specific ion. These tables are kept in the MCR. All the tables give energy per amu. Proton energy is therefore also tabulated as energy per amu and is about 3/4% lower than previously tabulated values.

The new tables allow direct comparison between various particles as a function of either the same energy per amu or the same rigidity, whichever is desired.

Note that the tabulation is per amu, not per nucleon.

Table II-2. Charge and mass for various ions accelerated at Bevatron/Bevalac.

Ion	Z	A	M(^{12}C base)	$\frac{Z}{M}$	$M_e \cdot Z \times 10^{-6}$	M (Ion)	$\frac{Z}{M}$ (Ion)
H^1	1	1	1.007825	0.9922	549	1.007276	0.9928
D^2	1	2	2.0014102	0.4965	549	2.013553	0.4966
He^3	2	3	3.016030	0.6631	1098	3.014932	0.6635
He^4	2	4	4.002603	0.4997	1098	4.001505	0.4998
Li^6	3	6	6.015123	0.4987	1647	6.013476	0.4989
B^{10}	5	10	10.012938	0.4994	2745	10.010193	0.4995
C^{12}	6	12	12.000000	0.5000	3294	11.996706	0.5001
N^{14}	7	14	14.003074	0.4999	3843	13.999231	0.5000
N^{15}	7	15	15.000109	0.4667	3843	14.996266	0.4668
O^{16}	8	16	15.994915	0.5002	4392	15.990523	0.5003
O^{18}	8	18	17.999160	0.4445	4392	17.994768	0.4446
F^{19}	9	19	18.998405	0.4737	4941	18.993464	0.4738
Ne^{20}	10	20	19.992441	0.5002	5490	19.986951	0.5003
Na^{23}	11	23	22.987700	0.4785	6039	22.981661	0.4786
Mg^{24}	12	24	23.985044	0.5003	6588	23.978456	0.5004
Ar^{40}	18	40	39.962384	0.4504	9882	39.952502	0.4505
K^{39}	19	39	38.963709	0.4876	10431	38.953278	0.4878
Ca^{40}	20	40	39.962592	0.5005	10980	39.961612	0.5006
Ca^{48}	20	48	47.95253	0.4171	10980	47.941550	0.4172
Fe^{56}	26	56	55.934934	0.4648	14274	55.92066	0.4649
Kr^{84}	36	84	83.911505	0.4290	19764	83.891741	0.4291
Kr^{86}	36	86	85.910616	0.4190	19764	85.890352	0.4191

TABLE II-3. Bevatron Reference Markers.

Marker pulses are distributed throughout the experimental area and have the definitions listed in the table.

Marker Number	Nominal[3] flux density (gauss)	Momentum[4] per charge (GeV/cq)	Rigidity[4] (tesla meters)	Kinetic energy[4] GeV/amu +/- 0.3%		Frequency at field marker[4] (MHz)	
				Proton	$^{12}C(6+)$	Proton	$^{12}C(6+)$
B 1	1000	0.4572	1.525	0.1047	0.02764	1.0900	0.5932
B 2	2000	0.9144	3.050	0.3691	0.1061	1.7368	1.0966
B 3	3000	1.371	4.574	0.7181	0.2252	2.0540	1.4755
B 4	4000	1.828	6.099	1.109	0.3738	2.2142	1.7434
B 5	5000	2.286	7.624	1.521	0.5430	2.3023	1.9292
B 6	6000	2.743	9.149	1.946	0.7265	2.3548	2.0588
B 7	7000	3.200	10.673	2.379	0.9201	2.3882	2.1509
B 8	8000	3.657	12.198	2.817	1.121	2.4107	2.2176
B 9	9000	4.114	13.723	3.258	1.327	2.4264	2.2672
B 10	10000	4.571	15.248	3.701	1.537	2.4379	2.3047
B 11	11000	5.028	16.772	4.147	1.750	2.4465	2.3338
B 12	12000	5.485	18.297	4.593	1.965	2.4531	2.3566
B 13	13000	5.942	19.822	5.041	2.183	2.4583	2.3748
B 14	14000	6.399	21.347	5.490	2.402	2.4624	2.3896
B 15*	15000	6.859	22.871	5.939	2.622	2.4658	2.4017
*	15530	7.099	23.679	6.178	2.754	2.4672	2.4079

* Available but not on normal distribution

Bevatron Reference Markers (continued)

NOTES:

1. Additional marker pulses on distribution panel are:

   a. -40 (40 ms before magnet turn on); Mag ON (magnet turn on); Inj ON (1S, injector turn on trigger); RF ON (2S, RF turn on trigger).

   b. FT ON (flat-top on), FT OFF; BP ON (back porch ON), BP OFF; MZ ON (mezzanine ON), MZ OFF.

      These markers indicate the beginning and the ending of the periods of constant Bevatron magnetic field.

2. B marker pips available on request for special requirements to ±1 gauss, within limits as per Note 3.

3. The B markers are derived from integrating "B" from a coil covering (radially) the center 2 feet of the aperture of the Bevatron. This field value corrected for the remnant field, which is about 38 gauss. The system is calibrated against the old I pip system to give the correct field reading at I-27 (magnet current = 5000 A, B = 12,425 gauss). The field valve is for a radius of 599 3/8 in.. The field values vary by up to 1% from previous I pip values. The stability and the reproducibility of the system is excellent.

4. The RF frequency, kinetic energy, momentum, and rigidity are values calculated for the tabulated field values and a closed orbit radius of 602 inches.

5. Requirements other than nominal on proton energy level or week to week stability should be noted in experimental proposal and brought to the attention of operations personnel at the start of experimental tune up.

6. Time between B marker pips is given approximately by 121 ms/kilogauss for Tap 5 operation (standard operation mode) and by 107 ms/kilogauss for Tap 3 operation. (Tap numbers are associated with the voltage applied to the Bevatron magnet. (Tap 5 → 14 kV, Tap 3 → 16 kV.)

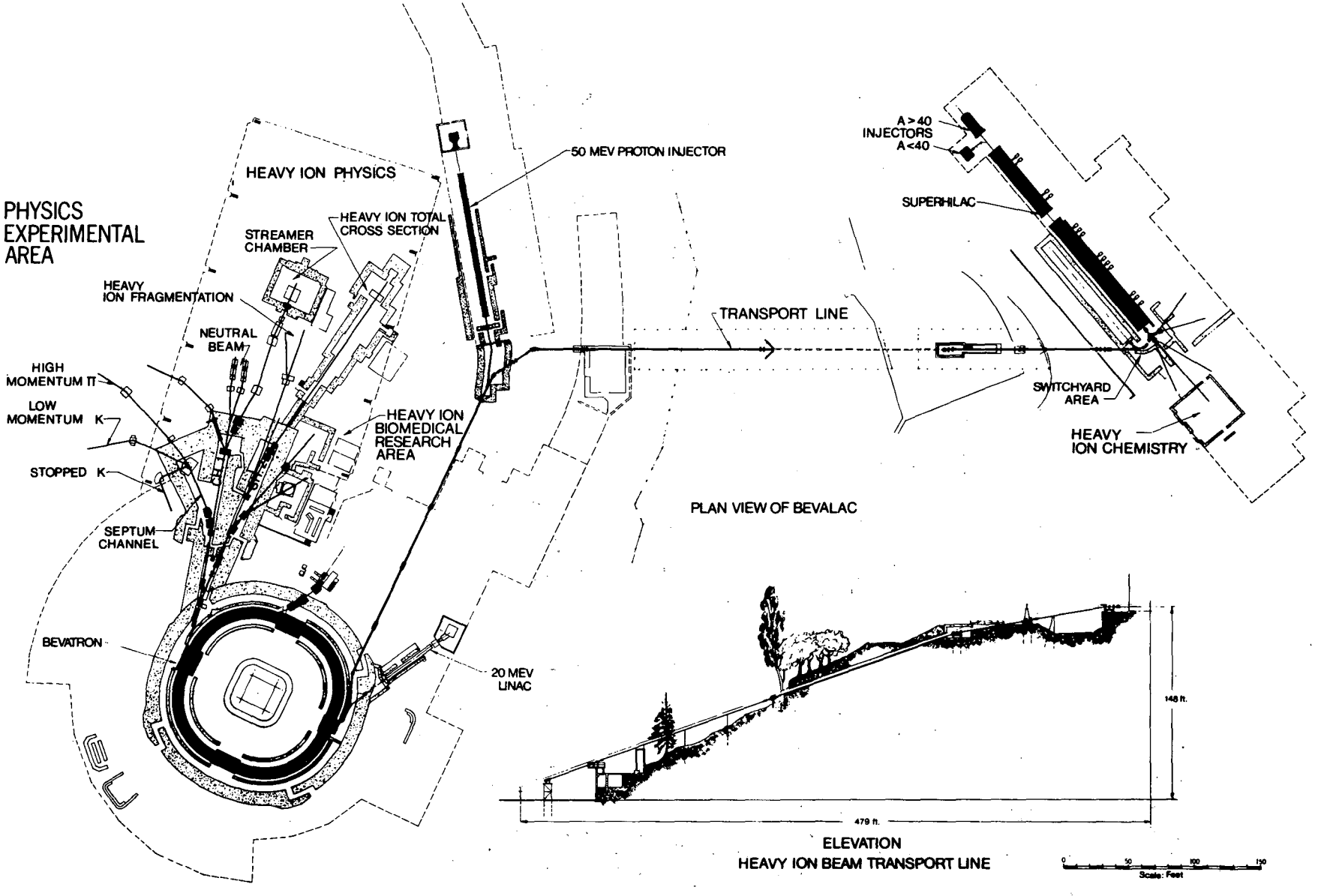
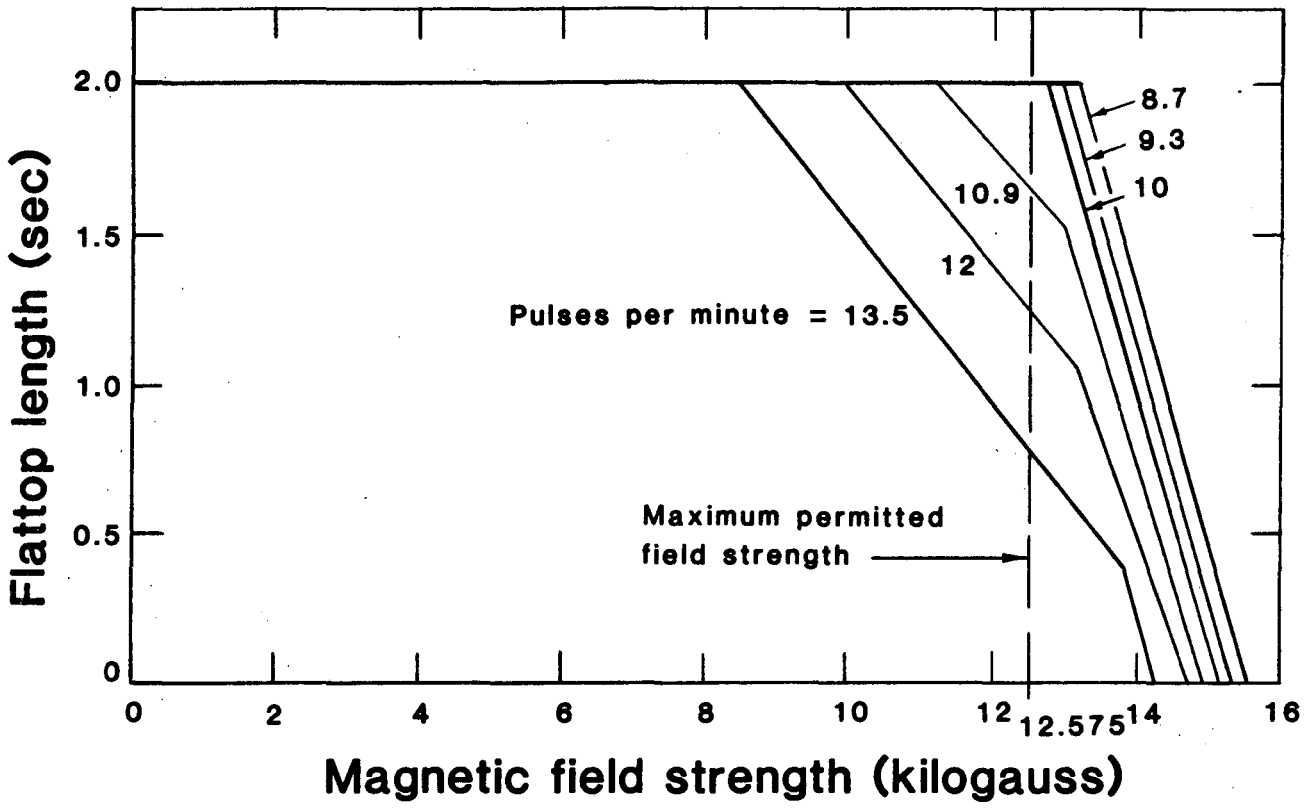

PHYSICS
EXPERIMENTAL
AREA
HEAVY ION PHYSICS
50 MEV PROTON INJECTOR
A > 40
INJECTORS
A < 40
SUPERHILAC
HEAVY ION TOTAL
CROSS SECTION
STREAMER
CHAMBER
HEAVY
ION FRAGMENTATION
NEUTRAL
BEAM
TRANSPORT LINE
HIGH
MOMENTUM π
LOW
MOMENTUM K
STOPPED K
HEAVY ION
BIOMEDICAL
RESEARCH
AREA
SWITCHYARD
AREA
HEAVY
ION CHEMISTRY
SEPTUM
CHANNEL
PLAN VIEW OF BEVALAC
BEVATRON
20 MEV
LINAC
148 ft.
479 ft.
ELEVATION
HEAVY ION BEAM TRANSPORT LINE
Scale: Feet
XBL 736-740C

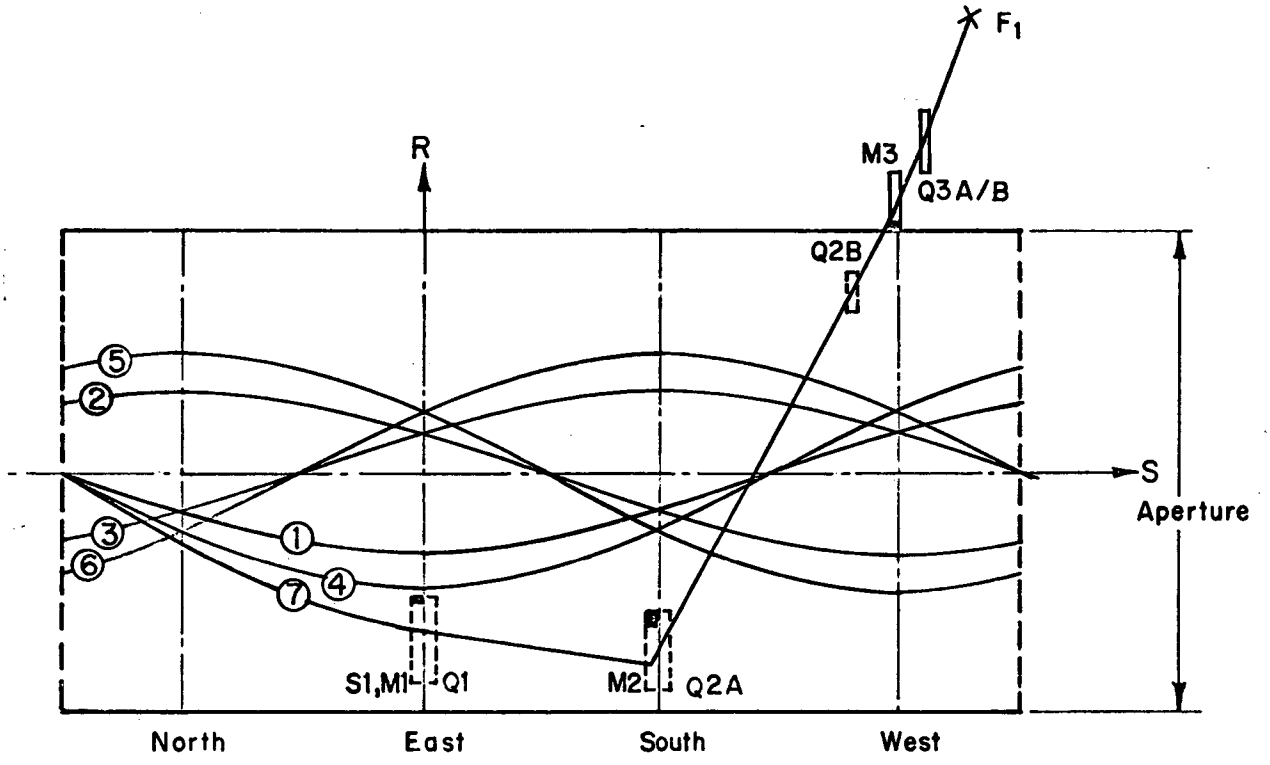
Fig. II-1



REVISED: NOVEMBER 1979

XBL 7610-4132

Fig. II-2

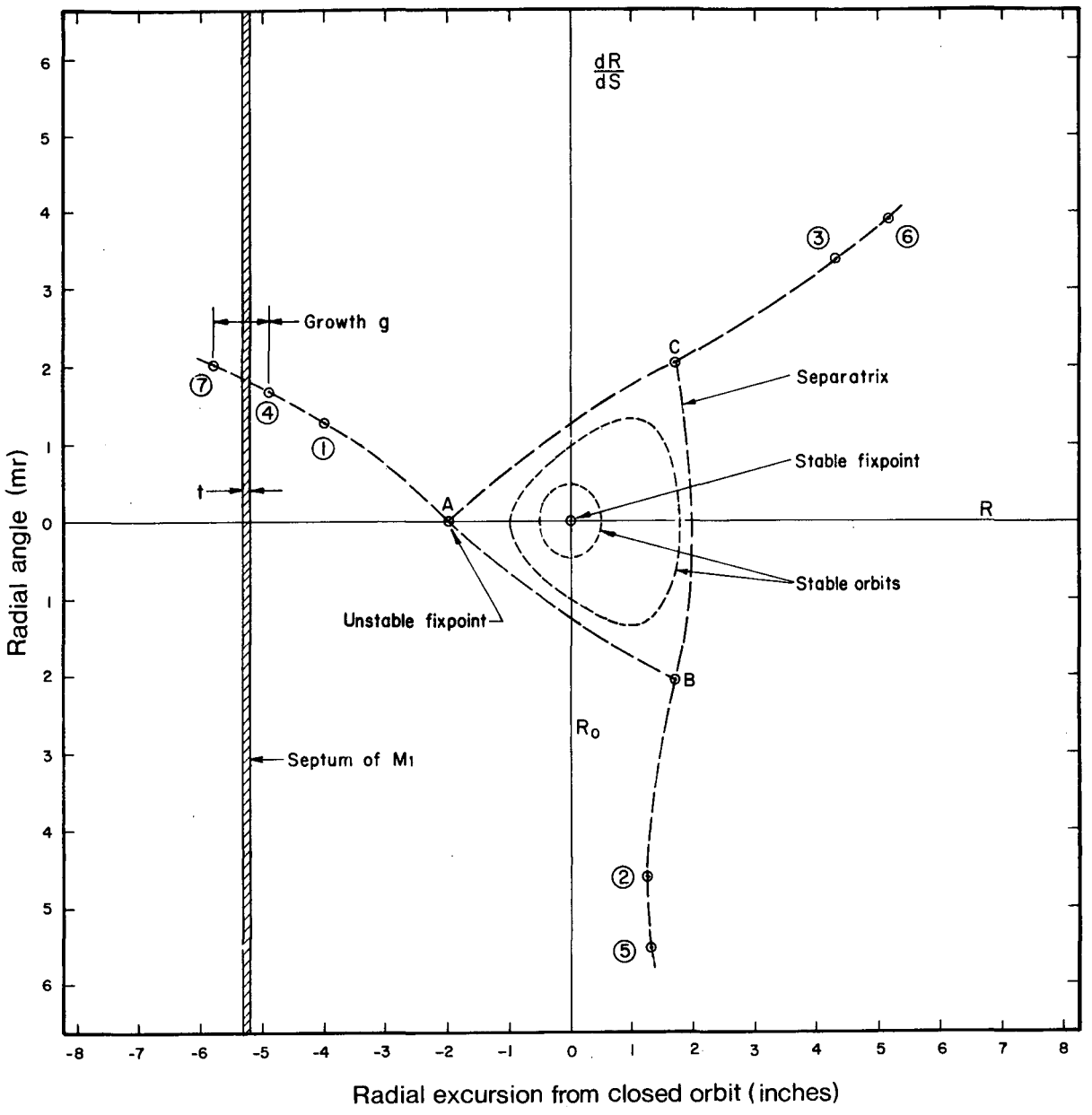


Resonant extraction scheme for the Bevatron

Note: The particle motion shown as a sinusoidal motion with $\nu_R = 2/3$ gives a somewhat simplified picture.

Fig. II-3

XBL 731-19



Radial phase diagram of 2/3 integral resonance excited for extraction at east straight section.

Fig. II-4

XBL 7212 5641

III. BEVALAC BIOMEDICAL FACILITY

A. GENERAL DESCRIPTION

The Bevalac Biomedical Facility is an area specially designated for tumor, tissue, cellular, molecular, neuro, developmental and space radiobiology, radiography, and radiological physics. The Biomedical Facility has its own control room, three irradiation caves, and two preparation rooms. Although reserved for PAC-approved biomedical studies, the area can accommodate simple emulsion exposures and equipment calibrations, as they can be fit into the operating schedule. The maximum beam energy which can be transported into the biomedical area is 1 GeV per nucleon.

Cave I, about 22 by 24 feet and primarily used for radiotherapy, contains a movable alignment bench with the primary shielding, dosimetry, range modulation, and beam field-shaping equipment. A magnet system has been installed that will be used instead of the present lead scattering system to enlarge the beam field.

Cave II is about 20 by 30 feet and has, at present, two major instrumented beam lines. The primary line, used for all of the biological experiments, contains two alignment benches, each about 10 feet long and separated by about 1 meter. The other beam line contains one bench and is primarily used for physics experiments that relate to the radiobiological research.

Cave III will probably be used for radiography, radioactive beam studies, and possibly for radiotherapy. The beam line for Cave III runs through Cave II.

The beam can be shared on an alternating basis between Cave I and Cave II and eventually between Cave I and Cave III, but it is not possible to alternate between Cave II and Cave III.

Photos and diagrams (Figs. III-1 through III-13) of major biomedical equipment are to be found at the end of this section.

B. BIOMEDICAL BEAMS B1 AND B2

These beam lines provide transport of heavy ions to Caves I and II in the biomedical area. After extraction, the beam is brought down the EPB II beam line. Steering magnet BOM1 must be energized to bring the beam into the biomedical area. Next the beam passes through BOS1, a vertical steering magnet used to adjust the elevation of the beam in either cave. Following this element comes a set of horizontal-jawed collimators. This device can be used to block unwanted portions of the beam (such as unwanted isotopes created in the production of radioactive beams) or to reduce greatly the beam intensity for low level studies. Care should be taken to insure that it is fully open in normal beam tuning. Next, the steering magnet BOM2 is used to bring the beam into Cave I or Cave II. Energizing this magnet brings the beam into Cave I. It is the control of this magnet that allows for rapid beam switching (on the order of one minute) between Caves I and II.

The beam reaches Cave I by passing through focusing quadrupole magnets B1Q1A and B1Q1B, a set of lead scattering foils, and a final wire chamber, B1WC1. The beam reaches Cave II by passing through two sets of focusing quadrupole magnets (B2Q1A and B2Q1B, and B2Q2A and B2Q2B), three wire chambers (B2WC1, B2WC1A, and B2WC2), a set of lead scattering foils, and a final steering magnet, B2M1. Wire chamber B2WC2 sits on the front

of the first biology beam line bench. If the beam is to be brought to the physics bench, steering magnet B2M1 is reversed in polarity and wire chamber B2WC3 is activated.

When Cave III is brought into operation, it will use the same beam line as the biology bench line.

For all beam energies relevant to biological use (250 MeV/amu to 1 GeV/amu), the pulse rate is 15 pulses per minute. Beam currents on target are essentially independent of energy. Slightly greater intensities are available at the higher energies due to better extraction efficiency from the Bevatron.

Fig. III-14 is a diagram of the layout and beam lines of the Biomedical Facility.

1. Instrumentation

The alignment benches are constructed of two parallel, 2-in.-diameter precision-ground steel rails, 10 feet long, separated by 14.3 in. rail centers and mounted on a sturdy frame of welded channel iron. Beam center is 15.25 in. above the center line of the rails. Preliminary alignment was done with surveying instruments, so that the beam axis of the bench intersects the beam pipe axis at the center of the last bending magnet.

Final alignment of the bench is aided by use of multiwire proportional chambers (MWPC) at four critical positions in the external beam transport system. The final MWPC is located on the optical bench. The chamber in this final position has 6-mm wire spacing; another chamber with 1-mm wire spacing is also available. Horizontal and vertical profiles of each beam pulse are displayed on monitor screens, both in the

Bevatron Main Control Room (MCR) and the biomedical control room. Quadrant electrodes in the transmission ionization chambers provide signals for final critical beam alignment. These signals may be displayed digitally, or analog signals can be generated for graphic display via the computer.

2. Ion Chambers

The basic ionization chamber used in biomedical dosimetry at the Bevalac consists of three foils mounted in a gas-tight aluminum housing. Two clear Kapton H windows complete the gas seal. The housing is cylindrical with an inner clear diameter of 8 in., an outer diameter of 11-1/4 in., and a thickness of 2-3/8 in.

The three foils are a quadrant foil, a high-voltage foil, and a concentric-ringed foil. The ringed foil is constructed of a 3-mil Kapton H gold-plated membrane chemically etched on both sides, then stretched and glued to a ring. One side provides a pattern for electrical connections to various parts of the foil. The other provides various circular areas. The present patterns established for the three kinds of spacing are as follows:

Blue or black bodies: 1, 3, 6, 9, 15, and 18 cm.

Yellow bodies: 1, 2, 4, 6, 8, 10, and 18 cm.

Magenta bodies: 1, 2, 3, 4, 5 , 6 and 18 cm.

The quadrant foil is similar, except that the gold-plated side is etched to form four isolated sections. In both foils the areas not used for rings or quadrants or used to form connections to those areas are grounded.

The high-voltage foil is a double gold-coated, 3-mil Kapton H foil. It is sandwiched between two rings and constructed to eliminate high electrostatic fields in the gas at the edge of the high-voltage foil. The separation between each outer foil and the inner high-voltage foil is 1.3 cm. The ringed foil is both a beam-distribution-sensing device and a dose-measuring device, while the quadrant foil is primarily for beam positioning and sensing.

The chamber is flushed with dry nitrogen gas, in most cases with a low flow rate (0.01 $ft.^3/h$) and a minute overpressure generated by a gas bubbler connected to the exit gas port on the chamber. Each collecting electrode is connected to a recycling integrator channel located within 10 feet of the ionization chamber. These are a modification of a LLNL design and have a conversion constant of 1 count/10^{-11} coulombs. They are linear over about seven decades of current, with maximum current of approximately 7×10^{-6} A. The outputs of the recycling integrators are connected to scalers in a CAMAC crate located in the biomedical control room. The scalers are interrogated and reset by the computer before and after each beam pulse. The counts are added to the previously accumulated counts. A background count correction is made.

While any combination of areas may be selected for determining the dose that was delivered to the sample, the actual dose cutoff in Cave II is determined from the charge collected from the central 1-cm area. The basic calibration factors for each collecting area are determined by the area of the collecting electrode and its separation from the high-voltage electrode. Until values of W have been determined, we assume a value of

34.9 eV/ip for heavy ions in nitrogen gas. The other assumption we have made is a value of 1.125 for the relative mass stopping power of water to nitrogen.

A Far West thimble chamber with its associated secondary National Bureau of Standards (NBS) calibration is used for the primary dose calibration in the therapy cave and for cross checking and transfer measurements in the biology cave. This type of chamber is commonly referred to as an egg chamber.

3. Intensity Distribution

In addition to the ionization chamber and wire chambers, which give a gross measure of intensity distribution over the beam cross section, photographic emulsions may be exposed in the beam and scanned with a densitometer to get a profile of beam distribution. Six to eight exposures covering a dose range of at least 100 to 1 may be made on an 8 x 10-in. film, so that a dose vs. density film calibration can be determined as well as having an optimum exposure for a profile scan.

If one assumes that the beam profile will be Gaussian-shaped, and this is generally a good assumption (when sufficient scattering material is used), then the beam sizes available will consist of these Gaussian distributions of various widths, and may be characterized by a unique value of sigma. The dose rate will vary inversely with the square of sigma.

To ensure uniform beam intensity profiles, a beam scattering system is installed after the last quadrupole in the Cave I beam line and prior to the last bending magnet in the Cave II beam line. Lead sheets with total thicknesses from 1/64 in. to 1/2 in. can be inserted in the beam

giving variable field sizes from about 1 cm diameter to well over 20 cm diameter at the target position, 6 meters downstream. The Gaussian field shape can be flattened with occluding rings placed downstream of the scattering sheets in Cave I. Such a system at the 184-Inch Synchrocyclotron has yielded 30-cm circular fields of He particles with a 2% overall uniformity. This scheme is used in the therapy cave (Cave I) at the Bevalac and is practical for fields up to about 20 cm and ions no heavier than neon. A magnet wobbler system has been installed in Cave I that can produce larger fields with less scattering material. This system is being developed for future use.

For further discussion regarding beam size and distribution see Appendix A subsections on lead scatterers and sigma.

4. Variable Water Column

The variable water absorber or water column can vary the range (energy) of the particles striking a target by introducing a measured amount of water into the beam path.

Two water columns are available, one with a clear diameter of 6 in., the other of 8 in. The maximum depth is 30 cm of water for the 6-in. column and 40 cm of water for the 8 in. column. The thickness, controlled by computer or manual control of a movable lucite window, is read by an optical encoder to the nearest 0.1 mm $\pm$ 1 digit. The water column is usually left in place on the alignment bench. When it is empty its minimum thickness is the 0.6 cm of the two lucite windows.

5. Ridge Filter

Some biological samples are thick compared to the width of the Bragg peak, so that when irradiating with that part of the curve, the dose is substantially different in different parts of the sample. The Bragg curve can be modified over any predetermined portion by interposing in the beam a filter of nonuniform thickness (called a ridge filter) which, when moved across the beam, covers the sample with a series of Bragg curves of different penetrations. A computer program is available for calculating the relative widths and thicknesses of the ridges. So far, two types of filters have been made, linear and spiral.

Construction and testing of special filters require substantial lead time. The present collection of spiral ridge filters consists of 4-, 6-, 8-, 10-, 12-, and 14-cm spread filters that were designed for use with a 400-MeV carbon beam; 6-, 10-, and 12-cm neon filters, a 10-cm argon filter, and a 12-cm silicon filter.

6. Collimation

Some experiments require restriction of the beam to a target area with minimum irradiation of surroundings. This is usually done by passing the beam through an aperture. These are of brass, 2 in. long, and interchangeable in a sturdy prealigned holder on the alignment bench. Currently available diameters (and some irregular shapes) are from 2 to 38 mm. Larger diameter apertures can be made and individually mounted on a stand. The apertures are placed on the bench according to the requirements of the experiment. Cerrobend alloy is used to make the larger apertures of irregular area or shape while the smaller ones are machined from brass. A lead time of 24 hours is required for cerrobend

collimators of special size and shape. If precise delineation of the target is not required, the aperture holder is removed from the bench.

7. Sample Holders

Small animals may be exposed to the beam singly, several at a time in an array in a large beam field, or sequentially, one at a time. Several holders have been fabricated to expose animals singly and others could be made with sufficient lead time. A holder containing an array of animals is more complex and should be provided by the experimenter. A two-dimensional sample translator is available that will support seven mice or four to five rats and is positioned sequentially and remotely for rapid exposure. Whole body exposure for mice can be achieved conveniently in a cylindrical holder 6 cm in diameter by about 3 cm deep using a sequential method. Rats should be exposed singly, or in an array, rather than sequentially.

Biological samples of cells or tissue culture are usually irradiated on 35-mm petri dishes or flasks. The 35-mm petri dishes can be placed in 3-in. square aluminum holders for gas-environment control, and irradiated individually. Small flasks can be placed on the sample translator and irradiated sequentially. Other special positioning jigs devices are available that may be useful for a new experiment.

8. Cell Culture Experiments

Researchers doing cell culture work should provide their own supplies (medium, plastic ware, cells, etc.). The simplest way is to order them from commercial sources and have them sent to LBL for preparation. Some supplies can be purchased from LBL.

9. Special Experimental Conditions

Each experiment is unique in its design and objectives. Any exceptional requirements for equipment and/or data acquisition should be discussed well in advance with the staff biology physicist, Ext. 5575.

Suggestions for new standard equipment desired in the Biomedical Facility for general use should be conveyed to him/her.

C. POLICY FOR ANIMAL USE AT LBL

1. In order to maintain an efficient and properly functioning animal care facility, the following standards must be observed: Investigators, both resident and visiting, whose proposals call for the use of laboratory animals, must arrange for procurement of the necessary animals from approved sources for delivery to LBL in consultation with the head of Animal Services. A lead time of at least two months will be necessary for ordering animals. Animals will generally not be accepted from experimental facilities without special quarantine arrangements and advance approval by the head of Animal Services and the LBL veterinarian. These special arrangements will be reviewed and approved by the LBL Animal Care Committee. The head of Animal Services is Robert W. Springsteen, Building 74, Room 159A, Ext. 5221. The LBL veterinarian may be contacted through Mr. Springsteen.

All proposals requiring laboratory animal usage must contain a statement of intent with respect to the type and amount of anesthetic, analgesic, and/or tranquilizing drugs used on animals during actual research or experimentation. These must be appropriate to relieve all unnecessary pain and distress for the subject animals.

The above statement complies with Section 2.28 of the Federal Animal Welfare Regulations. Experiments involving necessary pain or distress without use of drugs must be reported to the LBL Animal Welfare Committee, Building 74, and include a brief statement explaining the reasons.

2. LBL presently does not have approved biohazards facilities; therefore, infectious organisms, either free or in animal carriers, cannot be accepted at LBL, nor can such infectious agents be used in the laboratory facilities.

3. If radioactive isotopes are to be used in the experimental protocol, the responsible Safety Services engineer must be notified of such intent, and provisions made for disposal of radioactive residues and carcasses.

D. USER COMPUTER FACILITIES

There are two major computer facilities in use. One, a DEC 11/44 is used primarily for operating the control system and recording both therapeutic and biological exposure data. The other, a DEC 11/45, is used primarily for acquiring and recording data related to physics experiments in Cave II. It is available to experimenters in need of such a facility.

The DEC 11/45 consists of the following:

- DEC 11/45 computer with 128K memory and floating point processor.
- IBM-compatible 9-track magnetic tape drive.
- One RK-05 disc drive that accepts a 1.2 megaword disc cartridge.
- Two Ampex disc drives with 33 megawords each.
- CAMAC crate and modules.

The computer uses the RSX-11M Version 4 operating system and has a FORTRAN IV Plus (F4P) compiler, a FORTRAN 77 compiler, and a BASIC interpreter. Substantial CAMAC-based data acquisition software exists, as well as a graphics support package for a Textronix 4000 series terminal. We presently have a system called Multi-QDA installed and in use.

For applications of this computer, contact the staff biology physicist, Ext. 5575.

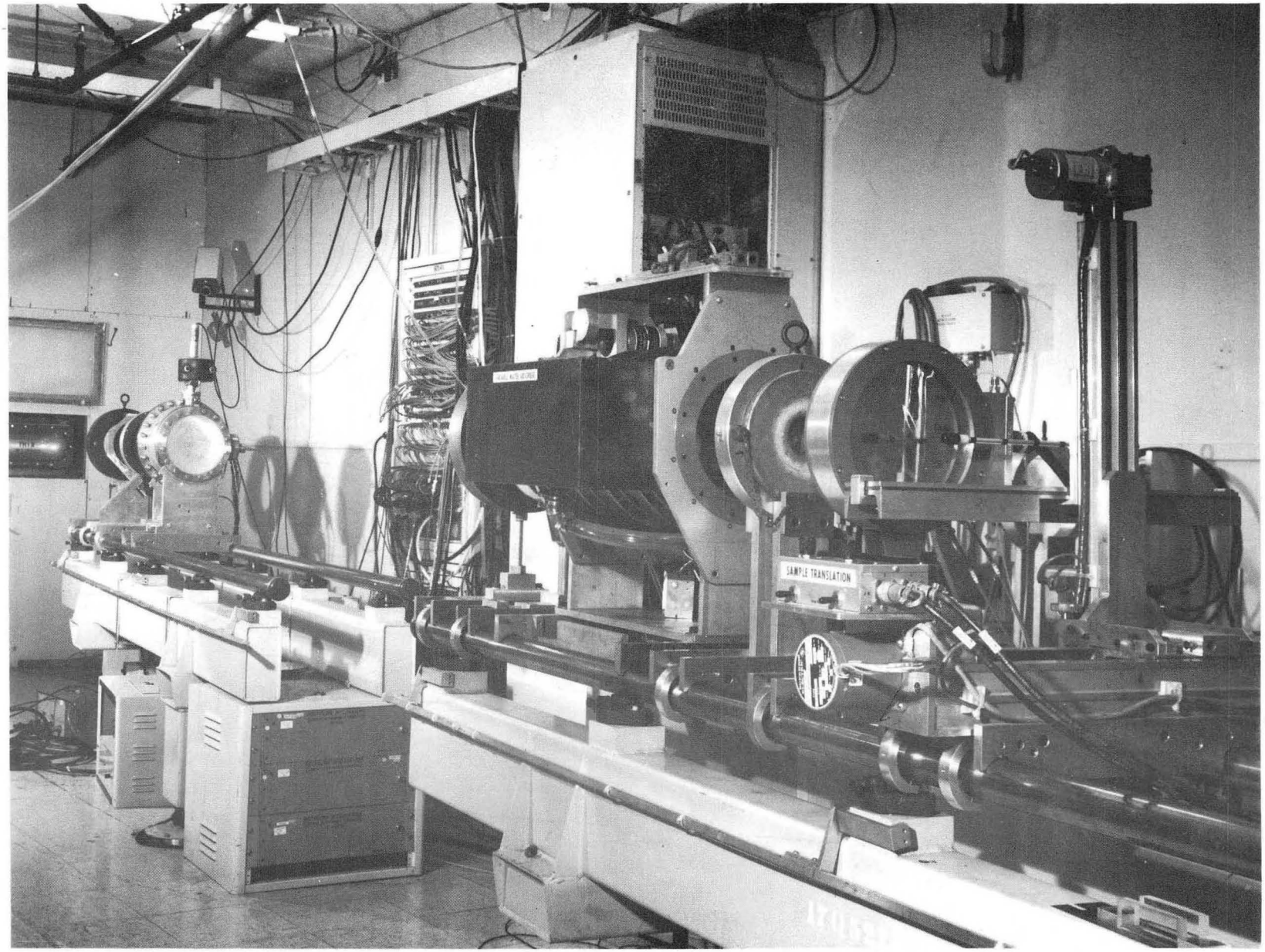


Fig. III-1

XBB 840-9526

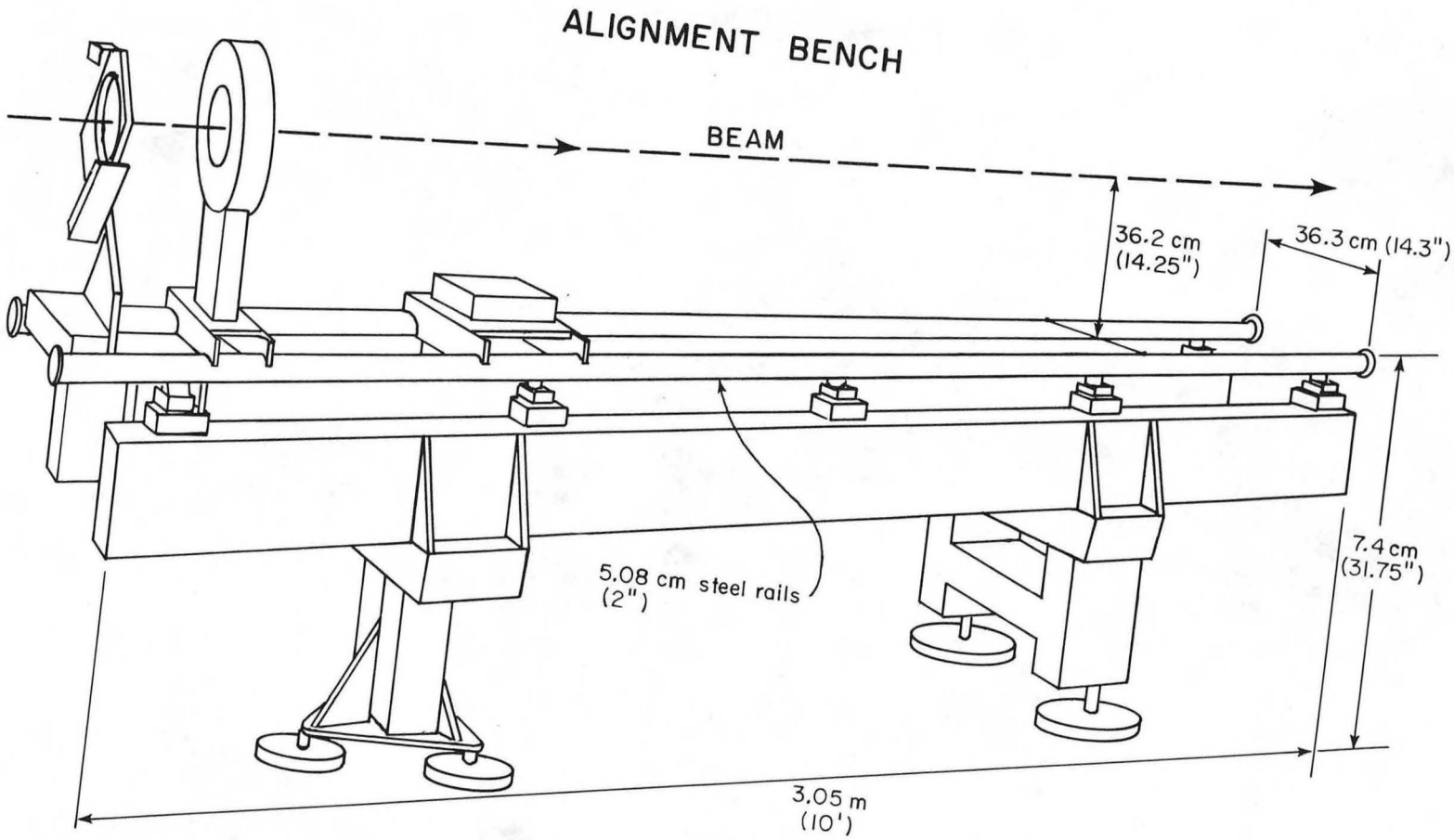

ALIGNMENT BENCH
BEAM
36.2 cm
(14.25")
36.3 cm (14.3")
5.08 cm steel rails
(2")
7.4 cm
(31.75")
3.05 m
(10')
XBL 7610-4134A

Fig. III-2

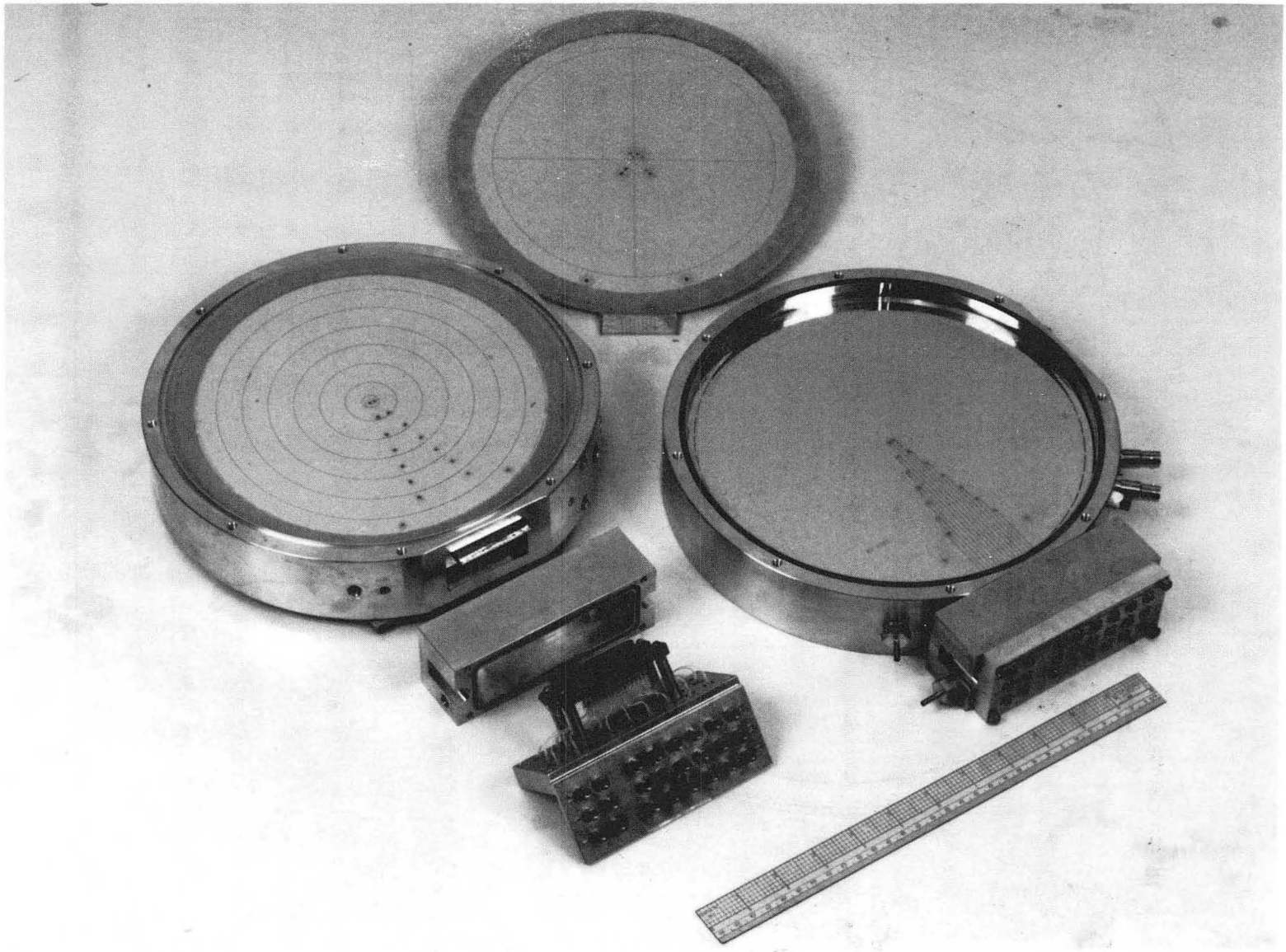
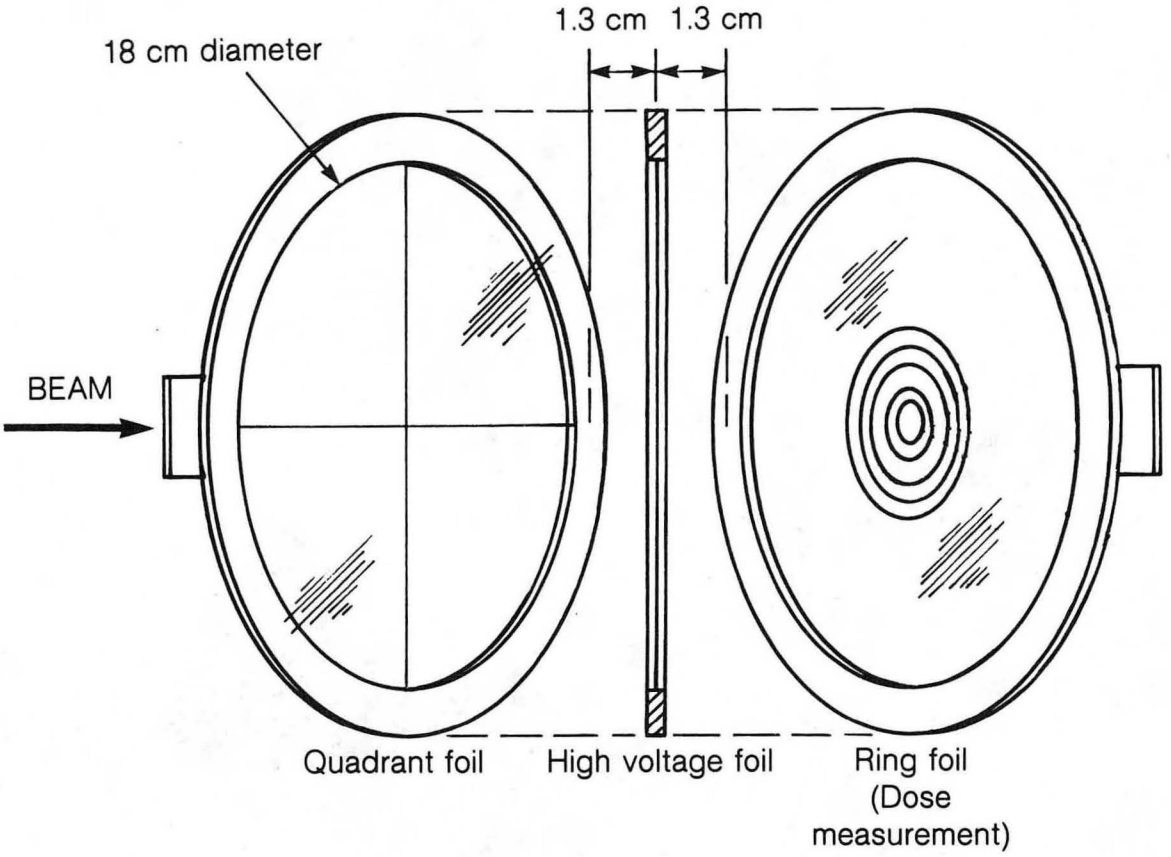


Fig. III-3

CBB 837-6371



Ionization chamber foils

XBL 7611-9940 A

Fig. III-4

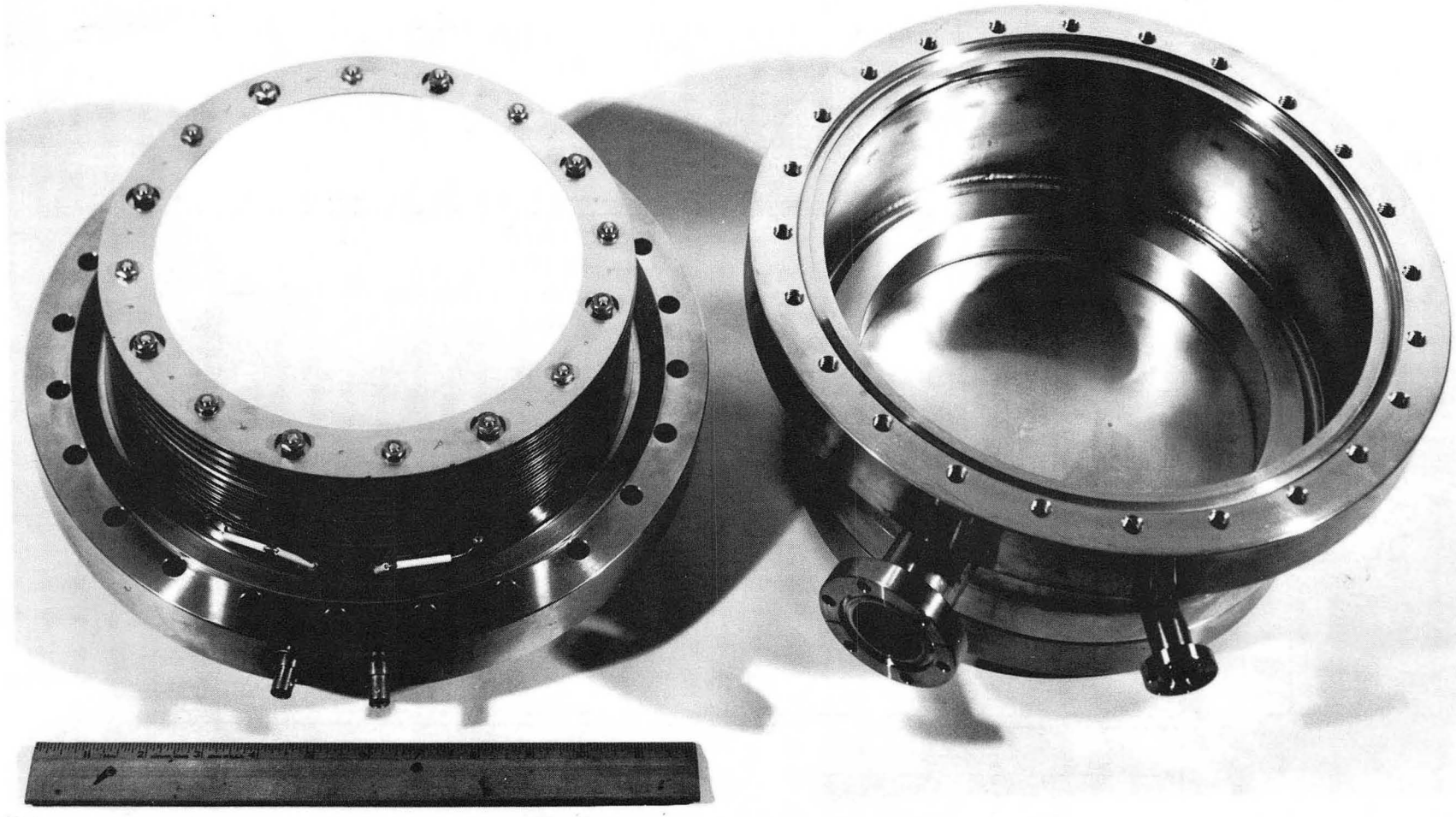


Fig. III-5

CBB 786-7968

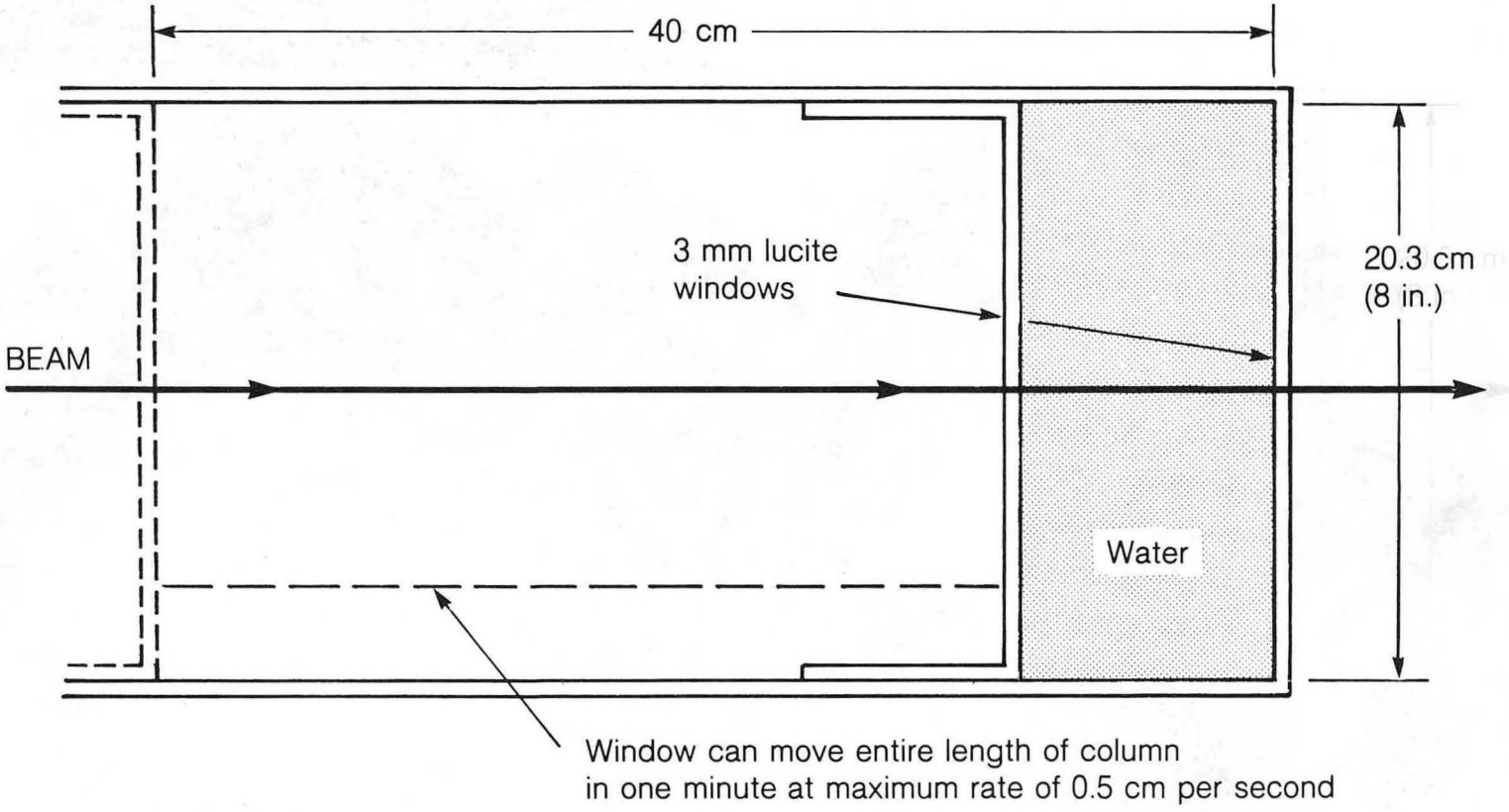


Diagram of variable water absorber

XBL 7610-4131A

Fig. III-6

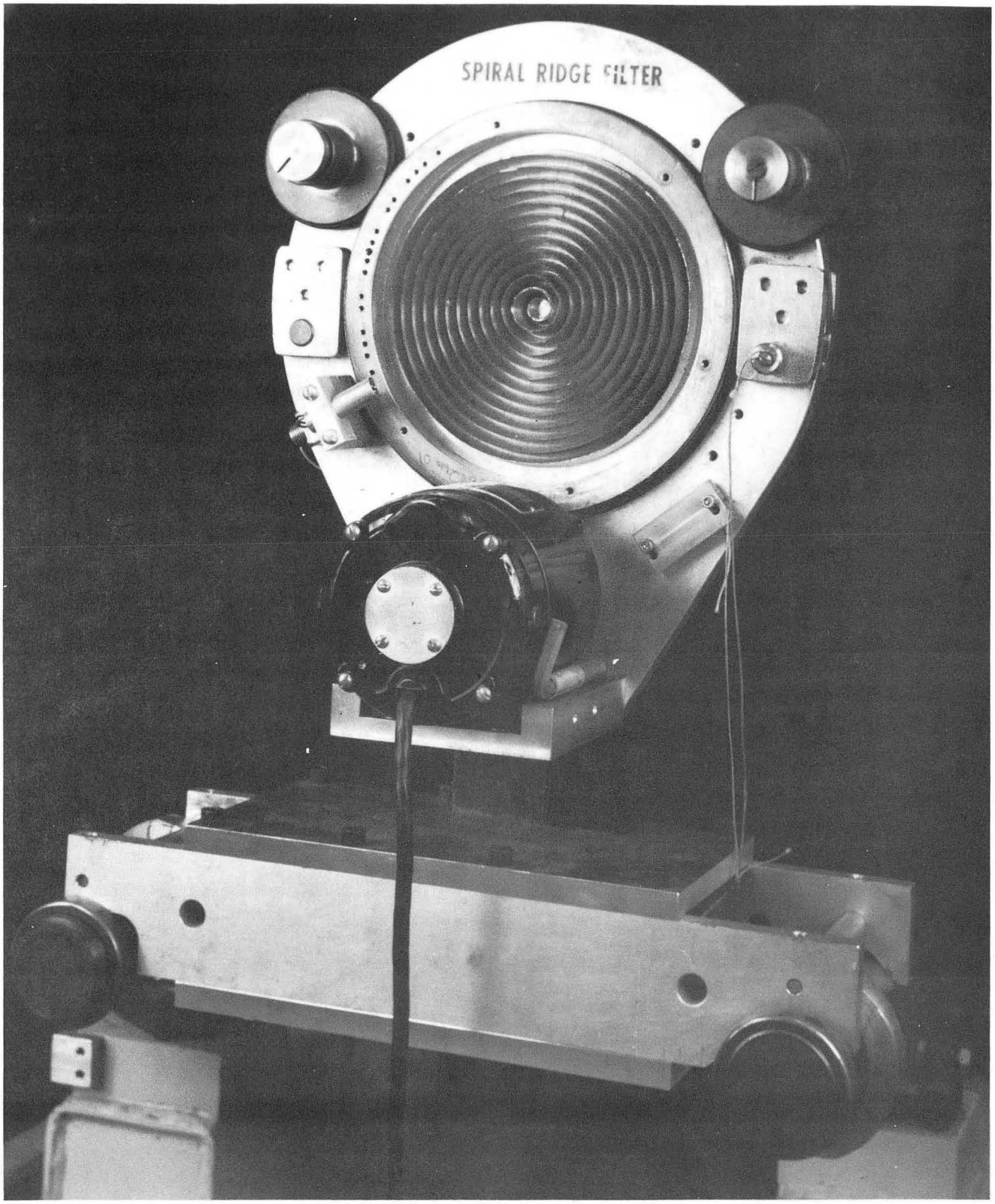


Fig. III-7 XBB 840-9528

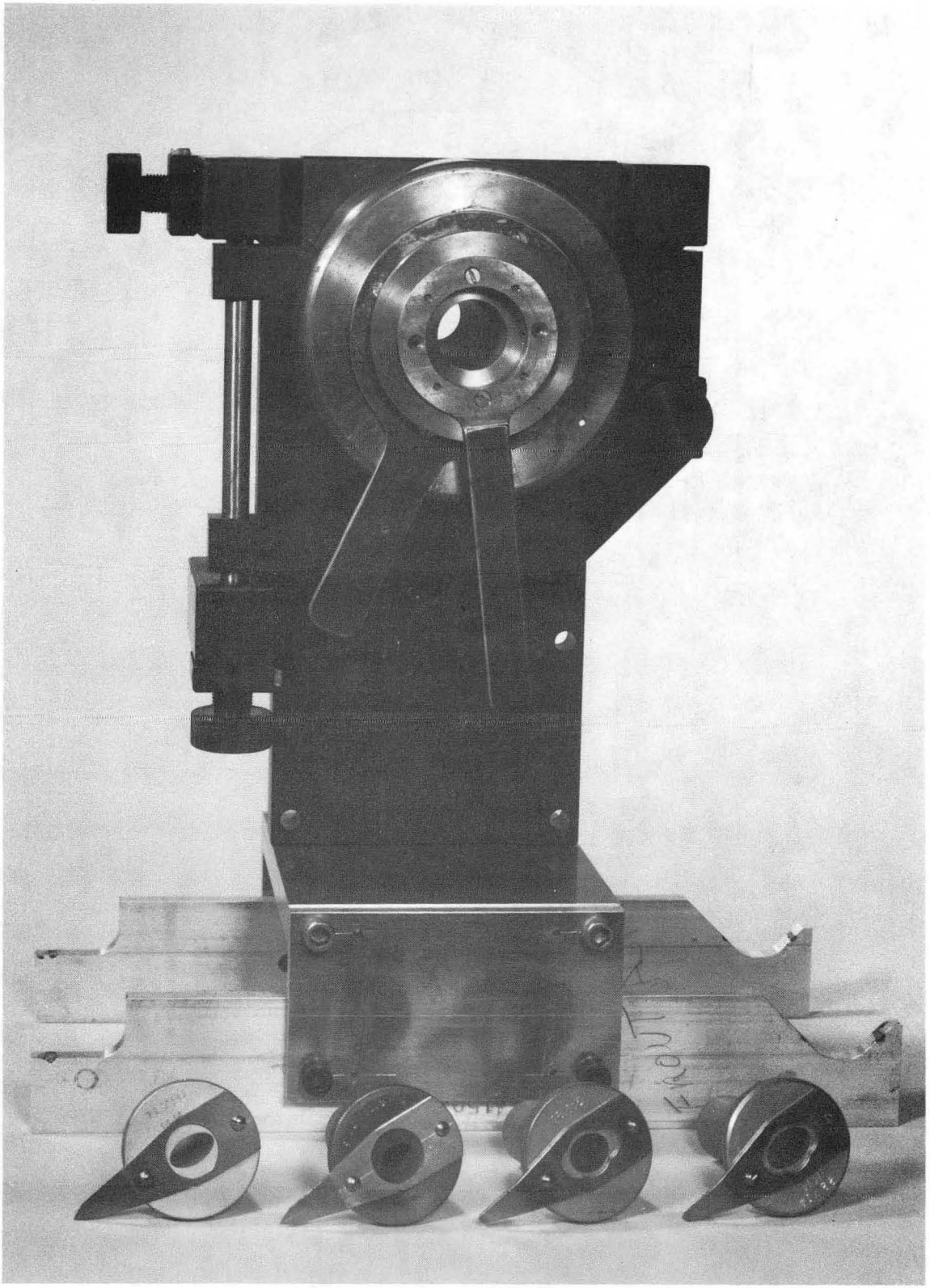


Fig. III-8 CBB 755-3516

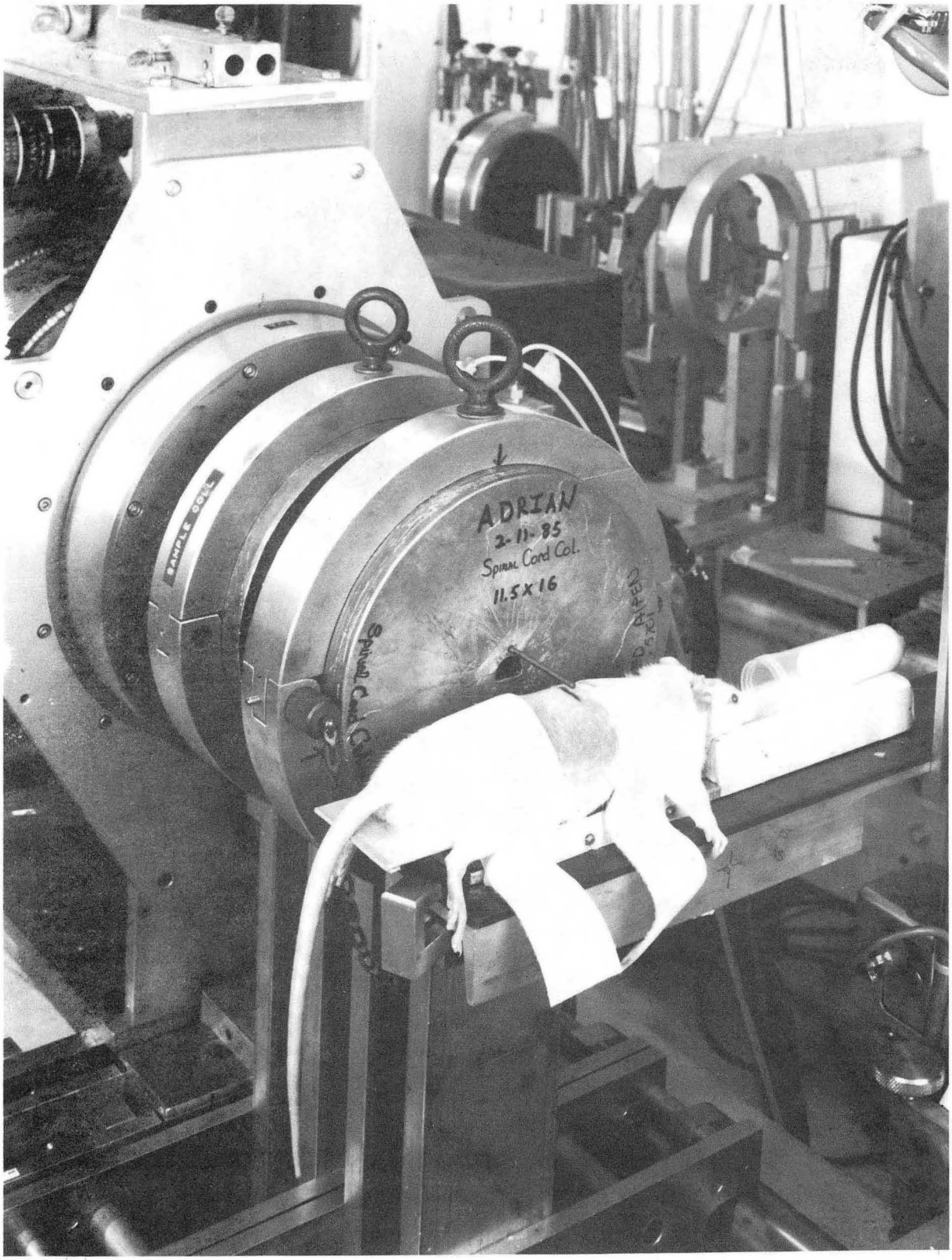


Fig. III-9 CBB 853-1819

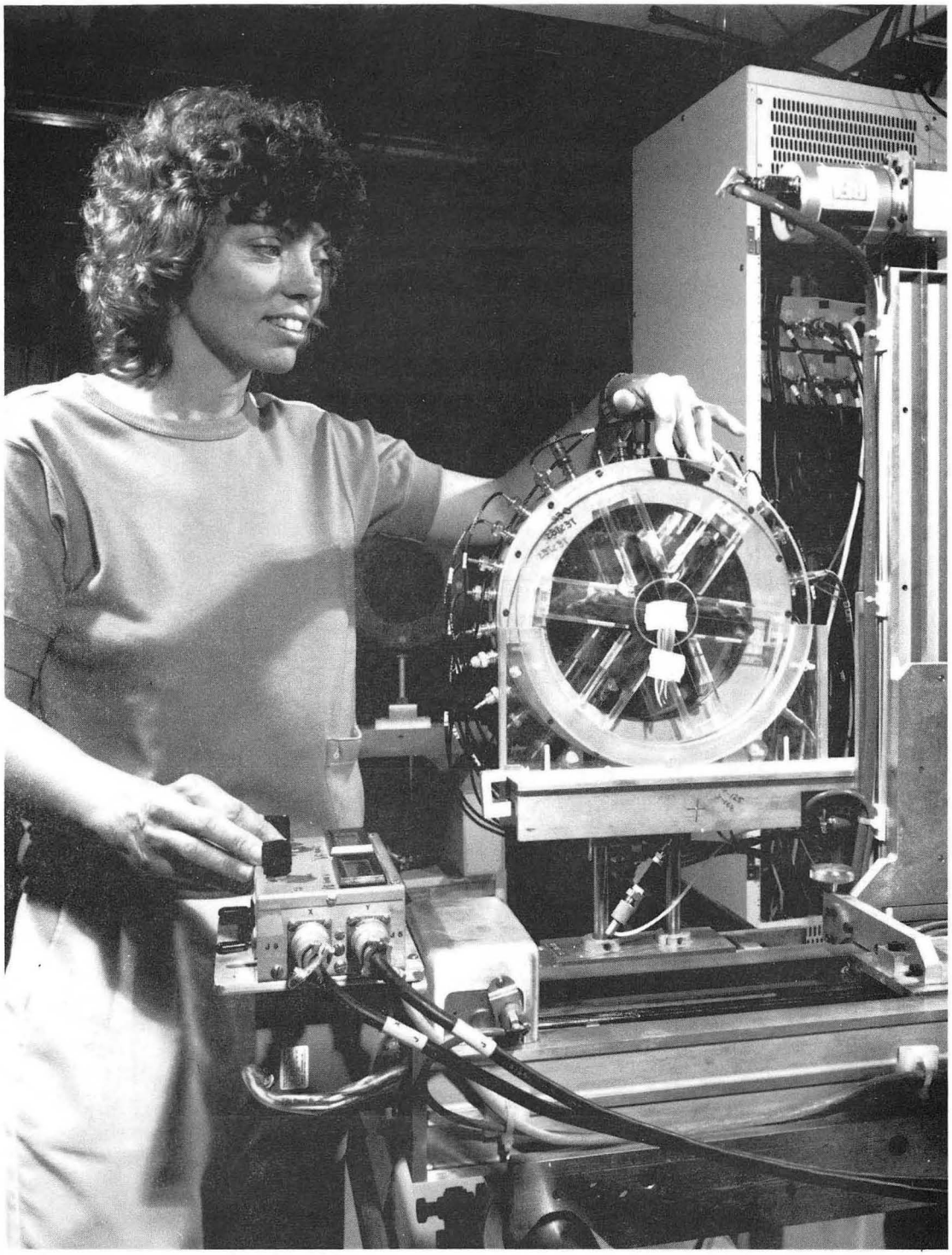


Fig. III-10 CBB 837-6451

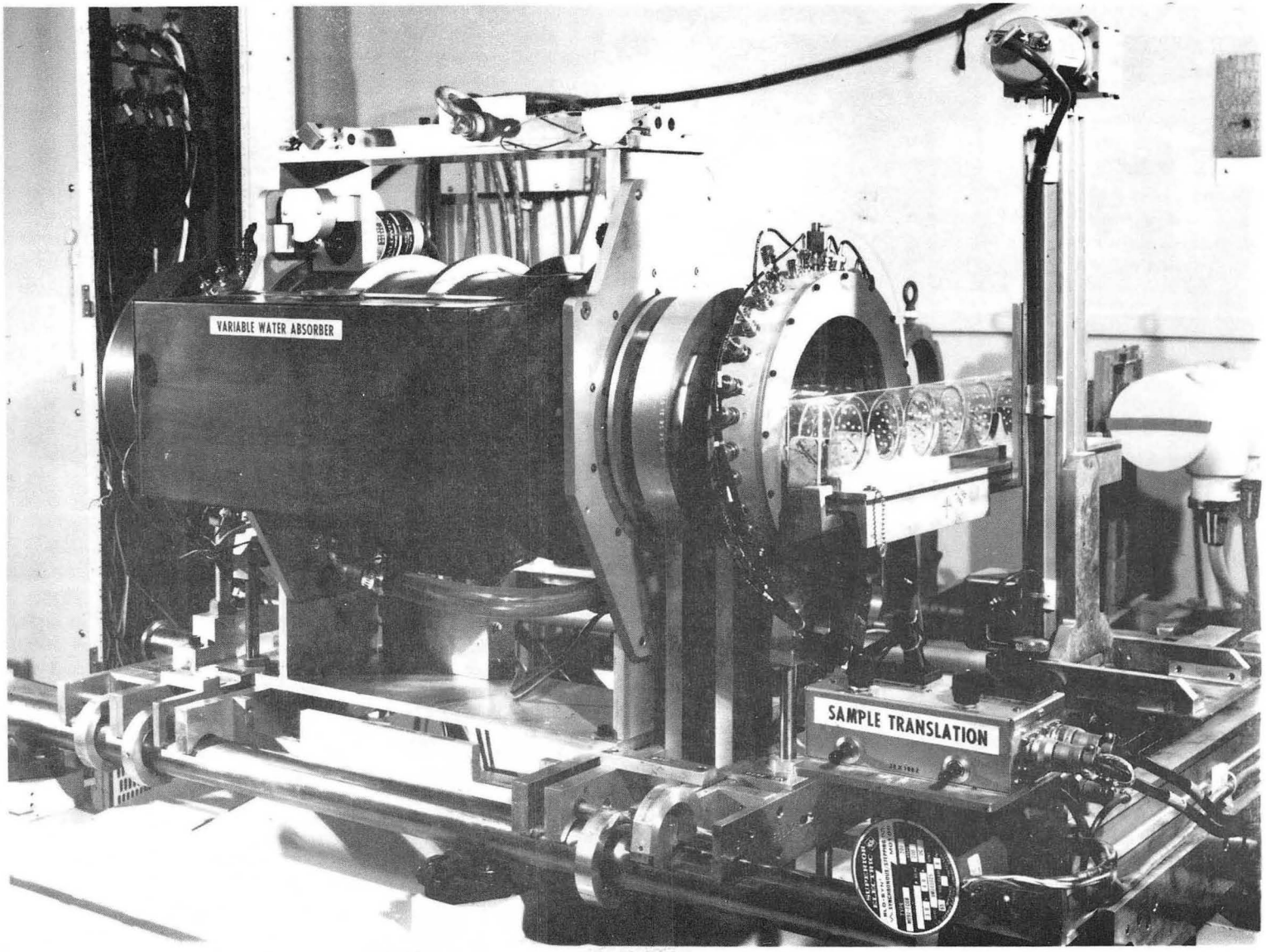


Fig. III-11

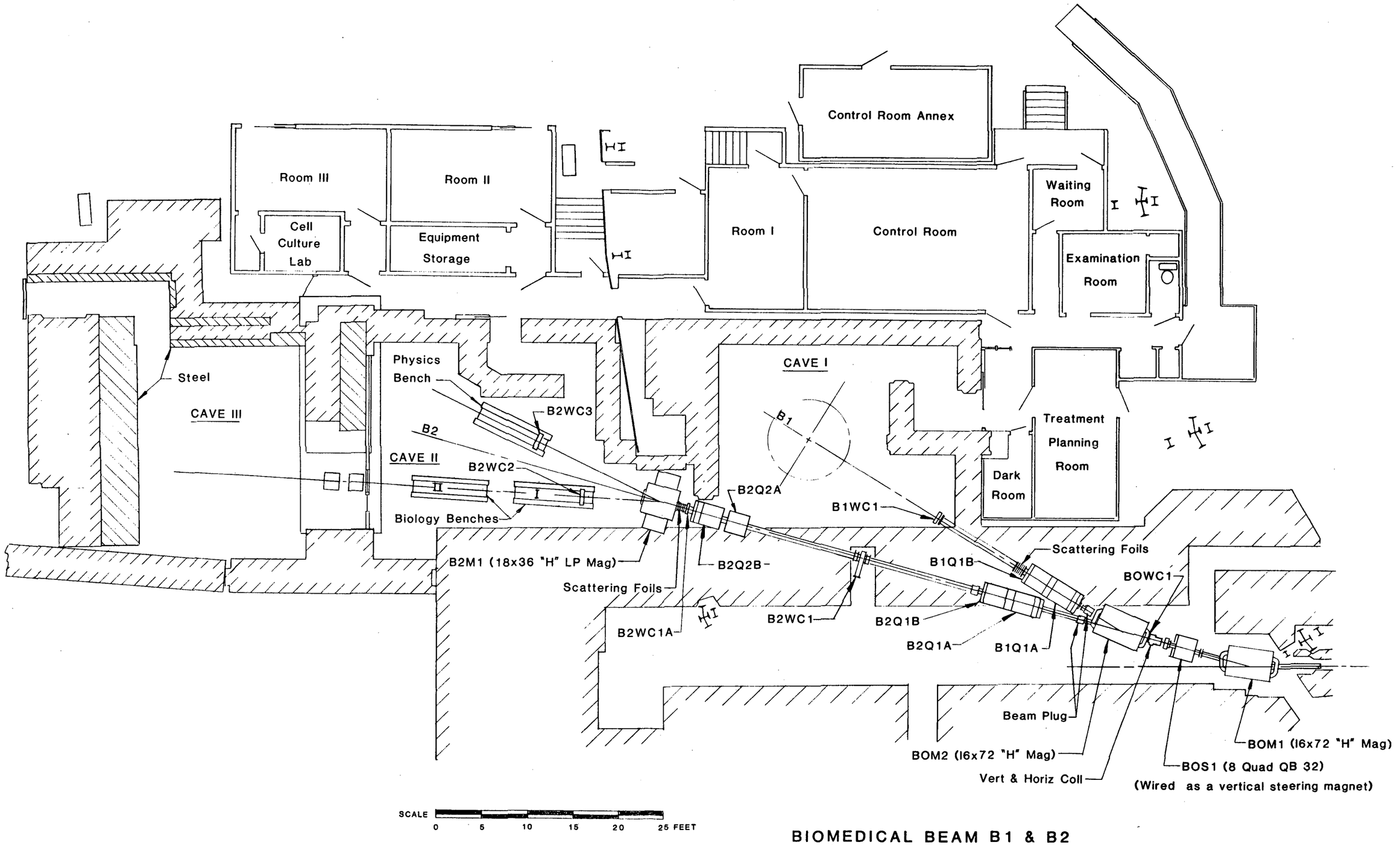
CBB 832-1172

Fig. III-12

CBB 769-8489

Fig. III-13

CBB 769-8491



BIOMEDICAL BEAM B1 & B2

-- XBL 848-3490 --

Fig. III-14

IV. OPERATIONAL DATA

A. STANDARD CONDITIONS

We have established a set of standard conditions that will cover the requirements of 95% of the experimenters. We strongly urge that these conditions be used as far as possible to allow for cross comparisons of various systems. In essence, the conditions are as follows:

1. Sufficient lead scatterer to be used to provide a field 6 cm in diameter with a maximum of $\pm$ 10% variation in uniformity across the field for the ion and energy chosen.
2. One fixed place is to be used for the irradiation on the second alignment bench.
3. A standard configuration of ion chambers, water column, and collimators should be in place.
4. The water column settings should provide standard positions along the depth-dose Bragg curve.

In addition, if uniformity of dose with depth is a requirement, a 10-cm spread Bragg peak can be provided by using a spiral ridge filter or comparable system. If absolutely necessary, a larger field can be provided by moving the sample further down the bench. However, in the case of the spread peak, a field diameter greater than 7-cm is extremely difficult to provide in Cave II and it is recommended to do the exposures in the therapy cave (Cave I).

B. BEAM DATA

Table IV-1 on page IV-3 lists the ion, energy/amu, range, and stopping power for most of the ions we have used. Values are those at the sample for the standard conditions wherever they have been

established. We normally quote the nominal Bevatron energy because of possible confusion that might occur when other conditions besides the standard ones are used. Otherwise many different energies might be cited for the same accelerated energy from the Bevatron, resulting in requests for many more accelerated energies than is practical. One additional caution is that the stopping powers quoted are for the plateau conditions only. These values are easily calculated and are characterized by a relatively narrow distribution. Values near the peak or in the spread peak are difficult to specify due to different methods of calculating them as well as the fact that the distribution broadens considerably at the end of the range. When a consensus of how to calculate them or when a satisfactory means of measuring and representing these values is established, we will list the information in this handbook.

Field values are exact. Other values are calculated or estimated with the exception of some ranges that are indicated by * where the range is measured to the peak. Also indicated by * are estimated values for the lead scatterer for those ions and energies which have not been measured under standard conditions.

The intensity values are estimated average values for planning purposes. Actual values at irradiation time may differ considerably, either higher or lower. Material in the beam, exclusive of scatterer is currently (January 1985) as follows in water-equivalent centimeters: machine exit to cave entrance--0.530 gm/cm^2; machine exit to sample (water column in place)--3.623 g/cm^2. See Appendix D, page D-7.

Table IV-1. Biomedical Cave II Beam Data (Standard Conditions).

Ion	m Sym z	Bevatron			Sample position					
		Nom KE (MeV/ amu)	Mag field (gauss)	Exact KE (MeV/ amu)	Lead scat. foil (64th's)	KE (MeV/ amu)	Range (cm water)	DE/DX (KeV/ um)	Nominal inten. (Part./ pulse)	Nominal inten. (rads/ min)
Helium	$^{4}_{2}He$	150	2405	151.5	1*	130.9	12.43	2.36	1×10^{9}	50
		225	3000	226.5	2	210.3	28.31	1.73	1×10^{9}	50
Carbon	$^{12}_{2}C$	225	2997	226.3	3*	171.3	6.63	17.67	5×10^{9}	500
		250	3180	251.7	4*	197.6	8.48	16.11	5×10^{9}	500
		308	3576	309.8	6*	256.8	13.27	13.74	5×10^{9}	500
		400	4163	402.8	8*	351.9	22.24	11.69	5×10^{9}	500
		470	4579	472.8	12	416.7	29.25	10.76	5×10^{9}	500
Neon	$^{20}_{10}He$	425	4311	427.6	3	364.8	13.9*	31.86	2×10^{9}	1000
		557	5080	561.3	6	495.0	23.08	27.74	2×10^{9}	1000
		670	5666	668.8	8	600.1	31.0*	25.88	2×10^{9}	1000
Silicon	$^{28}_{14}Si$	320	3657	322.7	4	207.8	3.9*	84.92	1×10^{9}	500
		456	4493	458.9	5*	361.3	9.95	62.71	1×10^{9}	500
		530	4893	528.5	6*	432.2	13.30	57.59	1×10^{9}	500
		670	5666	669.4	7	577.3	20.5	51.41	1×10^{9}	500
Argon	$^{40}_{18}Ar$	330	4135	332.8	2	218.0	3.8*	136.24	5×10^{8}	250
		470	5091	474.2	4	368.9	8.89	102.60	5×10^{8}	250
		570	5710	572.5	7	458.3	8.61	92.77	5×10^{8}	250
Iron	$^{56}_{26}Fe$	600	5730	605.7	5	463.3	8.24*	192.59	1×10^{8}	100

C. DEPTH DOSE CURVES

The ionization curves shown in Figs. IV-1 through IV-13 represent typical conditions. The range and shape of each curve may change under actual experimental conditions due to the presence of different equipment in the beam line. A listing of material in the beam line is provided in Appendix D.

The curves are plotted as water absorber reading (X) versus relative ionization (Y). The proximal peak is the first sharp peak encountered in the curve. It will usually be found the width of the spread peak back from the sharply dropping part of the curve (distal peak). For example, in Fig. IV-3 the proximal peak is at 17.6 and the distal peak is at 27.6, thus the distance between them is 10-cm or equal to the width of the 10-cm spiral ridge filter.

Table IV-2. TABLE OF BRAGG CURVES

Ion	Energy	Lead Scatterer	Comments	Figure No.
Carbon	250	0/64	Not standard condition	IV-1
	400	20/64	Not standard conditions	IV-2
	470	12/64	Cave I, 10-cm SRF	IV-3
Neon	425	3/64	Standard condition	IV-4
	670	8/64	Std Cond. new SEM in place	IV-5
	670	7/64	10-cm spiral ridge filter	IV-6
Silicon	320	4/64	Standard conditions	IV-7
	530	2/64	Standard condtions	IV-8
	670	7/64	Standard conditions	IV-9
Argon	330	2/64	Standard conditions	IV-10
	470	4/64	Approximately 100 keV/μm	IV-11
	570	2/64	Not standard	IV-12
Iron	600	5/64	Standard Conditions	IV-13

See Appendix F for a sample of the Bragg curve acquisition routine dialogue and a sample of the numerical data obtained.

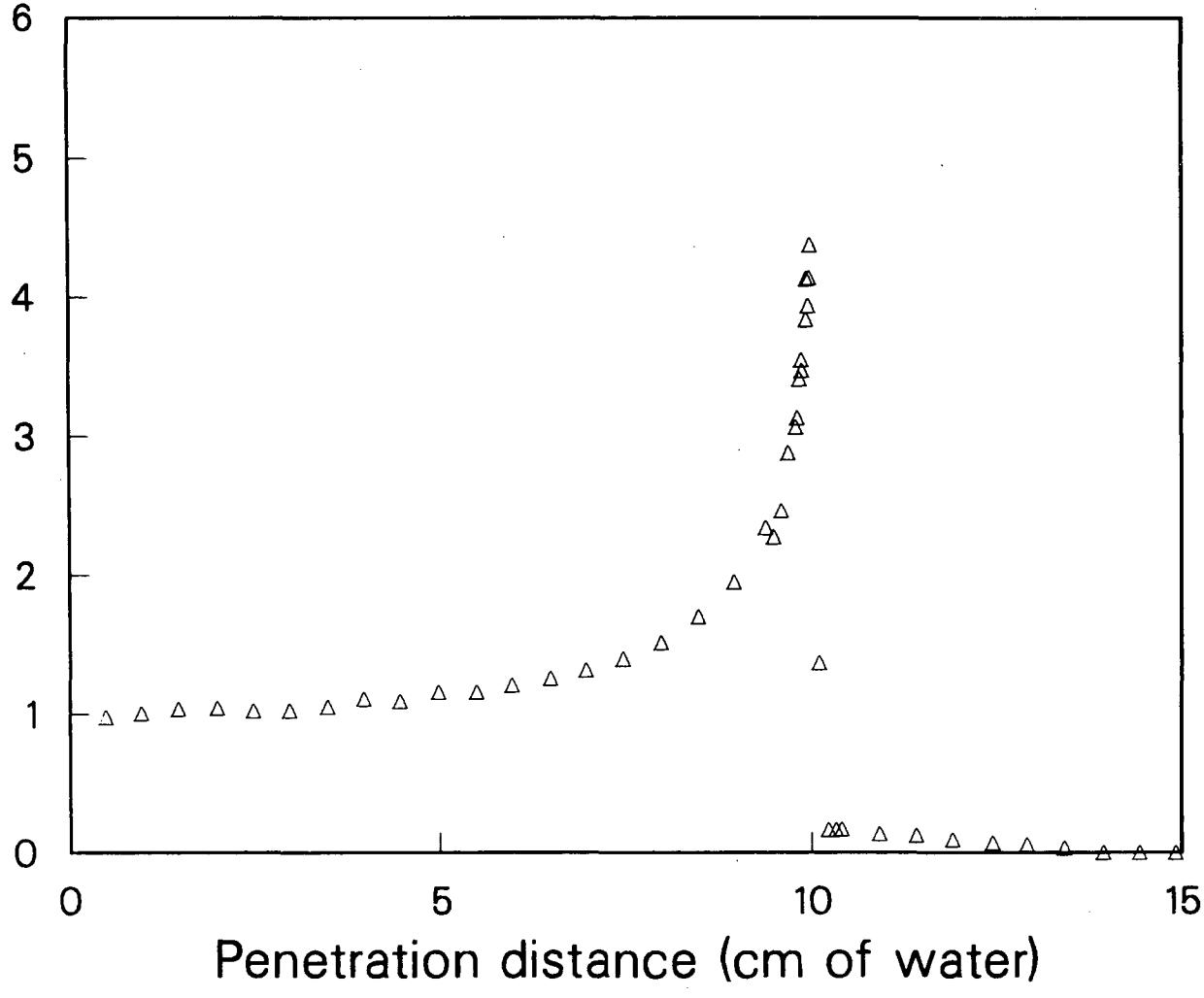


Fig. IV-1

Carbon 250 MeV/amu
0/64 Lead Scatterer

Bragg Peak:
10 cm

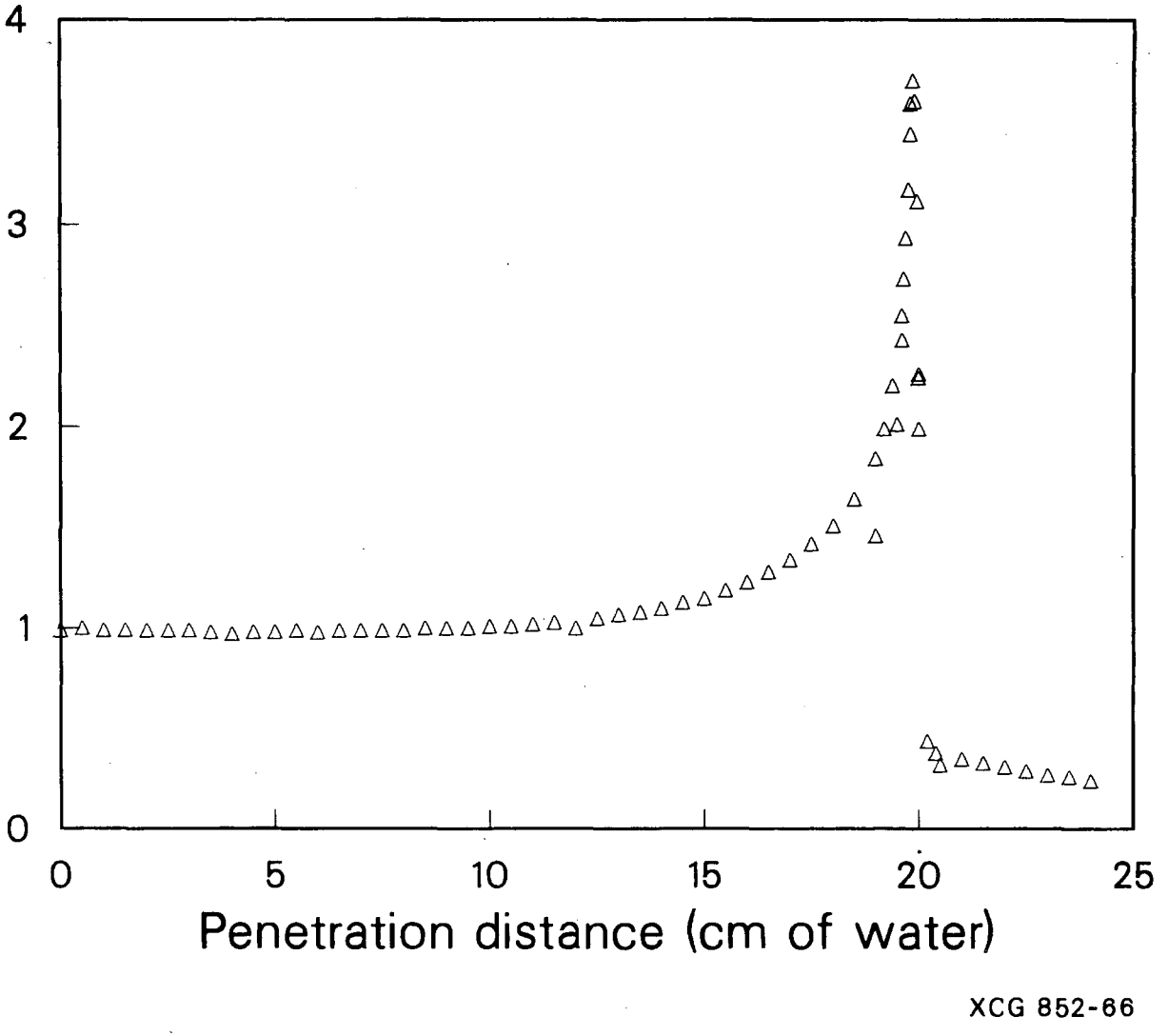


Fig. IV-2

Carbon 400 MeV/amu
20/64 Lead Scatterer

Bragg Peak:
19.85 cm

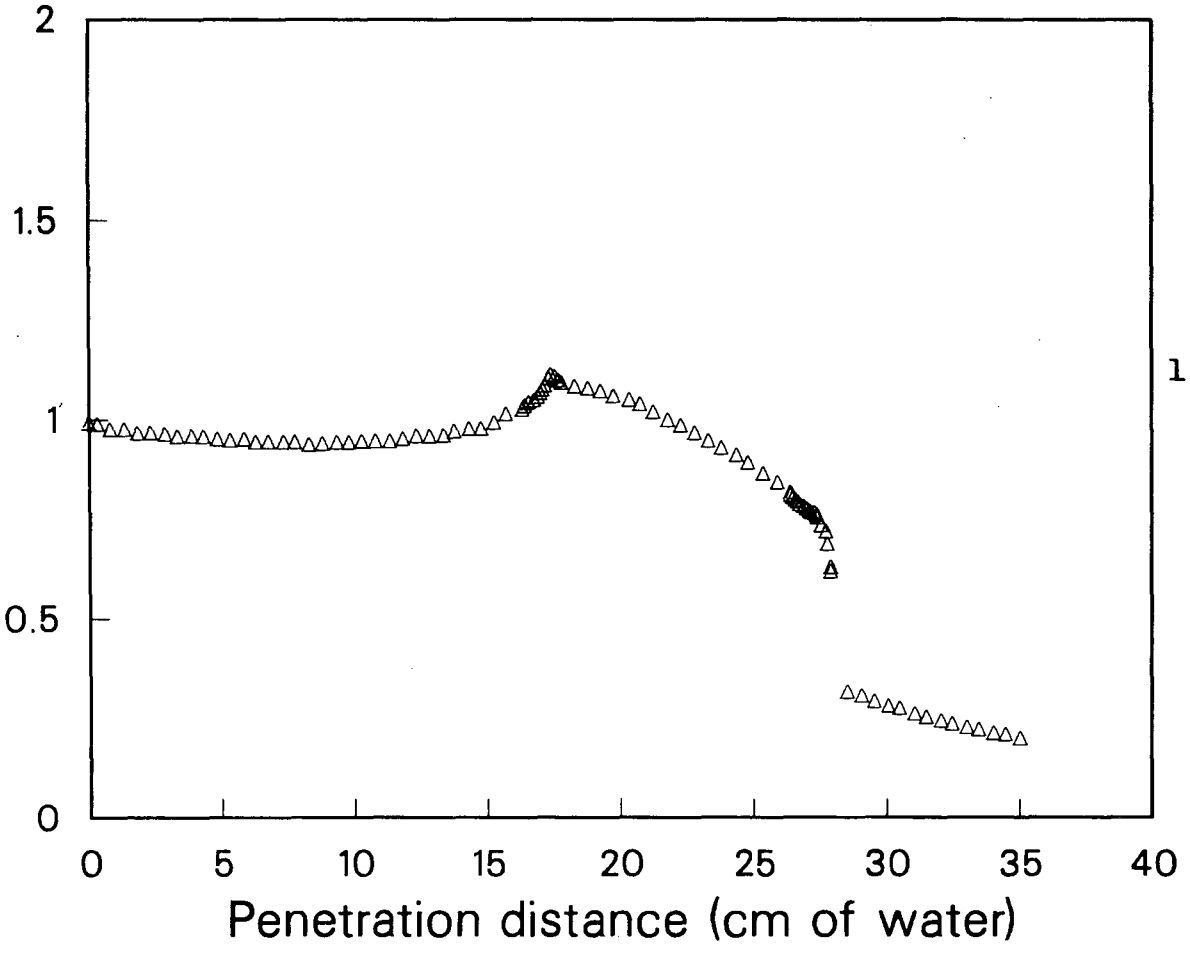


Fig. IV-3

Carbon 470 MeV/amu
12/64 Lead Scatterer
10 cm Spiral Ridge Filter
Cave 1

Spread Out Bragg Peak:
Proximal Peak - 17.6 cm
Distal Peak - 27.6 cm

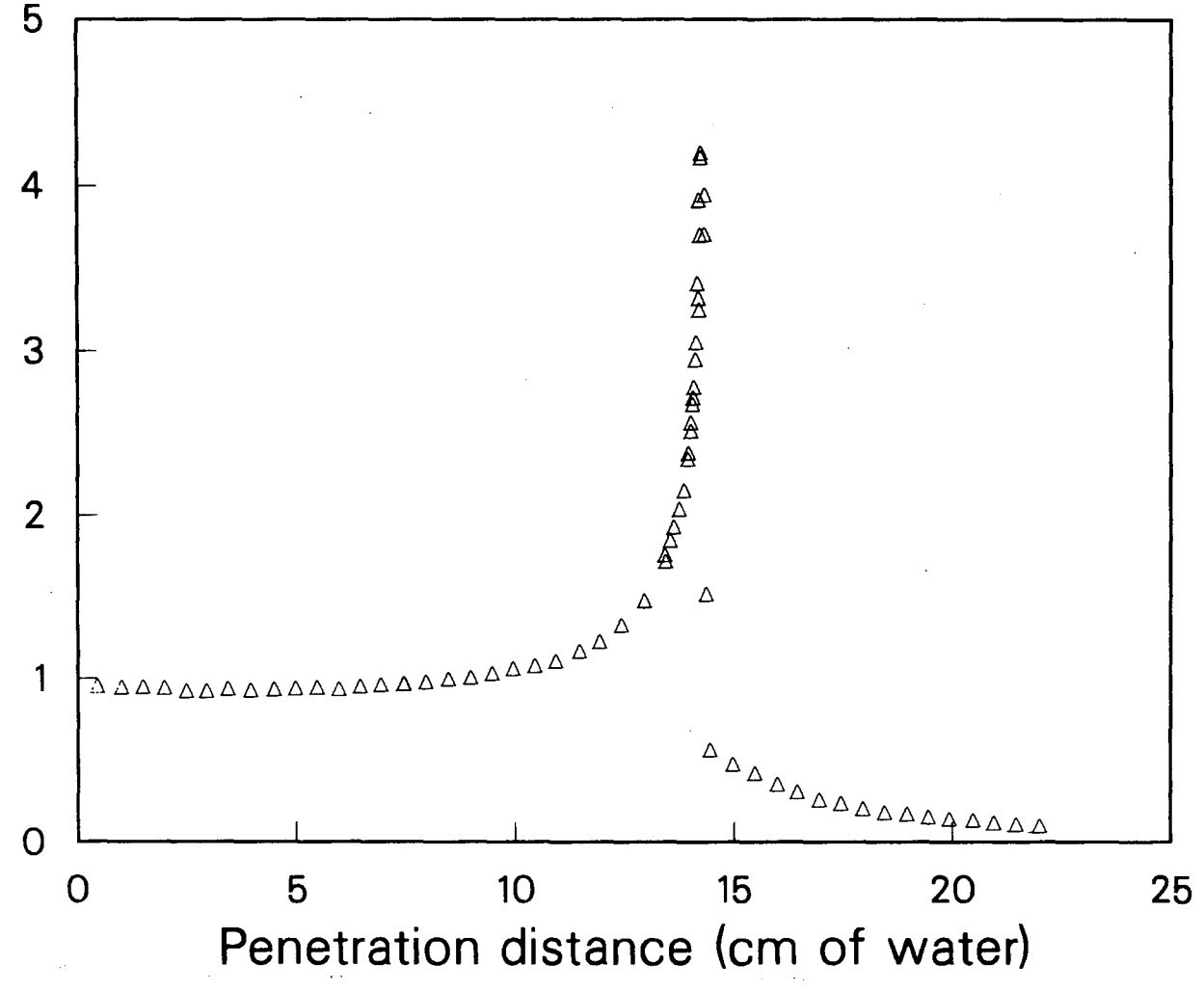
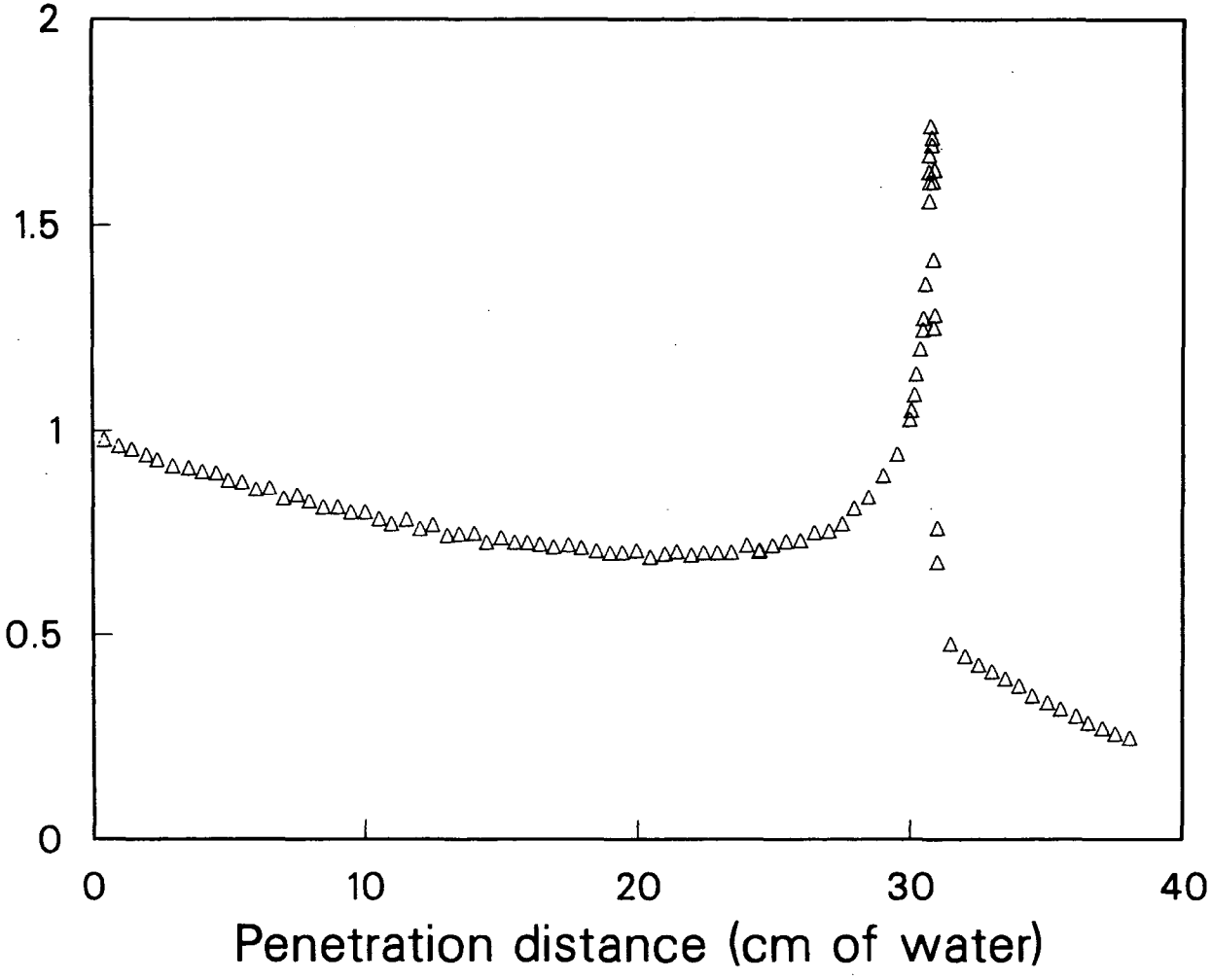


Fig. IV-4

Neon 425 MeV/amu
3/64 Lead Scatterer
Standard Conditions

Bragg Peak:
14.28 cm

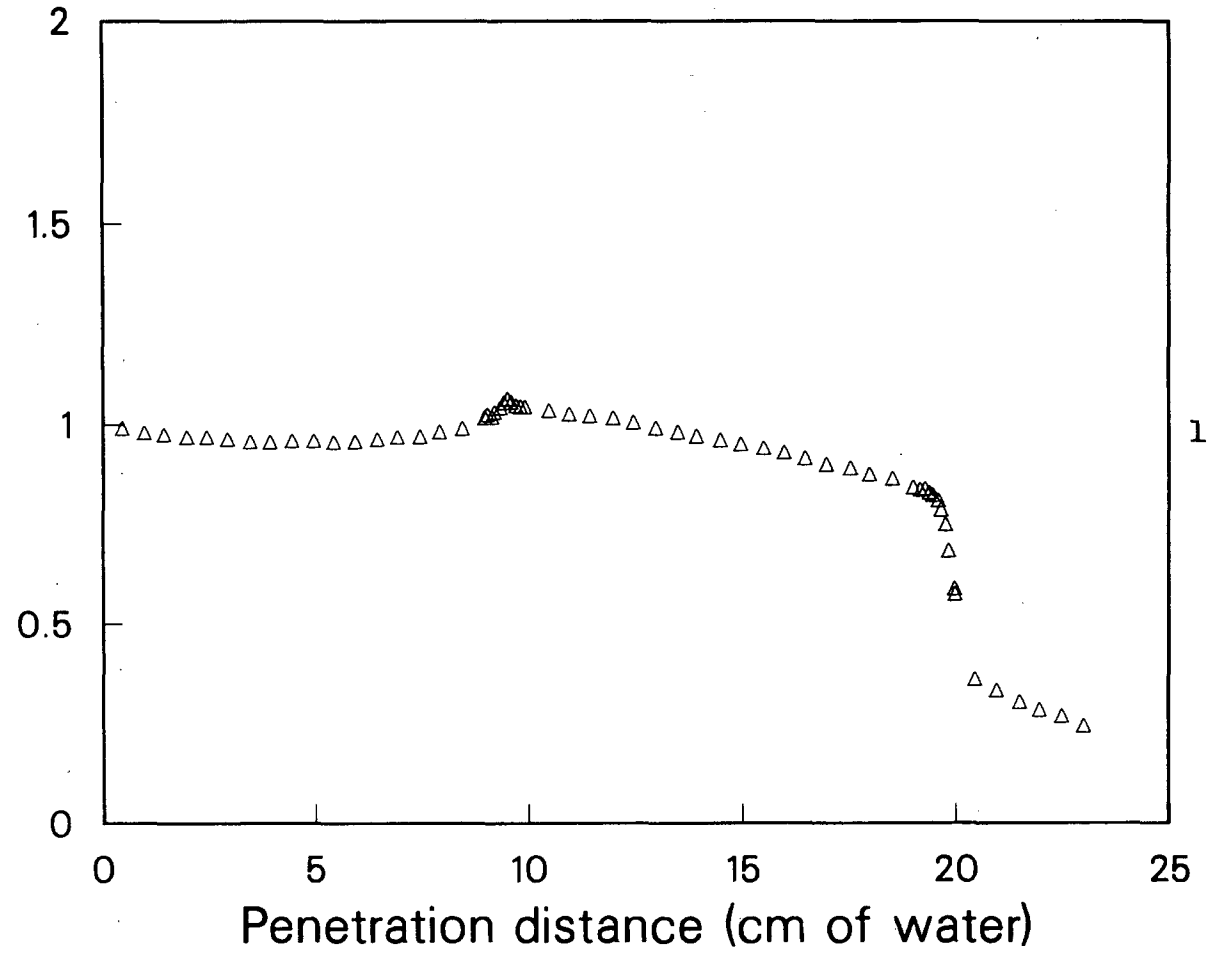


XCG 852-65

Fig. IV-5

Neon 670 MeV/amu
8/64 Lead Scatterer
Standard Conditions

Bragg Peak:
30.78 cm



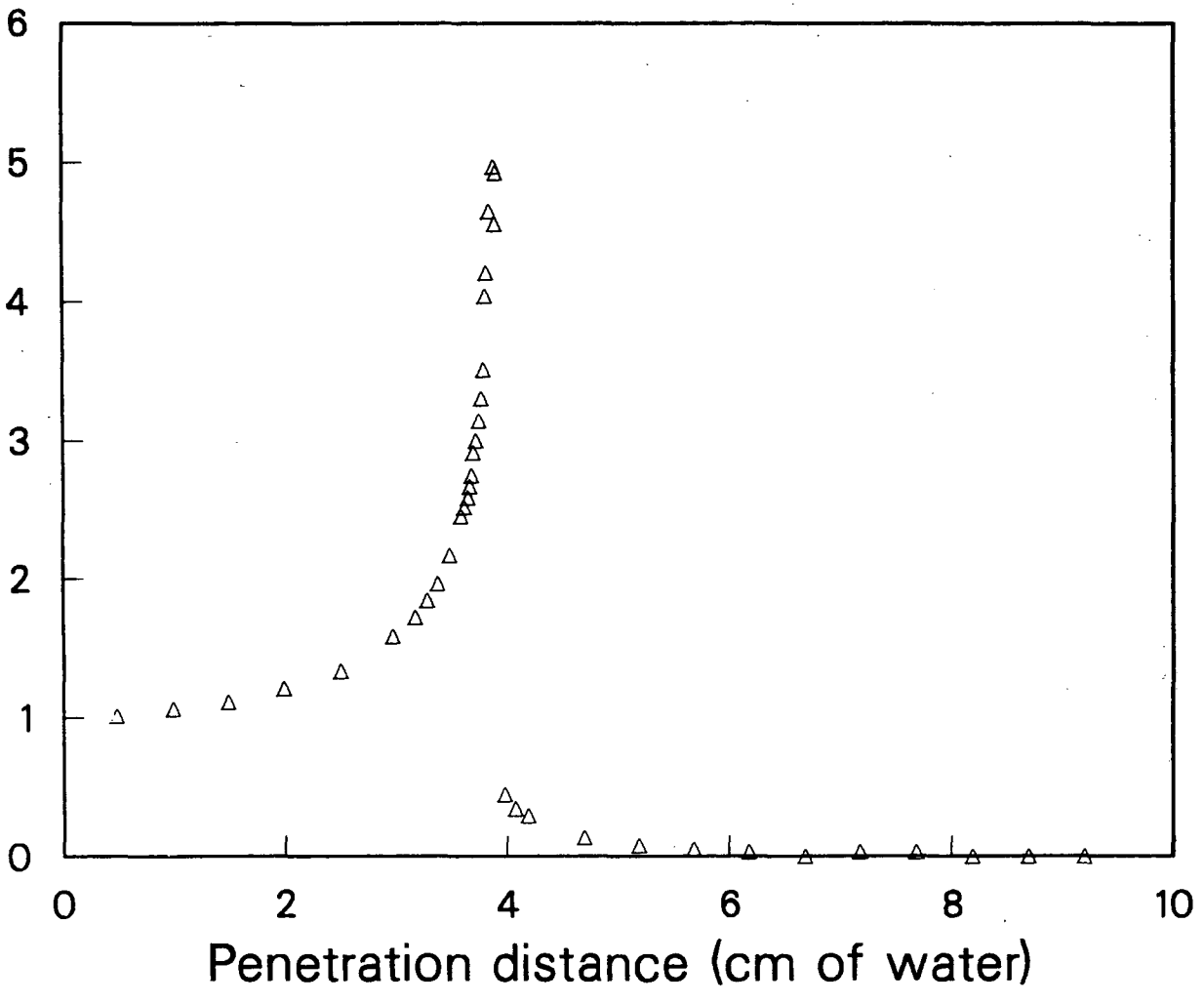
XCG 852-61

Fig. IV-6

Neon 670 MeV/amu
7/64 Lead Scatterer
10 cm Spiral Ridge Filter

Spread Out Bragg Peak:

Proximal Peak - 9.60 cm
Distal Peak - 19.6 cm



XCG 852-57

Fig. IV-7

Silicon 320 MeV/amu
4/64 Lead Scatterer
Standard Conditions

Bragg Peak:
3.90 cm

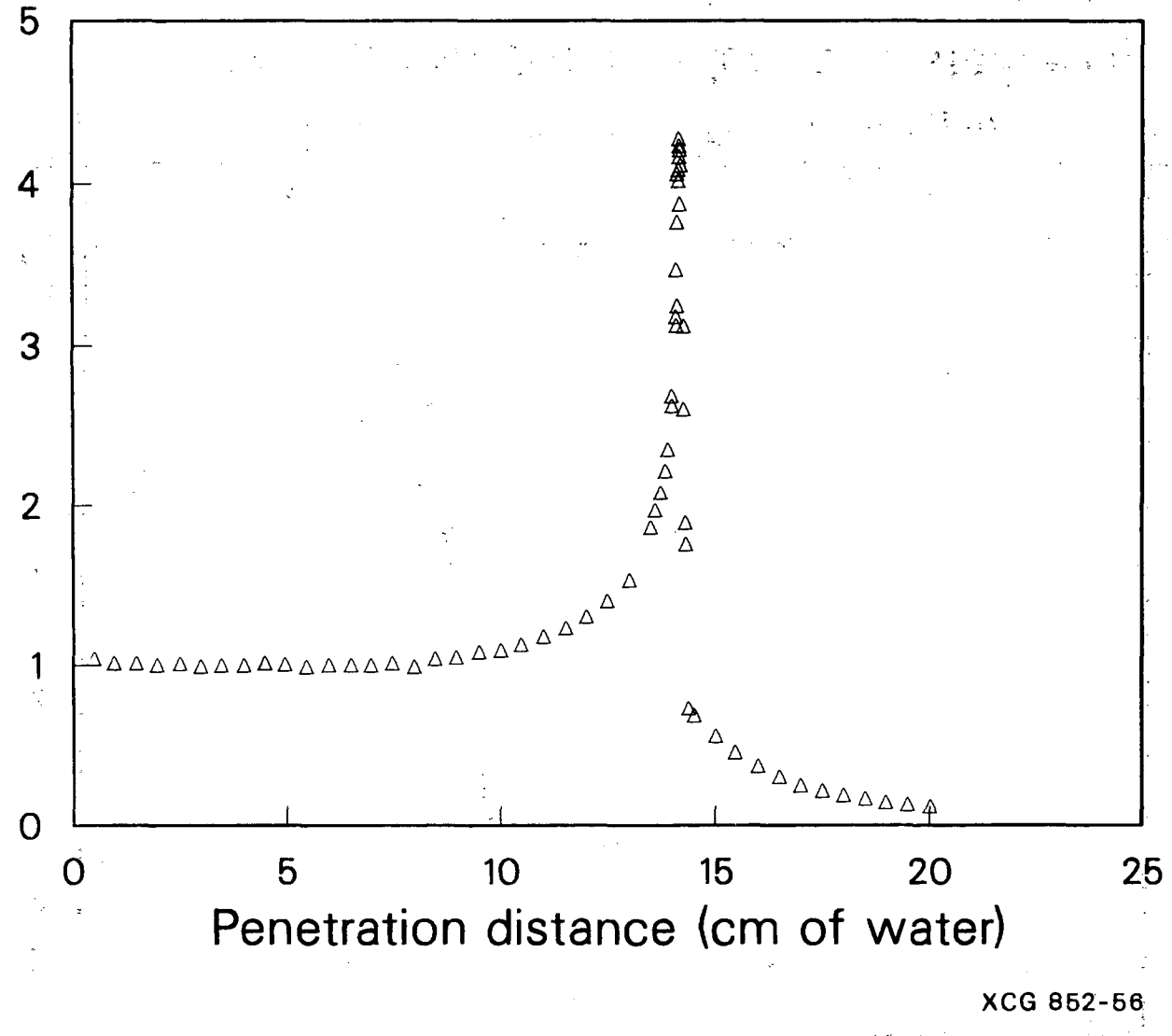


Fig. IV-8

Silicon 530 MeV/amu
2/64 Lead Scatterer
Standard Conditions

Bragg Peak:
14.2 cm

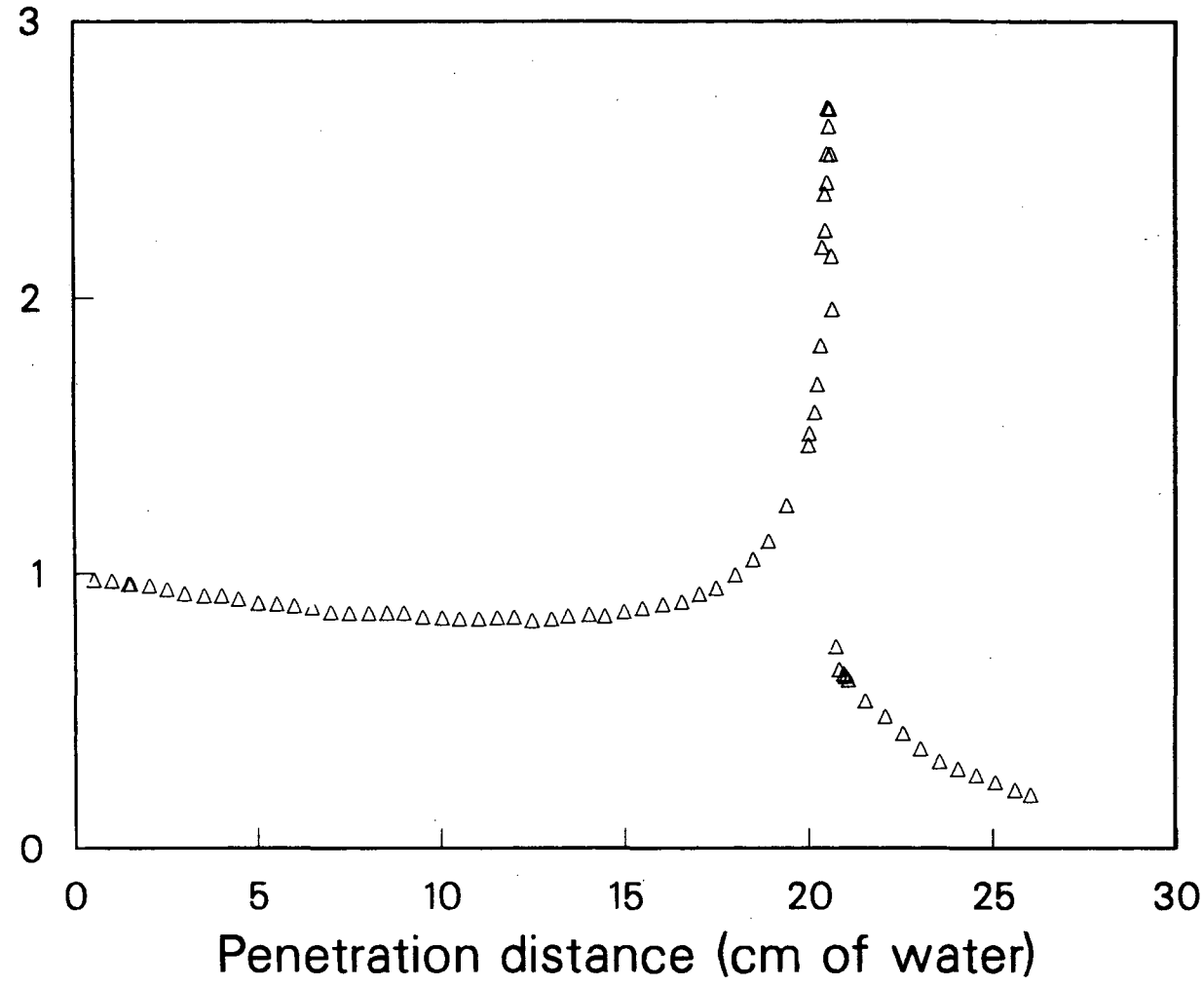


Fig. IV-9

Silicon 670 Mev/amu
7/64 Lead Scatterer
Standard Conditions

Bragg Peak:
20.6 cm

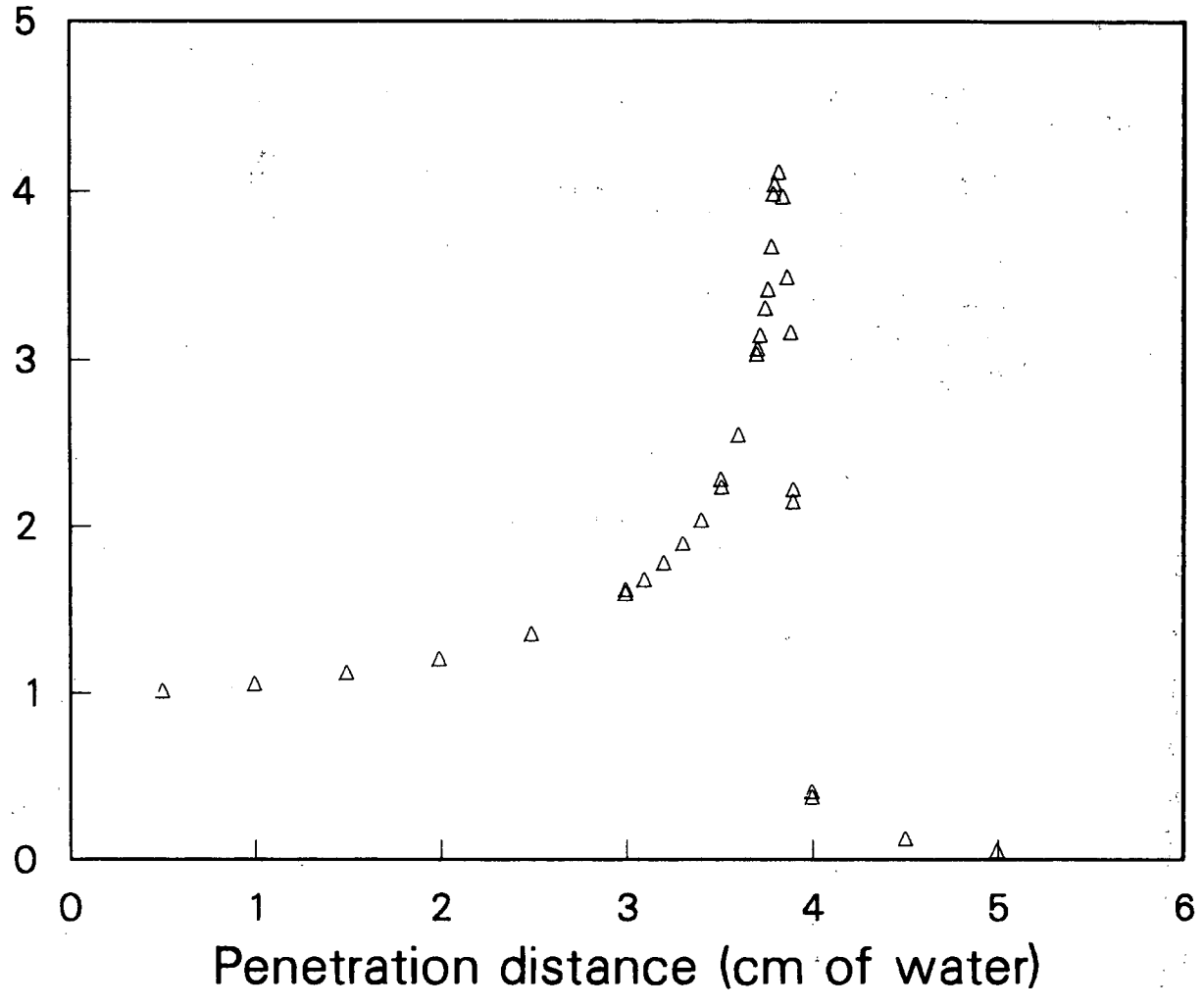


Fig. IV-10

Argon 330 MeV/amu
2/64 Lead Scatterer
Standard Conditions

Bragg Peak:
3.82 cm

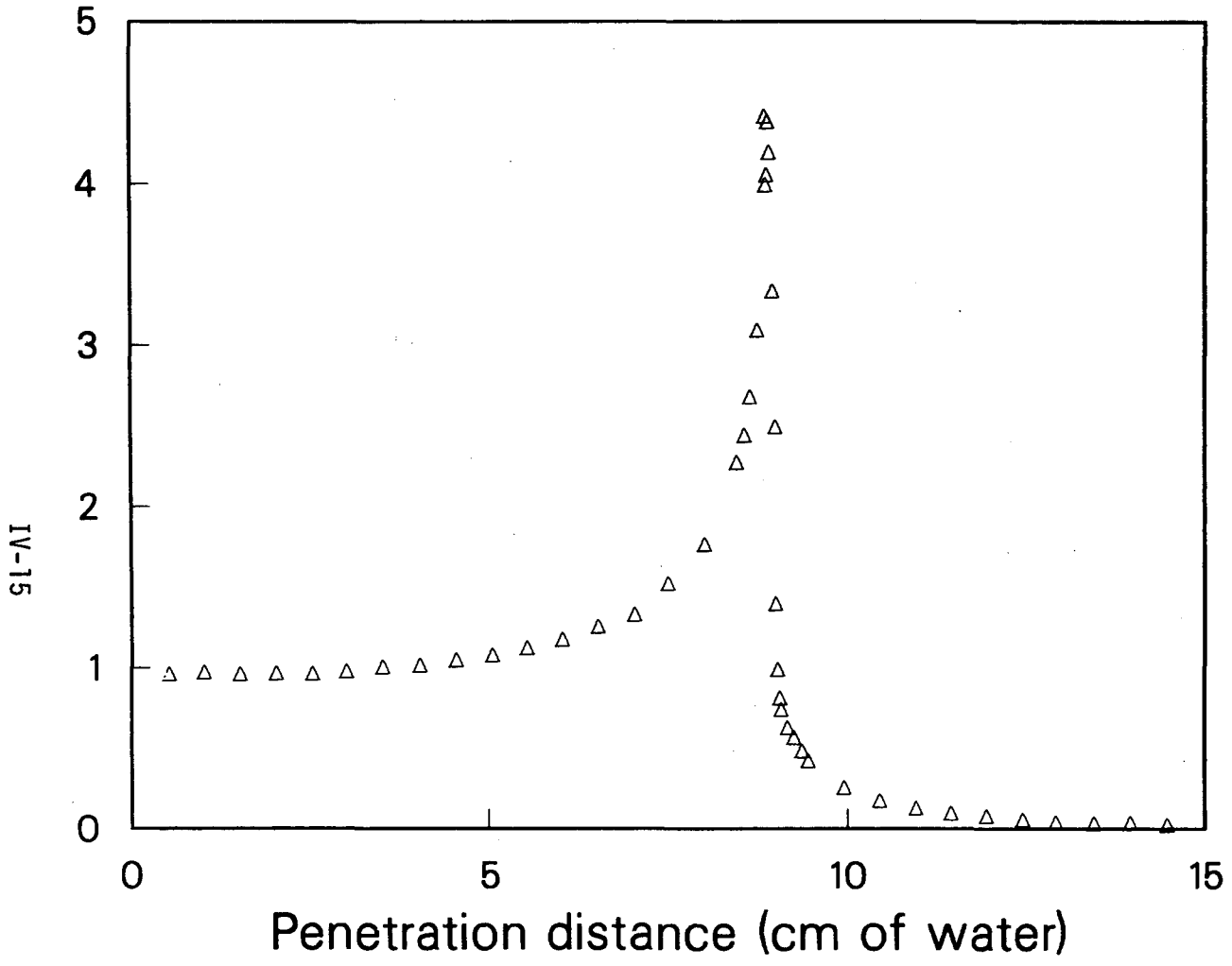


Fig. IV-11

Argon 470 MeV/amu
4/64 Lead Scatterer

Bragg Peak:
8.90 cm

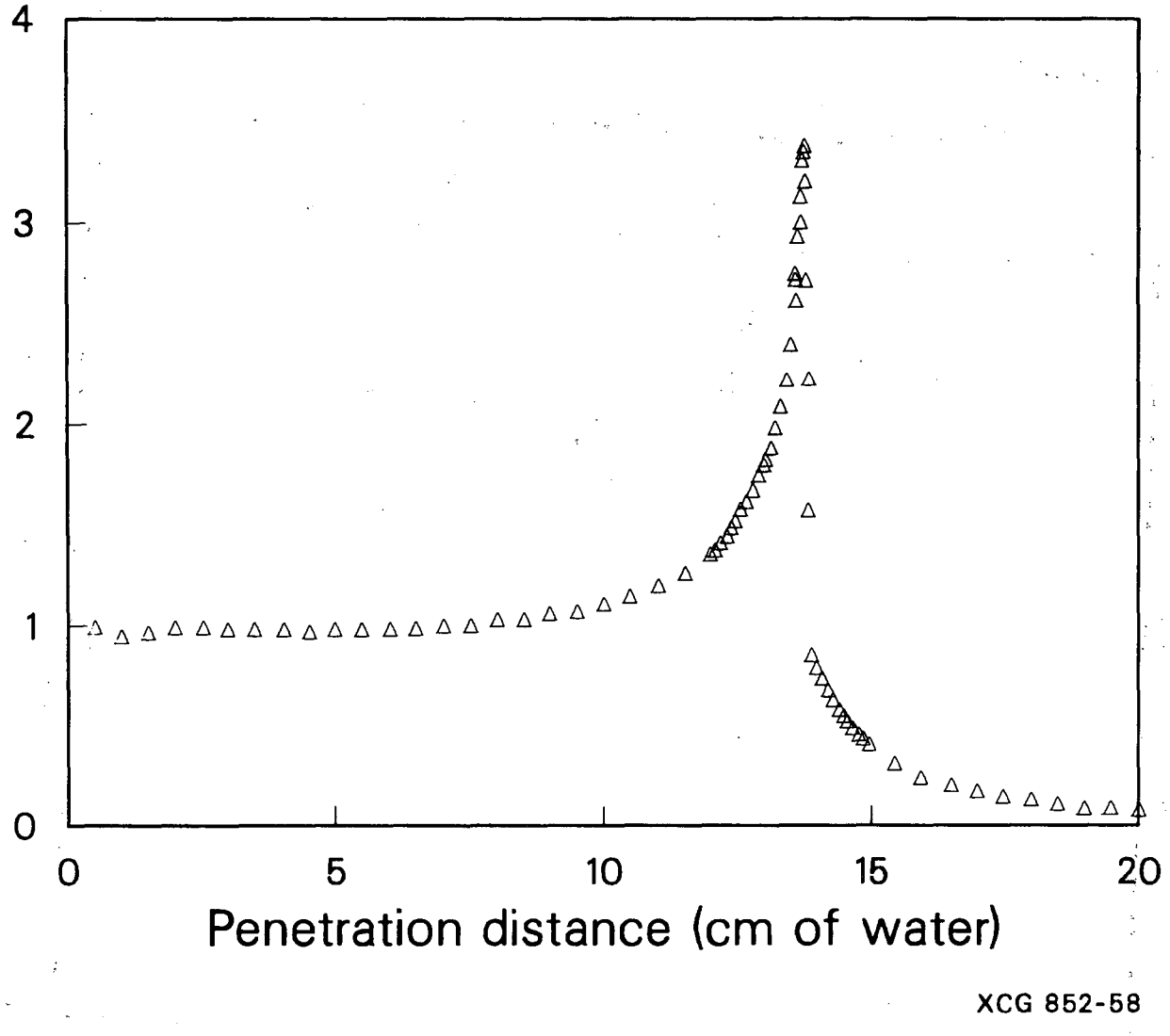


Fig. IV-12

Argon 570 MeV/amu
2/64 Lead Scatterer

Bragg Peak:
13.74 cm

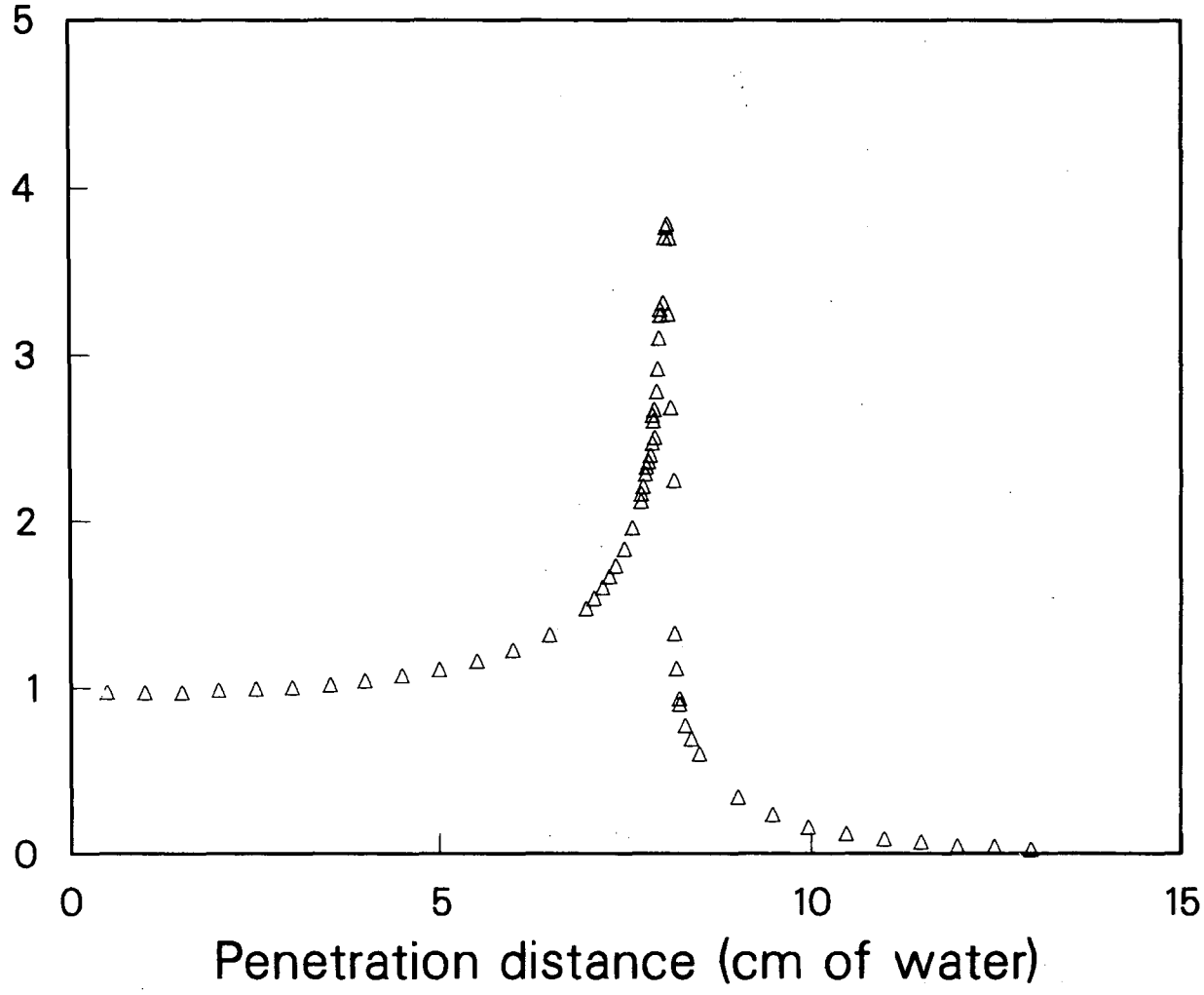


Fig. IV-13

Iron 600 MeV/amu
5/64 Lead Scatterer
Standard Conditions

Bragg Peak:
8.10 cm

D. DATA SHEETS

Data taken during sample irradiations are available from the computer in two forms. One is a dump of every measured value taken each time a sample is irradiated. This consists of over 100 unlabeled numbers and is unreadable without a key to the channel table system. The other form is single sheets of selected and labeled data from each exposure. The former data are easy to obtain and take reams of paper. The latter are more time consuming to obtain. The method for obtaining them is a routine in the operating system of the computer. A sample of the second form is included with explanatory notes in Appendix F.

Rad doses are based on physical dimensions of the ionization chambers and W(34.9 eV/ion pair). At the plateau of the Bragg ionization curve, the dose measured in the chamber is essentially the dose in the sample if the sample is placed near the chamber. However, for irradiations near the peak, whether single or spread, corrections must be made for any material between the sample and the chamber, and in either case if the sample is very far from the chamber. These corrections take two forms. Either a calculation based upon the Bragg depth dose curve is made, or a measurement is made with a separate thimble or egg chamber placed at the sample position behind any window or bolus used in the exposure.

E. SELECTED REFERENCES

The references cited below are offered as a list of those that might be relevant to the general field of biomedical research at the Bevalac. Your suggestions for additions to this list, as indeed for the entire handbook, will be most welcome.

1. Hall, E. J. (1973). Radiobiology of heavy particle radiation therapy: Cellular studies. Radiology 108, 119-129.

2. Leith, J. T., Woodruff, K. H., Howard, J., Lyman, J. T. Smith, P., and Lewinsky, B. S. (1975). Early and late effects of accelerated charged particles on normal tissues. In Proceedings of an International Workshop, Key Biscayne, Florida, October 1-3, 1975, American College of Radiology, pp. 361-384.

3. Leith, J. T., Woodruff, K. H., Lewinsky, B. S., Lyman, J. T., and Tobias, C. A. (1975). Tolerance of the spinal cord of rats to irradiation with neon ions. Int. J. Radiat. Biol. 28, 393-398.

4. Raju, M. R., Blakely, E., Howard, J., Lyman, J. T., Kalofonos, D., Martins, B., and Yang, C. H. (1976). Cell survival as a function of depth for a neon ion beam. Radiat. Res. 65, 191-194.

5. Tobias, C. A., Blakely, E. A., Yang, T. C., Chatterjee, A., Smith, K. C., Craise, L. M., Madfes, I. S., and Abrams, F. E. (1976). The effects of accelerated heavy nuclei of neon and argon on mammalian cells in culture. International Symposium on Radiobiological Research Needed for the Improvement of Radiotherapy, Vienna, Austria, November 22-26, 1976, (IAEA-SM-212-58).

6. Woodruff, K. H., Leith, J. T., Lyman, J. T., and Tobias, C. A. (1976). Morphologic and morphometric analysis of the early effects of x-ray and heavy ion irradiation of hamster lung. Amer. J. Pathol. 82, 287-298.

7. Alpen, E. L., Blakely, E. A., Castro, J. R., Chatterjee, A., Chen, G. T. Y., Curtis, S. B., Howard, J., Lyman, J. T., and Ngo, F. Q. H. (1979). Radiobiological basis for heavy-ion therapy. In Prospects for Treatment of Radioresistant Cancers, M. Abe, K. Sakamoto, T. L. Phillips, Eds. pp. 159-183. Elsevier/North-Holland Biomedical Press, Amsterdam.

8. Hermens, A. F., Curtis, S. B., Tenforde, T. S., Barendsen, and G. W. (1979). Analysis of cell proliferation in a rat rhabdomyosarcoma irradiated with neon ions or with 300-kV x-rays. In High LET Radiations in Clinical Radiotherapy, supplement to the European J. Cancer, pp. 226-227, G. W. Barendsen, J. J. Broerse, K. Breur, Eds. Pergamon Press, Oxford and New York.

9. Blakely, E. A., Ngo, F. Q. H., and Yang, T. C. H. (1980). The repair-misrepair model of cell survival. In Radiation Biology and Cancer Research, Proceedings, Thirty-Second Annual Symposium on Fundamental Cancer Research, Houston, Texas, Feb. 26-Mar. 1, 1979, pp. 195-230, A. Meyn and R. Withers, Eds. Raven Press, New York.

10. Raju, M. R., Bain, E., Carpenter, S. G., Howard, J., and Lyman, J. T. (1980). Cell-survival measurements as a function of depth for a high-energy argon-ion beam. Radiat. Res. 84, 158-163.

11. Yang, T. C. H. and Tobias, C. A. (1980). Radiation and cell transformation in vitro. In Advances in Biological and Medical Physics, T. L. Hayes, Ed., Vol. 17, pp. 417-461. Academic Press, New York.

12. Alpen, E. L., Powers-Risius, P., Fry, J. M., and Ainsworth, E. J. (1981). Harderian gland carcinogenesis by heavy ions. In Proceedings, International Workshop on Pion and Heavy Ion Radiotherapy, Vancouver, B. C.

13. Tenforde, T. S., Tenforde, S. D., Crabtree, K. E., Parks, D. L., Schilling, W. A. Parr, S. S., Flynn, M. J., Howard, J., Lyman, J. T., and Curtis, S. B. (1981). RBE values for radiation-induced growth delay in rat rhabdomyosarcoma tumors exposed to plateau and peak carbon, neon, and argon ions. Int. J. Radiat. Oncol. Biol. Phys. 7, 217-221.

14. Curtis, S. B., Schilling, W. A., Tenforde, T. S., Crabtree, K. E., Tenforde, S. D., Howard, J., and Lyman, J. T. (1982). Survival of oxygenated and hypoxic tumor cells in the extended-peak regions of heavy charged-particle beams. Radiat. Res. 90, 292-309.

15. Leith, J. T., McDonald, M., Power-Risius, P., Bliven, S. F., and Howard, J., (1982). Response of rat spinal cord to single and fractionated doses of accelerated heavy ions. Radiat. Res. 89, 176-193.

16. Phillips, T. L., Ross, G. Y., Goldstein, L. S., Ainsworth, J., and Alpen, E. (1982). In vivo radiobiology of heavy ions. International J. Radiat. Oncol., Biol., Phys. 8, 2121-2125. (Special Issue: "Particle Accelerators in Radiation Therapy"; Proceedings of the CROS/RTOG Part III International Workshop, Houston, Texas, Feb. 10-11, 1982).

17. Ainsworth, E. J., Kelly, L.S., Mahlmann, L. J., Schooley, J. C., Thomas, R. H., Howard, J., and Alpen, E. L. (1983). Response of colony forming units-spleen to heavy charged particles. Radiat. Res. 93, 180-197.

18. Fry, R. J. M., Powers-Risius, P., Alpen, E. L., Ainsworth, E. J., and Ullrich, R. L. (1983). High-LET radiation carcinogenesis. Adv. Spac. Res. 3, 241-248.

19. Raju, M. R., Carpenter, S. G., Tokita, N., Howard, J., and Lyman, J. T. (1983). Biological response across a ridge filter carbon ion Bragg peak. Int. J. Radiat. Oncol., Biol., Phys. 9, 67-70.

20. Saunders, W. M., Chatterjee, A., Chen, G. T. Y., and Alpen, E. L. (1983). A comparison of water equivalent thickness measurements using a frozen beagle: CT scanning techniques vs. heavy ion beam technique. In Proceedings, Seventh International Congress of Radiation Research, pp. D4-23. J. J. Broerse et al., Eds, Martin Nijhoff Publ., Amsterdam.

21. Biology and Medicine Division (1977). Biological and medical research with accelerated heavy ions at the Bevalac 1974-1977. LBL-5610, 227 p.

22. Pirruccello, M. C. and Tobias, C. A., Eds. (1980). Biological and medical research with accelerated heavy ions at the Bevalac, 1977-1980. LBL-11220, 419 pp.

23. Raju, M. R. (1974). Pions and heavy ions in radiotherapy. Presented at the XIth International Cancer Congress, Florence, Italy, October 20-26, 1974. Excerpta Medica International Congress Series No. 353, Vol. 5, Surgery, Radiotherapy and Chemotherapy of Cancer, pp. 161-167.

24. Castro, J. R., and Quivey, J. M. (1977). Clinical experience and expectations with helium and heavy ion irradiation. In Proceedings of the International Conference on Particles and Radiation Therapy, Lawrence Berkeley Laboratory, Berkeley, California, September 1976. Internat. J. Radiat. Oncol., Biol., Phys., Part 11, 3, 127-132.

25. Castro, J. R., Tobias, C. A., Quivey, J. M., Chen, G. T. Y., Lyman, J. T., Phillips, T. L., Alpen, E. L., and Singh, R. P. (1979). Results of tumor treatments with alpha particles and heavy ions at Lawrence Berkeley Laboratory. In High LET Radiations in Clinical Radiotherapy, supplement to the European J. Cancer, pp. 67-74, G. W. Barendsen, J. J. Broerse, K. Breur, Eds. Pergamon Press, Oxford and New York.

26. Castro, J. R. (1979). Progress report on heavy particle clinical radiotherapy trial at Lawrence Berkeley Laboratory July 1975-July 1979. LBL-9738, 13 pp.

27. Castro, J. R., Saunders, W., Woodruff, K. H., Quivey, J. M., Phillips, T. L., Chen, G. T. Y., Lyman, J. T., Collier, M., Pitluck, S., and Tobias, C. A. (1982). Clinical radiotherapy with heavy charged particles at Lawrence Berkeley Laboratory. In Progress in Radio-Oncology, p. 81. K. H. Karcher et al., Eds. Raven Press, New York.

28. Lyman, J. T., (1983). Computer modeling of heavy charged particle beams. In Pion and Heavy Ion Radiotherapy: Pre-Clinical and Clinical Studies, (Proceedings of the International Workshop on Pion and Heavy Ion Radiotherapy: Pre-Clinical and Clinical Studies, Vancouver, B. C., Canada, July 29-31, 1981). L. D. Skarsgard, Ed. Elsevier Science Publ. Co., New York, pp. 139-147.

29. Attix, F. H., and Roesch, W. C., Eds. (1966). Radiation Dosimetry. In 3 vols. 2nd ed. Academic Press, New York.

30. Attix, F. H., ed. (1972). Topics in Radiation Dosimetry, Supplement 1, Academic Press, New York.

31. Chatterjee, A., Maccabbee, H. D., Tobias, C. A. (1973). Radial cutoff LET and radial cutoff dose calculations for heavy charged particles in water, Radiat. Res. 54, 479.

32. Curtis, S. B. (1979). Calculations of radiation quality of heavy-ion beams. In High LET Radiations in Clinical Radiotherapy, supplement to European J. Cancer, pp. 218-219, G. W. Barendsen, J. J. Broerse, K. Breur, Eds. Pergamon Press, Oxford and New York.

33. Zaider, M., Dicello, J. F., Brenner, D. J., Takai, M., Raju, M. R., and Howard, J. (1981). Microdosimetry of range-modulated beams of heavy ions: I. Determination of the yield of projectile fragments from microdosimetric spectra for neon-10 beams. Radiat. Res. 87, 511-520.

34. Grunder, H. A., Hartsough, W. D., Lofgren, E. J. (1971). Acceleration of heavy ions at the Bevatron, Science 174, 1128.

35. Alonso, J. R., Chatterjee, A., and Tobias, C. A. (1979). High purity radioactive beams at the Bevalac. IEEE Trans. Nucl. Sci. 26, 3003.

36. Chatterjee, A., Jackson, H. C., Lin, J. C., and Zunzunegui, M. V. (1979). An imaging instrument for positron emitting heavy ion beam injection. IEEE Trans. Nucl. Sci. NS-26, 634.

37. Chu, W. T., Alonso, J. R., and Tobias, C. A. (1981). Heavy ion beam studies and imaging with a multiplane multiwire proportional chamber. IEEE Trans. Nucl. Sci. NS-28, 2198-2200.

38. Chatterjee, A., Saunders, W., Alpen, E. L., Alonso, J., and Scherer, J. (1982). Physical measurements with high-energy radioactive beams. Radiat. Res. 92, 230-244.

39. Schimmerling, W., Subramanian, T. S., McDonald, W. J., Kapland, S. N., Sadoff, A., and Gabor, G. (1983). Beam analyses spectrometer for relativistic heavy ions. Nucl. Instrum. and Meth. 205, 531-543.

40. Benton, E. V., Henke, R. P., and Tobias, C. A. (1973). Heavy-particle radiography. Science 182, 474-476.

41. Sickles, E. A., Benton, E. V., Tobias, C. A., and Woodruff, K. H. (1979). Mammography using Bevalac-accelerated heavy particles: A novel approach to dose reduction. In Reduced Dose Mammography, W. W. Logan and E. P. Muntz, Eds., pp. 501-505. Masson Publ. Co., New York.

42. Chatterjee, A. and Magee, J. L. (1978). Relationship of track structure of heavy particles to the physical distribution and chemical effects of radicals. J. Booz and H. G. Ebert, Eds. In Sixth Symposium on Microdosimetry, Brussels, Belgium.

V. EXPERIMENTAL PROCEDURES

A. GENERAL INFORMATION

1. Drawings of Set-up

Once an experiment is approved and scheduled, the experimenter should discuss with the staff biology physicist, Ext. 5575, any physical problems associated with placing samples in the beam. We especially encourage experimenters to visit the biomedical facility in advance to work out details of experiment protocol. If this is impossible, complete drawings and photos of experimental apparatus or samples should be sent to the staff biology physicist as far in advance as possible.

2. Arrival for Run

At the time of running, it is advisable to arrive a day ahead to make final experimental arrangements and then periodically check with the biomedical control room, Ext. 6037, to confirm your exact running time. Be sure to leave with the operator the phone number(s) where you can be reached. A "Request for Bevalac Beam Time" sheet (see Appendix C) should be filled out with the staff biology physicist, if not already on file from previous runs or consultation. An experimental set-up can then be entered into the computer, with all the parameters for running specified. The operator will use this set-up sheet to aid in setting up the actual experiment. The experimenter should furnish personnel to place the samples in the beam, and to type in the proper dose values in the biomedical computer.

3. Beam Spots

Beam spots on either polaroid or x-ray film can be taken at any point during the run. Polaroid spots provide a quick check on beam size, position and range, and some information on uniformity. X-ray film is better for this latter purpose. Port or localization films can be done to ascertain positioning of animals or samples. X-ray film can be processed in less than five minutes if one hour lead time is given to start processor. Film densitometry may take several days, although we are working to shorten this time.

4. Once an Experiment is Ready for Beam

When samples are in position, the operator or experimenter will enter the sample number and dose information at the control console, and the irradiation will begin. A written sample number dose protocol sheet is advisable to insure against mistakes. The computer program will automatically cut off the beam spill when the desired dose is reached, and will record the data for each irradiation.

5. Intercoms

There are two intercom systems installed in the biomedical area. The first is a no-hands system in which speakers can remain live in critical areas (caves, halls and prep rooms), and the experimenter may communicate with the biomedical control room simply by speaking loudly. Operation of this system is indicated when the "Push to Call" button is lighted on the face of the intercom box. You can request the open-line system by pressing the "Push to Call" button. This intercom is part of our safety system, especially useful if the experimenter needs emergency help.

The second intercom is via telephones linking the irradiation caves and the biomedical control room. This system is provided for conversations that are to be kept private, when background noise interferes with communications for lengthy conversations or, of course, when the other system is busy.

6. Parking

Parking in the immediate vicinity of the biomedical facility is restricted to three spaces reserved for the experimenter who is running. The traffic lanes must be kept clear around the clock for fork lift operators and emergency vehicles.

7. Pre-Irradiation Set-up

Dry runs are a definite help whenever possible. At such time most parameters of the experiment can be examined and solutions arrived at prior to actual beamtime.

8. Post-Irradiation Clean-up

Because biomedical runs are scheduled to accommodate as many users as practical in quick succession, your effort in leaving the preparation room, cave or other facilities in a neat condition will be greatly appreciated by the following experimenters.

B. CAVE ACCESS

Each person entering the cave areas during runs has primary responsiblity for his or her own safety. The following procedures have been established to help ensure the safety of everyone using the biomedical cave facilities.

The information panel next to each cave door is shown in Fig. V-1. When "No Entry" is lighted, all beam plugs have been pulled and beam is presumed to be coming into the cave. No one should attempt to enter the cave under this condition.

When "Beam Program Ready" is lighted, the safety chain circuits are complete and the biomedical beam plug is in, but can be pulled momentarily. One should contact the biomedical operators or Main Control Room (MCR) operators (depending on which sign is lighted) before attempting to enter the cave.

When "Safe to Enter" is lighted, the safety chain has been broken, and the cave may be entered at will.

There are two modes of operation:

Mode I: In this mode persons wishing to enter the cave are enabled to control access and are directly responsible for ensuring that the cave is clear before closing the door. This mode is indicated by the lighted sign "Gate Station Enabled, Press Button to Park Gate Open." For access, either push the "Open Gate" button or request the biomedical operator to open the door. Do not attempt to open the door if either the "No Entry" or the "Beam Program Ready" signs are lighted. In the former case the door will not open, and in the latter you must check with the biomedical operator before entering. If the "Safe to Enter" light is on, you may

open the door without contacting the console operator. In this mode, the door will remain open until the "Close Gate" button is pressed. Taking a key before entering the cave is at the discretion of the person if he or she is listed on the sheet on the door authorizing certain people to enter without a key. All others must take a key from the 9-key panel at the door before entering the cave.

Upon leaving, the last person out will search the cave, ensure that no one remains, check to see that all keys are in place and turned, push the "Gate Close" button and inform the biomedical operator that the cave is clear and ready for beam. In addition, the person searching the cave and closing the door will make up the search chain by pushing the "Search Complete" button then the operator chain by pushing the "Operator Chain Complete" button. The lights in these buttons will change from green to red as the safety chains are made up. The biomedical operator will further check by scanning the cave by TV camera, and then will announce that beam is coming on.

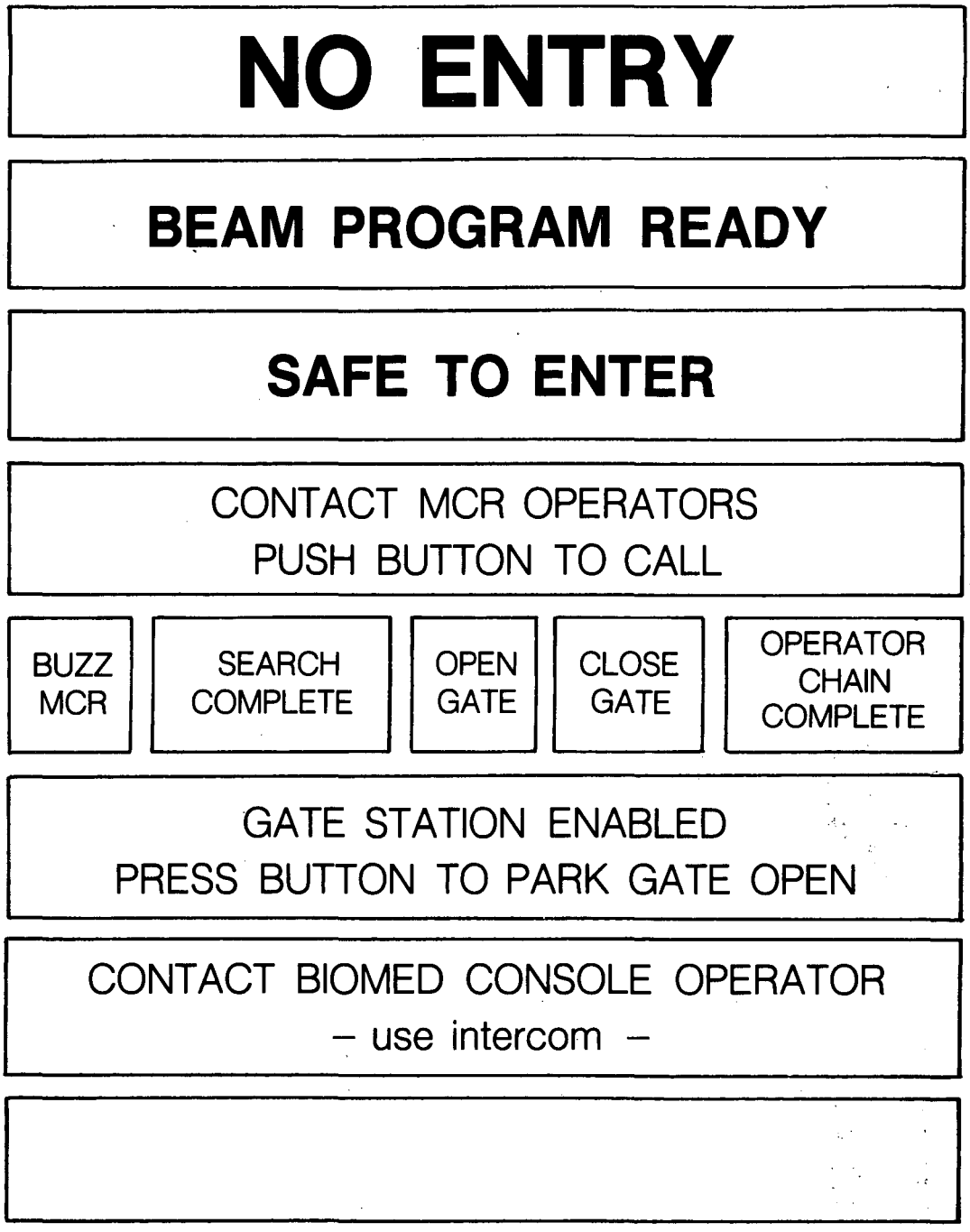
Mode II: The Bevatron MCR controls access to the cave and is involved directly in determining that the cave is clear before bringing beam into it. This mode is indicated when the sign "Contact MCR Operators" is lighted. For access to the cave, push the button "Buzz MCR", and wait for the door to be opened by the MCR operator. The door will open, wait six seconds and then close, unless someone is standing in the doorway; in this case the person's weight on the pressure pad causes the door to reopen, wait six seconds, then close again. When the "Take a Key" sign is lighted, each individual in a group entering the cave must take a key from the panel and be logged by the MCR operator via the TV

camera. When leaving the cave, push the button inside the door and again wait for the MCR operator to open the door. Return the key to the panel, and turn it to make up the safety chain. On the first time out of the cave, the experimenter must push the "Search Complete" button. The MCR operators can then complete the radiation chain, making the cave ready to take beam. The magenta lights will come on and stay on and an audible alarm will sound for ten seconds. After the first time out, the search will be maintained. Each person must take a key every time he/she enters the cave and return it to the panel upon leaving the cave. Again the MCR operator will complete the radiation chain. This mode is seldom used, but is an available alternative.

In all cases, when the safety chain is being completed (after the door is closed and all keys are in place and turned), the cave magenta lights will come on and stay on, and an audible alarm will be activated for ten seconds before the beam plug can be pulled.

Further safety measures include the following: (1) Safety switches (Fig. V-2) placed on the walls around the cave that can be turned to "Safe" any time, thus preventing the safety chains from being completed, and (2) an intercom that is live in the cave at all times during the run.

Throughout the biomedical facility there are red "Pull to Crash Off" boxes also (Fig. V-2). These are emergency electrical pull boxes that, when pulled, disable all electrical power to the entire biomedical complex and shut off the beam. These "Pull to Crash Off" boxes are usually separate from the safety switches in the cave.



XBL 8412-6048

Fig. V-1

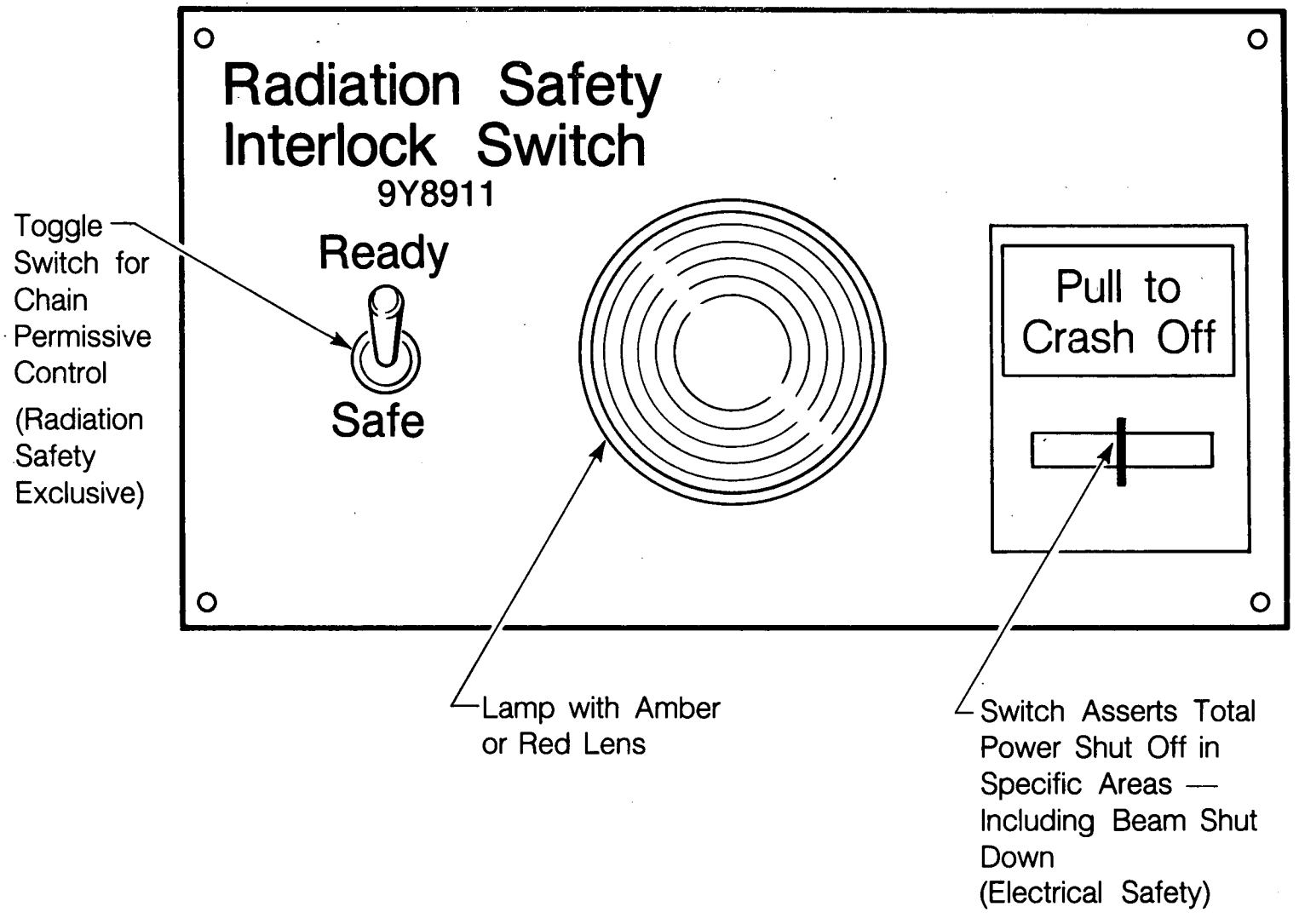


Fig. V-2

XBL 848-8608

APPENDIX A: TERMS AND CALCULATIONS

A. TERMS

1. Bragg Curve

The Bragg curve is obtained by placing ion chambers on each side of the water column. An egg chamber can be placed behind a transmission chamber or in a water phantom. The routine selects a fixed cutoff on the upstream chamber and normalizes the readings from the downstream chambers to the upstream chamber and to the first point taken. Certain elements are displayed on the terminal but a much larger choice of printouts is available. The two usual choices are the ratios from the 1-cm element of the dose chamber and/or all the elements from the dose chamber.

The 1-cm element is desirable for small samples and when there is sufficient beam current for adequate statistics. The sum of the rings from the dose chamber is appropriate to large samples and/or low beam currents. One can improve statistics for the 1-cm area by taking more pulses or a higher dose cutoff, but this may consume expensive amounts of beam time. Usually one Bragg curve per new experiment is sufficient. The range for a given energy is usually constant unless there have been changes made in the beam line. This is checked frequently and a curve does not need to be run for every experiment if each one is using the same energy and tune.

At present, all of the curves generated from the individual rings of the dose chamber, with the exception of their sum, are normalized to the 1-cm area of the monitor chamber. The sum of the rings is normalized to the sum of the rings of the monitor chamber.

2. Collimation

The primary purpose of collimation is to keep unwanted beam away from the edges of ion chambers, other parts of an animal, or other animals awaiting irradiation. Special purpose collimators, such as the one for the spiral ridge filter, are used to confine the beam to the useful portion of various devices. Most collimators less than 18 cm diameter should be removed from the bench during initial tune up (beam-bench alignment) and sigma (beam size) determination. Small collimators (less than 3-5 cm diameter) should be removed during Bragg curve measurements to improve statistics.

3. Egg Chambers

Egg chambers (Far West) are special ionization chambers having different geometry than the transmission chambers. They generally are available in two volumes, 1.0 cc and 0.1 cc. They are used in several ways. In radiotherapy they are used as the main calibration of dose to the tumor and the transmission chamber is used merely to monitor and deliver so many units based upon the egg reading in a simulated set up. In the biology cave they are used to determine the dose fall off or buildup to the sample when the transmission chamber cannot either be placed in close proximity to the sample during irradiation or at anytime prior to irradiation.The method of choice, when it can be done, is to move the dose chamber in place of the sample and take a ratio between the two positions relative to the monitor chamber (IC1) or backup chamber (IC2). In lieu of this, one can use the calibration of the egg chamber to determine the dose in

awkward situations. Another use of the egg chambers is to cross check the calibration of the dose chamber. A fourth use is when one wants to measure a depth-dose curve in specialized water phantoms.

4. Ion-Energy

There are several reasons for choosing different ion energies. The therapist is primarily interested in depth of penetration--the higher the ion energy, the greater the penetration. The heavier the ion, e.g. carbon vs. neon, the greater is the energy required for the same penetration. Another reason is that the biologist wishes to study the effect of different LETs. LET stands for Linear Energy Transfer and relates to the way different ions give up their energy as they slow to a stop in matter--the higher the energy (the faster a particle is traveling), the lower the LET. Tissue responds differently to particles with different LETs. The energy of the beam reaching the sample is dependent only upon the tuned energy in the Bevatron and material in the beam line between the Bevatron vacuum and the sample. It does not depend upon the source of the ions whether it be the local injector or the SuperHILAC.

5. Lead Scatterers

In order to provide a beam large enough in cross section to cover the maximum important dimension of the sample, lead foils (in 1/64-in. increments) can be introduced into the beam ahead of the final steering magnet in Cave II. The beam size is usually chosen to give a uniformity of $\pm$10% (see sigma). This size is chosen as a

compromise between covering the sample adequately and maintaining a sufficient dose rate. The dose rate varies inversely as the square of the beam diameter, that is, if you double the beam size, you quarter the dose rate. If the doses to the samples are low and the dose rate is not important one may choose larger beams to improve the uniformity.

6. Sigma

This gives an indication of beam size and is derived from information received from the rings of the ion chamber. The value of sigma when multiplied by 1.3 gives the diameter of the beam, in centimeters, to the 80% level. The assumptions made are that the beam is Gaussian in distribution, well centered, and symmetrical. As an example, you have an animal contained in a 6-cm-diameter holder and you want to irradiate it uniformly to within ± 10%. The sigma you would be looking for would be 6/1.3 = 4.6. Another way of checking for beam uniformity is to look at the dose on the various rings of the chamber. In our example above, if the dose on the third ring (4-6 cm) is 80% of the dose on the 1 cm ring, then the beam is large enough for the 6-cm holder.

[Note: Due to present constraints of the system, we are only able to offer precise dose cut-off over the central 1-cm of the field. This results in a uniformity of approximately +0 to -20%. In the future we hope to be able to average the fast cut off over the entire sample resulting in our ±10% figure.]

7. Spiral Ridge Filters

The primary purpose of a ridge filter is to provide a uniform dose effect over a tissue sample in depth. In therapy the width of the ridge (again in depth) is selected to cover the tumor dimension along the beam axis uniformly in effect (not necessarily in dose). Pre-therapy biology seeks to confirm the uniformity of the effect and the differences of different widths of ridge filters.

There are generally two positions for the ridge filter: (1) The entire ridge filter is centered in the beam (up position) and (2) the upper half of the ridge filter is centered in the beam (down position). Position (1) is always associated with the occluding ring-second scatterer configuration used to produce therapy-like large beams on targets well downstream of the ridge filter. Position (2) is associated with small high intensity beams with targets near the ridge filter. The filter should always be spinning in position (2) but spinning is optional in position (1) if the sample is 5 meters or more from the ridge filter. If the filter is inadvertently left in position (1) without the occluding rings in position, the experiment will generally be inconclusive.

8. Units

Dose is expressed in rads, which is a unit of absorbed dose. It is "the amount of energy imparted to matter by ionizing particles per unit mass of irradiated material at the place of interest."* Its units are 100 ergs per gm.

A roentgen is a measure of exposure only, not absorbed dose.** The primary interaction of x-rays with matter involve the production of energetic secondary charged particles, usually electrons. It is the interactions of these secondary charged particles with matter that accounts predominantly for the imparting of energy to any absorbing material.

9. Water Column: Variable Water Absorber (sometimes called range shifter). This device has two main functions. The primary function in radiotherapy is to reduce the range of the particles so that they stop at the tumor site. It can also be set so that the target sample can be at any equivalent depth. The particles generally stop in the concrete at the back of the cave when no absorber, water, or thick target is in the beam line. If one wishes to place, for example, the unmodified Bragg peak in the center of a 1-cm-thick sample and the range of the particle after passing through the lead scatterers and the various devices on the bench is 25.5 cm, then one would set the water column at 25 cm.

This would hold true anywhere along the beam line whether at the front of the cave or at the rear. There is one slight modification to this. If the range is 25.5 cm at the front end of the bench after passing through the various absorbers, water column, and final chamber but the sample is placed 3 meters farther downstream, then the range would be further shortened by the absorption of the air path by about 0.3 cm. Hence, the water column should be set at 24.7 cm.

There are better ways of modulating the beam range. One can use higher Z materials in a variable filter arrangement. However, if one wishes to provide a close approximation to a true depth-dose curve in tissue, then one should use a water absorber.

* (ICRU, 1954)
** (ICRU, 1962)

B. CALCULATIONS

1. Converting Dose to Particles/sq cm

$n(r)$ = number of particles/sq cm/rad

For Water:

$n(r) = 6.242 \times 10^7 / dE/dx$ (Mev/cm)

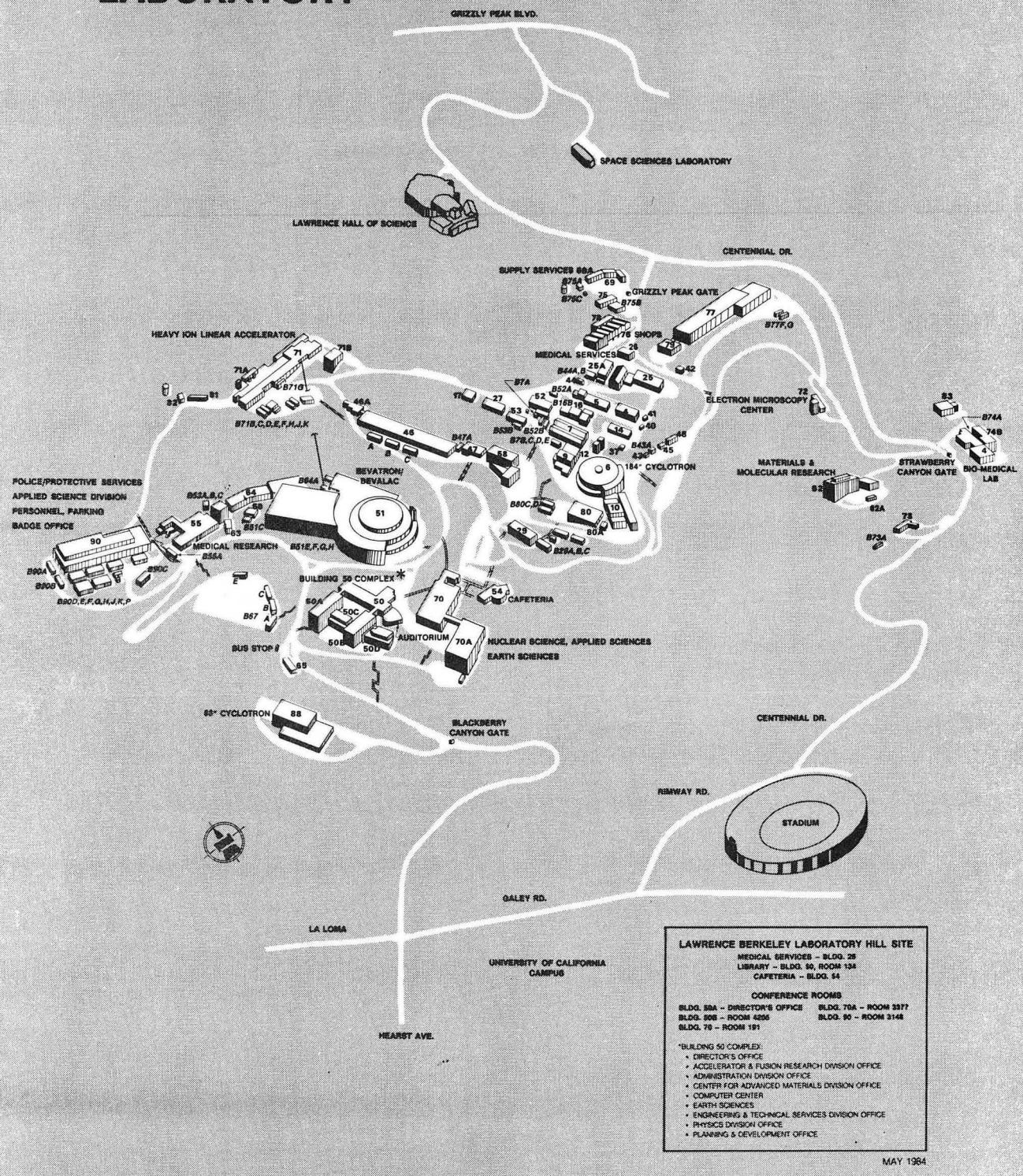
$n(r) = 6.242 \times 10^6 / LET$ (keV/um)

Example:

To convert 1 gray of plateau neon particles at 600 MeV/amu (standard conditions for 670 MeV/amu nominal Bevalac energy) you can refer to the beam data section or look up the value for LET in Appendix D. Obtaining a value of 26 keV/μm and substituting:

$$n(r) = \frac{(6.242 \times 10^6)\ (100)}{26} = 2.4 \times 10^5 \text{ particles/cm}^2$$

LAWRENCE BERKELEY LABORATORY



LAWRENCE BERKELEY LABORATORY HILL SITE

MEDICAL SERVICES – BLDG. 25
LIBRARY – BLDG. 50, ROOM 134
CAFETERIA – BLDG. 64

CONFERENCE ROOMS

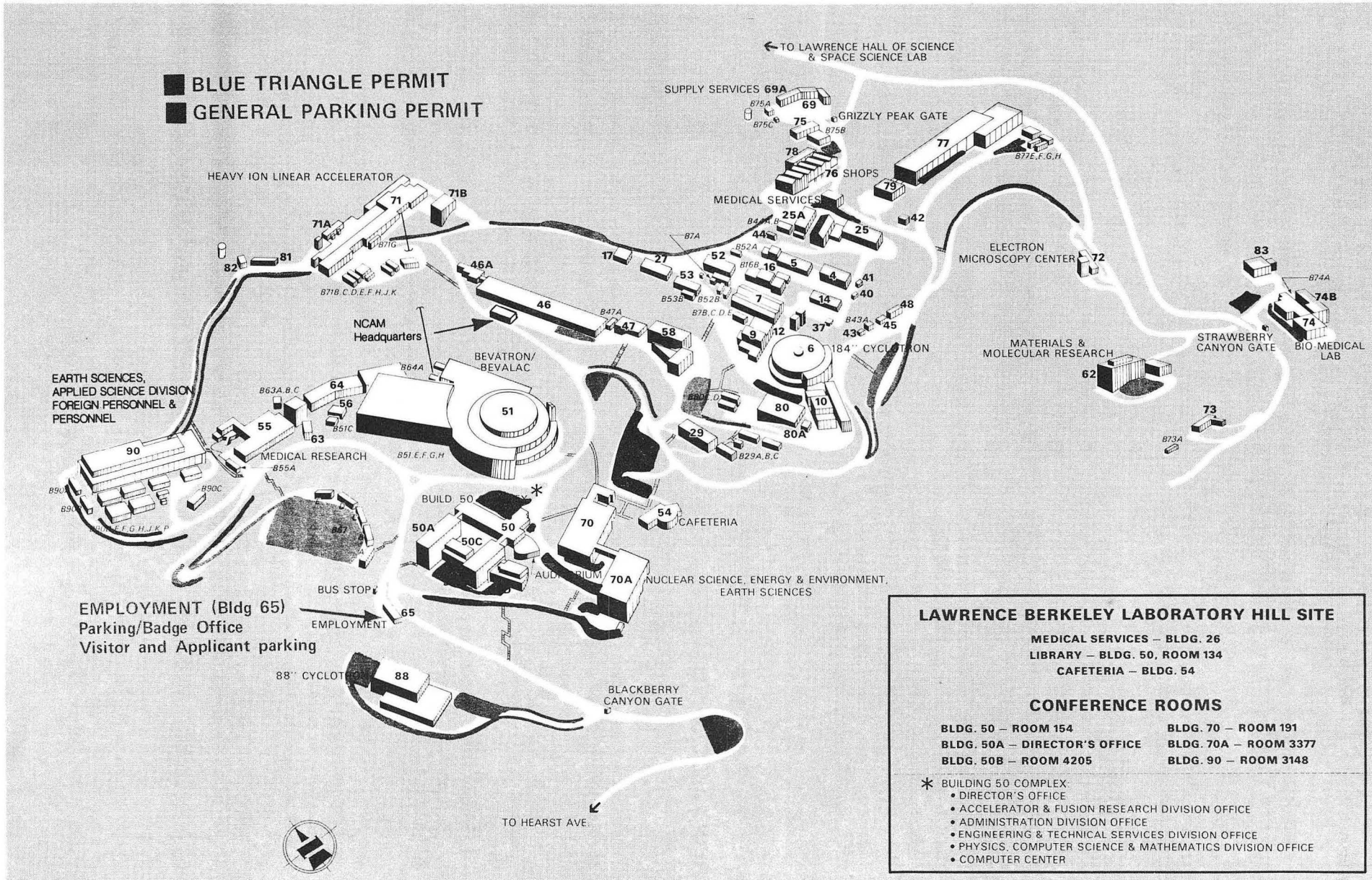
BLDG. 50A – DIRECTOR'S OFFICE
BLDG. 50B – ROOM 4206
BLDG. 70 – ROOM 191
BLDG. 70A – ROOM 3377
BLDG. 90 – ROOM 3148

*BUILDING 50 COMPLEX:

- DIRECTOR'S OFFICE
- ACCELERATOR & FUSION RESEARCH DIVISION OFFICE
- ADMINISTRATION DIVISION OFFICE
- CENTER FOR ADVANCED MATERIALS DIVISION OFFICE
- COMPUTER CENTER
- EARTH SCIENCES
- ENGINEERING & TECHNICAL SERVICES DIVISION OFFICE
- PHYSICS DIVISION OFFICE
- PLANNING & DEVELOPMENT OFFICE

MAY 1984

LAWRENCE BERKELEY LABORATORY



LAWRENCE BERKELEY LABORATORY HILL SITE

MEDICAL SERVICES – BLDG. 26
LIBRARY – BLDG. 50, ROOM 134
CAFETERIA – BLDG. 54

CONFERENCE ROOMS

BLDG. 50 – ROOM 154	**BLDG. 70 – ROOM 191**
BLDG. 50A – DIRECTOR'S OFFICE	**BLDG. 70A – ROOM 3377**
BLDG. 50B – ROOM 4205	**BLDG. 90 – ROOM 3148**

* BUILDING 50 COMPLEX
- DIRECTOR'S OFFICE
- ACCELERATOR & FUSION RESEARCH DIVISION OFFICE
- ADMINISTRATION DIVISION OFFICE
- ENGINEERING & TECHNICAL SERVICES DIVISION OFFICE
- PHYSICS, COMPUTER SCIENCE & MATHEMATICS DIVISION OFFICE
- COMPUTER CENTER

MAY 1983

See reverse side for General Traffic and Parking Regulations

XBG 579

GENERAL TRAFFIC AND PARKING REGULATIONS
LAWRENCE BERKELEY LABORATORY

Violators of traffic and/or parking regulations are subject to citation by LBL Protective Services Officers under provisions of the California Motor Vehicle Code, Section 21113(a), (b), and (c) which states:

> Persons operating and/or parking vehicles on University properties are subject to the conditions and regulations established and posted by the University for those areas. In the absence of any special conditions or regulations applicable to traffic or parking, all the provisions of the California Motor Vehicle Code relating to traffic or parking are applicable.

A. TRAFFIC REGULATIONS

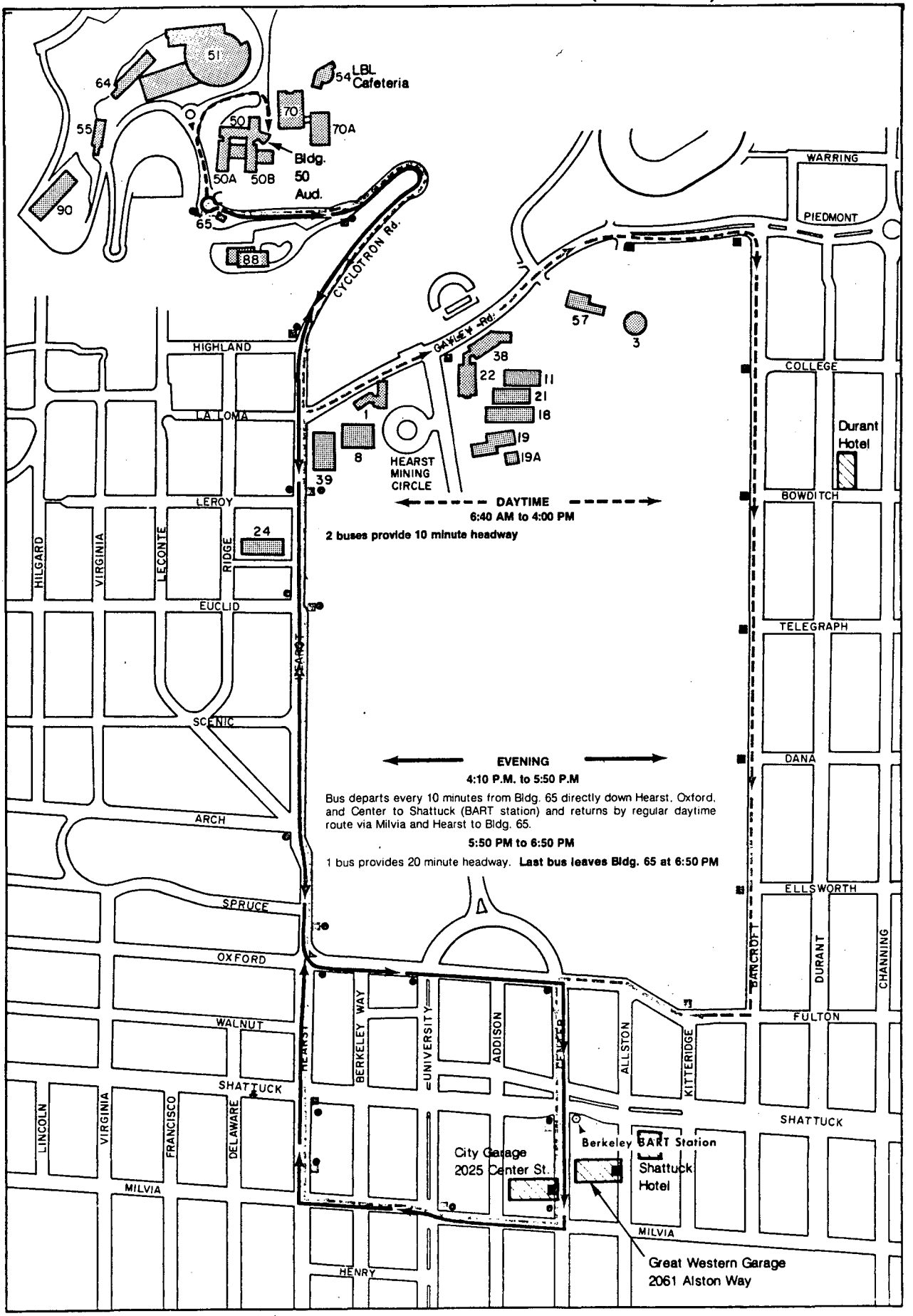
1. Permission to operate a vehicle on University of California, Lawrence Berkeley Laboratory property is subject to control by Protective Services Officers; this permission may be revoked at any time.
2. Each person who regularly drives or parks a private motor vehicle at LBL must have a valid LBL parking permit displayed in accordance with instructions issued with the permit. Temporary permits must be displayed, and expired permits will not be honored.
3. The basic speed limit on LBL property (for all but emergency vehicles) is 25 miles per hour or as much less than 25 miles per hour as pedestrian traffic and/or other conditions require for safe driving.
4. All vehicles shall yield to pedestrians and must proceed with caution throughout the Laboratory to observe the rights of pedestrians, bicyclists, slow-moving vehicles using the roadways, wildlife, etc.
5. Barriers, fences, or posts may be placed at any location deemed necessary for safety or convenience at the discretion of Laboratory authorities. Unauthorized removal of any such barriers, fences, or posts (except for emergency or maintenance vehicles) is a violation of law.
6. No vehicle shall be driven or parked on any area which has been landscaped or designated for landscaping, or on any walk or pathway intended for pedestrian use except for maintenance by an appropriate Laboratory employee or in case of emergency.

B. PARKING REGULATIONS

1. Park only in marked spaces and in designated parking strips along roadways. Observe parking restrictions in posted areas.
2. Parking in a manner that encroaches on or blocks an adjacent parking space or traffic way is prohibited.
3. Parking which allows a vehicle to project beyond the end line of any space or lane so marked is prohibited.
4. Mo-peds, scooters, motorbikes, and motorcycles shall not park in regular automotive spaces.
5. Orange Circle, Blue Triangle, and Blue Triangle/Official Vehicle regulations will be enforced for all marked spaces at LBL between the hours of 7:30 a.m. to 5:00 p.m., Monday through Friday, with the following exceptions:
   a. Orange Circle spaces are reserved for Orange Circle holders from 7:30 a.m. to 6:00 p.m., Monday through Friday, except on holidays unless otherwise posted.
   b. Blue Triangle and Blue Triangle/Official Vehicle spaces are open after 3:00 p.m. except in the Buildings 50/70 areas, which are open after 5:00 p.m. and on holidays.
   c. Official Vehicle spaces reserved by license number, and Handicapped spaces are reserved at all times.
6. Backing into parking spaces is prohibited in areas so posted.
7. Parking permits must be affixed to the bumpers of the vehicle for which they are issued. The stickers are void if they are transferred without notifying the Parking/Badge Office, Building 65. Permits shall be removed prior to sale of vehicle or upon termination from LBL. Expired permits are to be removed from vehicles. If assistance is needed to remove permits, contact the Motor Pool in Building 76.
8. Misuse of parking permits is cause for suspension of parking privileges.
9. Parking of vehicles for prolonged periods at LBL is prohibited except when arranged in advance with the Parking Committee.
10. The Laboratory Protective Services Office shall issue a direct court citation to Laboratory and private vehicles parked in red zones, blocking fire hydrants, fire trails, or emergency exits. The department responsible for the official vehicle will then determine the party who illegally parked the vehicle and give the ticket to that person to pay the fine with his or her own funds.

LBL OFF-SITE SHUTTLE BUS ROUTE (RED FLAG)

FEBRUARY 1984



DAYTIME Bus Stop

EVENING Bus Stop

XBL 838-10915A

LBL ON-SITE SHUTTLE BUS ROUTES

LBL SHUTTLE BUS SCHEDULE

Departure Times (Effective February 1984)

OFF-SITE SHUTTLE (Red Flag)
Route: 65 - Cyclotron Rd - Gayley - Bancroft - Oxford - Center - Milvia - Hearst - Cyclotron Rd. - 65 (see map for stops).

Bldg. 65	BART Station (Center and Shattuck)
6:30AM	6:40AM
6:40AM	6:50AM
•	•
•	•
every 10 mn.	every 10 min.
•	•
(no service after 4:00PM along Gayley & Bancroft Bus uses Hearst instead)	•
•	•
5:50PM	6:00PM
6:10PM	6:20PM
6:30PM	6:40PM
6:50PM	7:00PM

HILL SHUTTLE (Blue Flag)
Route: 65 - 55 - 90 - 51 - 50/70 - 46 - 46A - 27 - 25/26 - 42 - 77 - 72 - 62 - 72 - 77 - 42 - 48 - 6 - 29/54 - 65

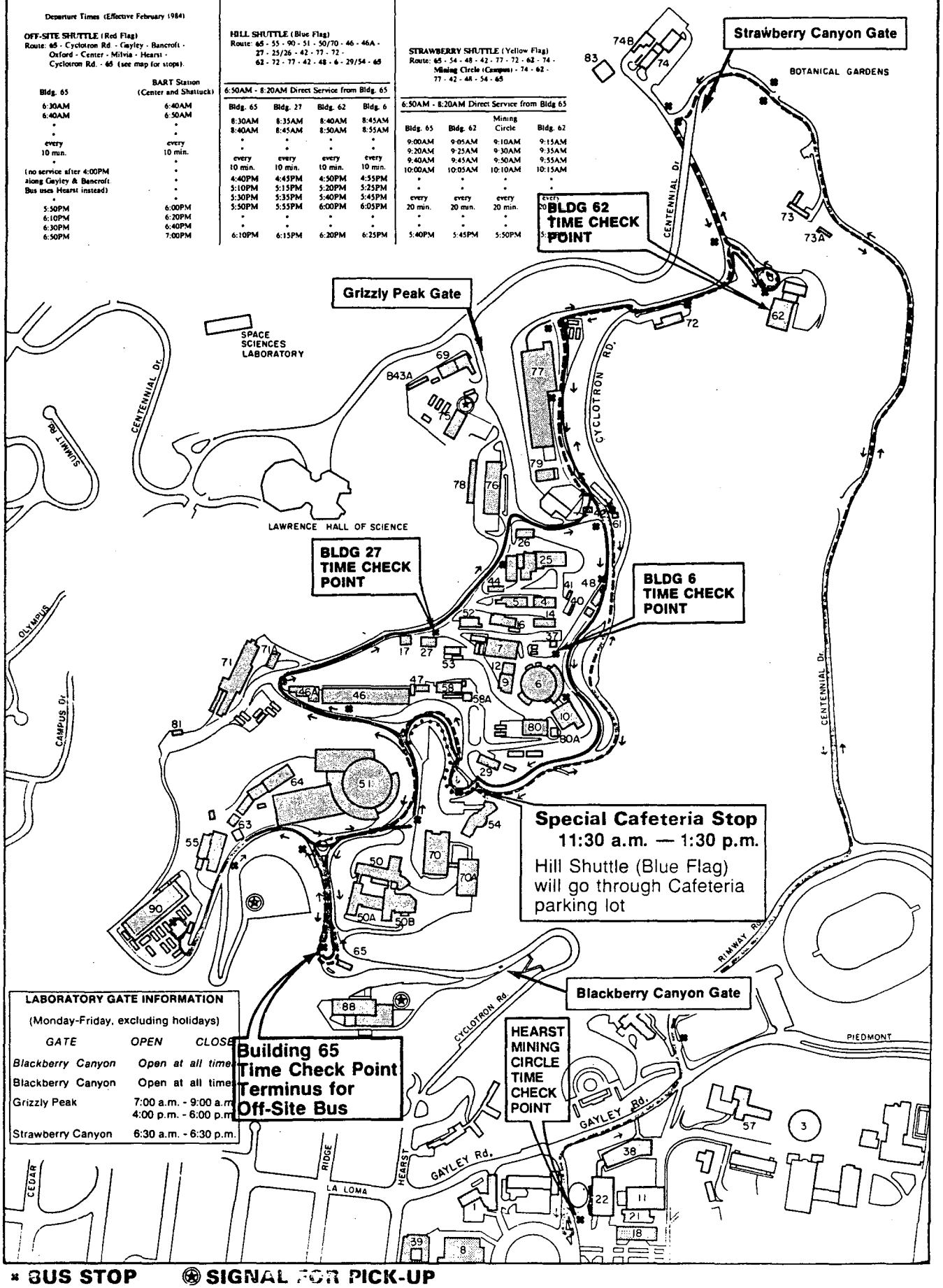
6:50AM - 8:20AM Direct Service from Bldg. 65

Bldg. 65	Bldg. 27	Bldg. 62	Bldg. 6
8:30AM	8:35AM	8:40AM	8:45AM
8:40AM	8:45AM	8:50AM	8:55AM
•	•	•	•
•	•	•	•
every 10 min.	every 10 min.	every 10 min.	every 10 min.
4:40PM	4:45PM	4:50PM	4:55PM
5:10PM	5:15PM	5:20PM	5:25PM
5:30PM	5:35PM	5:40PM	5:45PM
5:50PM	5:55PM	6:00PM	6:05PM
•	•	•	•
•	•	•	•
6:10PM	6:15PM	6:20PM	6:25PM

STRAWBERRY SHUTTLE (Yellow Flag)
Route: 65 - 54 - 48 - 42 - 77 - 72 - 62 - 74 - Mining Circle (Campus) - 74 - 62 - 77 - 42 - 48 - 54 - 65

6:50AM - 8:20AM Direct Service from Bldg 65

Bldg. 65	Bldg. 62	Mining Circle	Bldg. 62
9:00AM	9:05AM	9:10AM	9:15AM
9:20AM	9:25AM	9:30AM	9:35AM
9:40AM	9:45AM	9:50AM	9:55AM
10:00AM	10:05AM	10:10AM	10:15AM
•	•	•	•
•	•	•	•
every 20 min.	every 20 min.	every 20 min.	every 20 min.
•	•	•	•
•	•	•	•
5:40PM	5:45PM	5:50PM	5:55PM



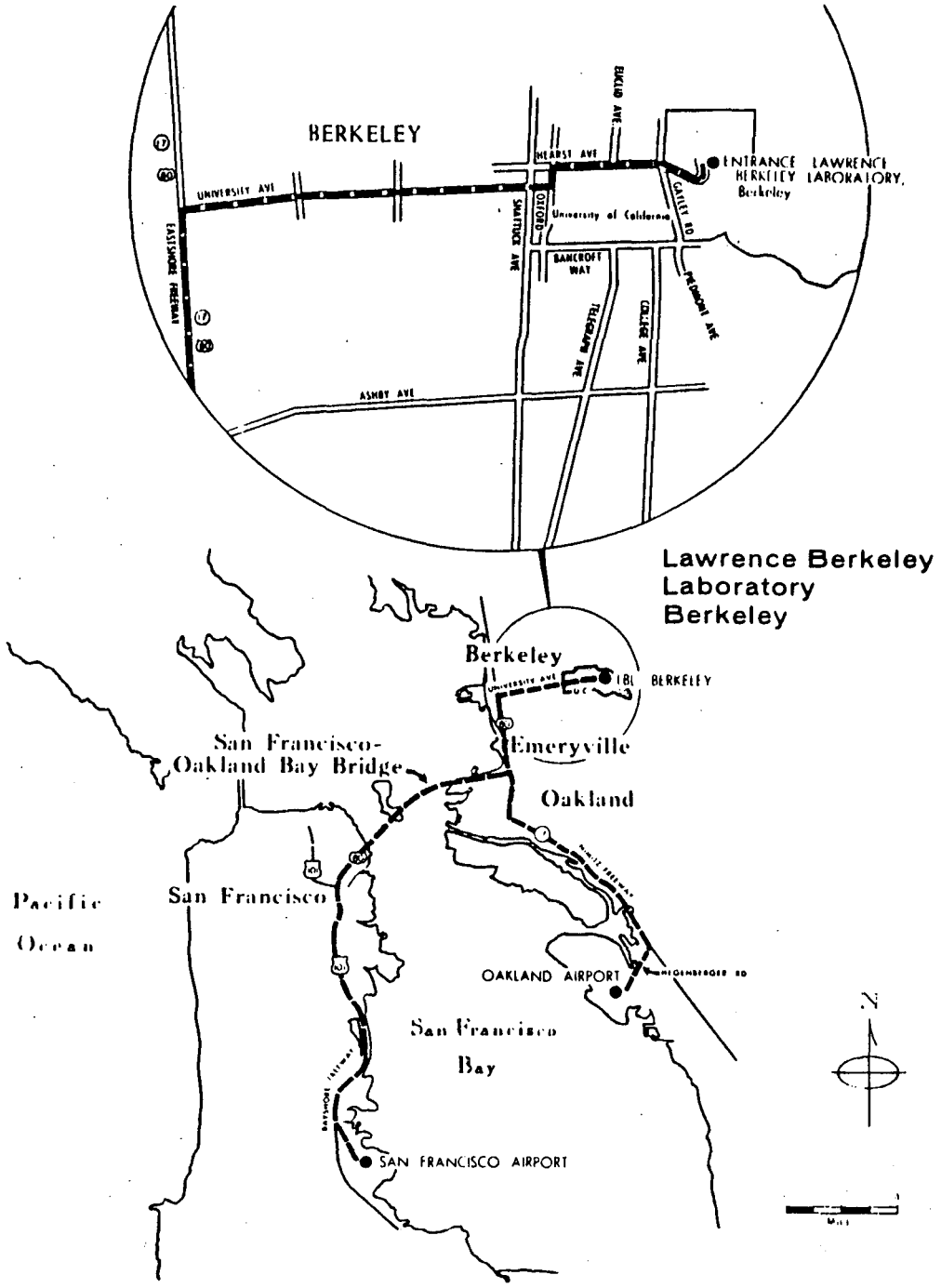
LABORATORY GATE INFORMATION

(Monday-Friday, excluding holidays)

GATE	OPEN	CLOSE
Blackberry Canyon	*Open at all times*	
Blackberry Canyon	Open at all times	
Grizzly Peak	7:00 a.m. - 9:00 a.m. 4:00 p.m. - 6:00 p.m.	
Strawberry Canyon	6:30 a.m. - 6:30 p.m.	

* BUS STOP ⊛ SIGNAL FOR PICK-UP

XBL 8212-7378A



SAN FRANCISCO AIRPORT TO LBL-BERKELEY

Driving time: 45 min. to 1 hr.
Distance: about 25 miles

Upon leaving the airport, bear right and go north on Highway 101 to San Francisco-Oakland Bay Bridge approach (about 13 miles). Watch for signs for "Bay Bridge" and Interstate 80.

After crossing the bridge (about 4.5 miles), bear left and look for signs pointing to Interstate 80 and to Berkeley. (About 1.5 miles from the end of the bridge there is a major intersection from which Interstate 80 goes northward.)

Go north about 2.4 miles on Interstate 80 and take the University Avenue turnoff (right) into Berkeley. Stay on University Ave., about 2.6 miles, to its eastern end at Oxford St. (western side of U.C. campus), bearing left.

Turn left onto Oxford St. and, bearing right, take the first right turn onto Hearst Ave. and follow it up the hill to LBL (Hearst Ave. becomes Cyclotron Road before the entrance to LBL).

From the east end of University Ave. to LBL is about 1 mile.

(Note: Some time can be saved by using the local helicopter service to the Emeryville heliport, at the foot of Powell Street.)

OAKLAND AIRPORT TO LBL-BERKELEY

Driving time: 35 minutes
Distance: about 16.5 miles

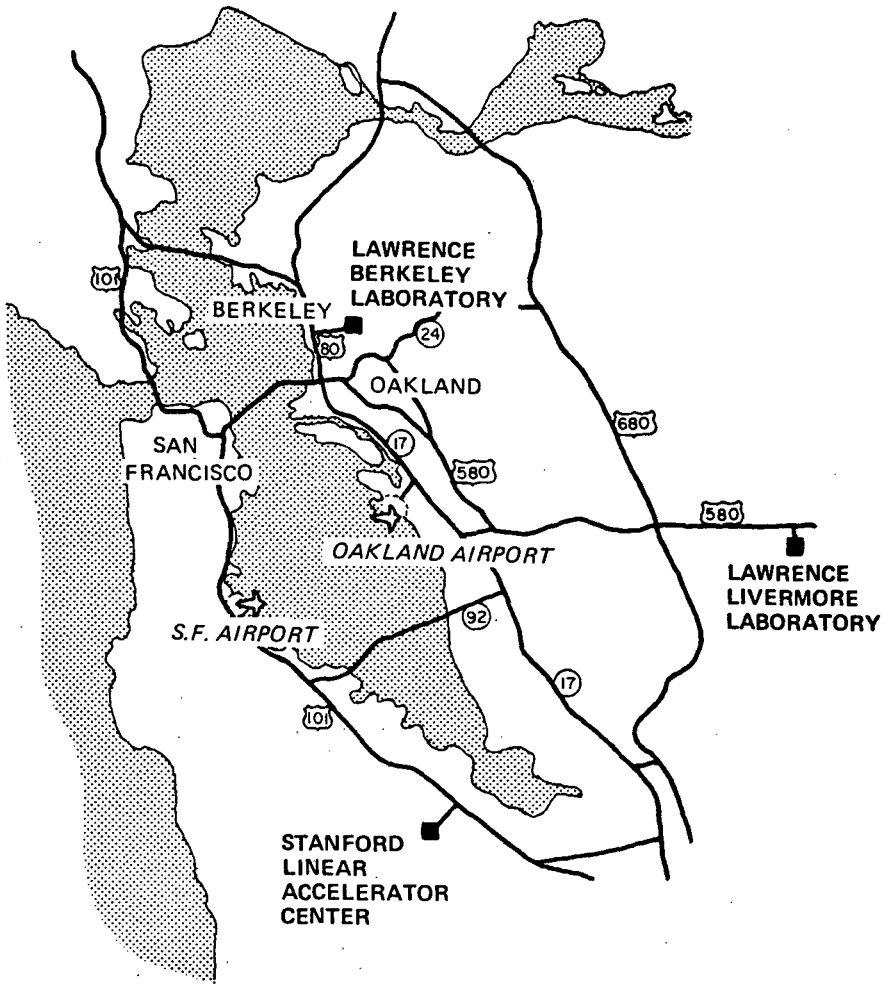
Take Hegenberger Road eastward from the airport for about 1.7 miles to Highway 17 (Nimitz Freeway). When approaching the Highway 17 intersection, bear right and watch for signs pointing to the turnoff to downtown Oakland.

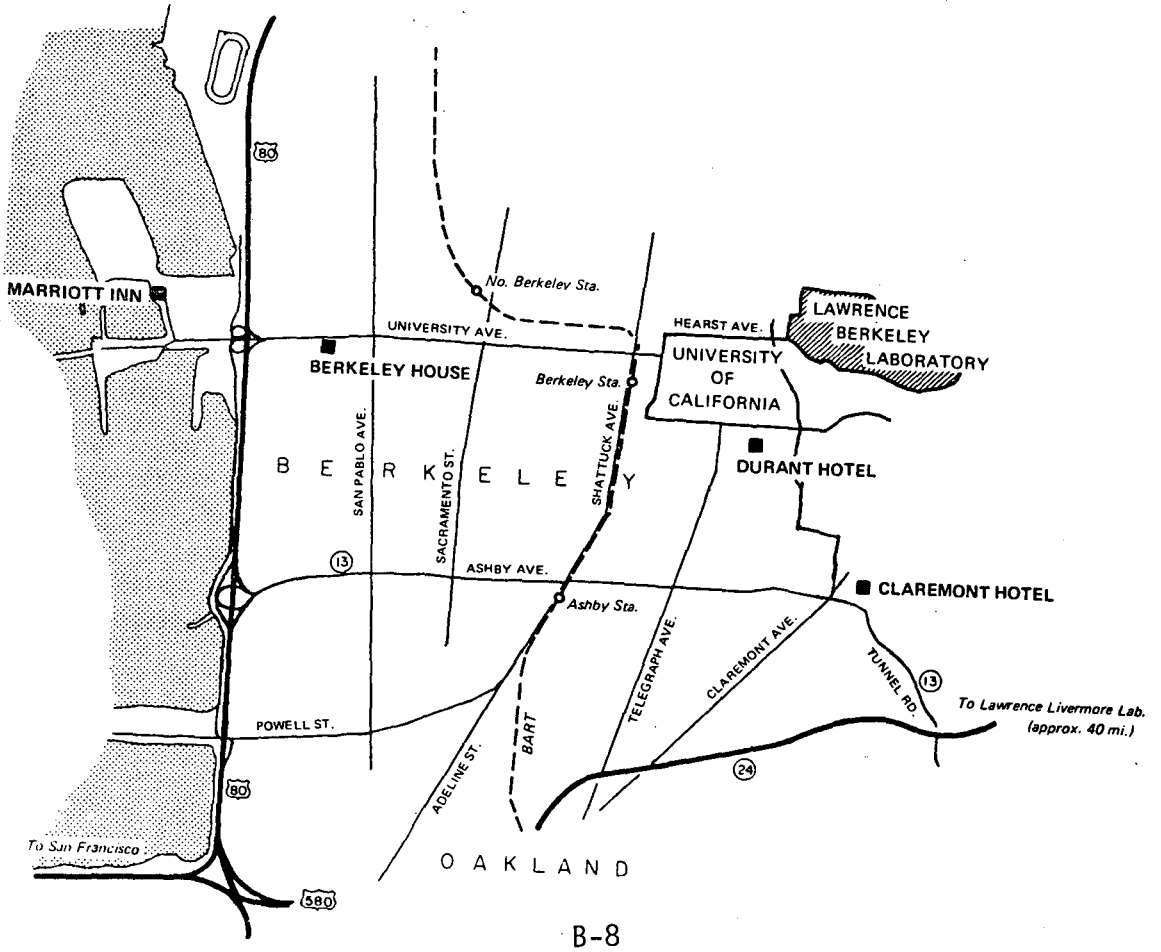
Then go northwest about 8.5 miles on Highway 17, bearing right, to the intersection with Interstate 80 (Eastshore Freeway). Go north on it for about 2.4 miles, again bearing right, and take the University Avenue turnoff (right) into Berkeley. Stay on University Ave., about 2.6 miles, to its eastern end at Oxford St. (western side of U.C. campus), bearing left.

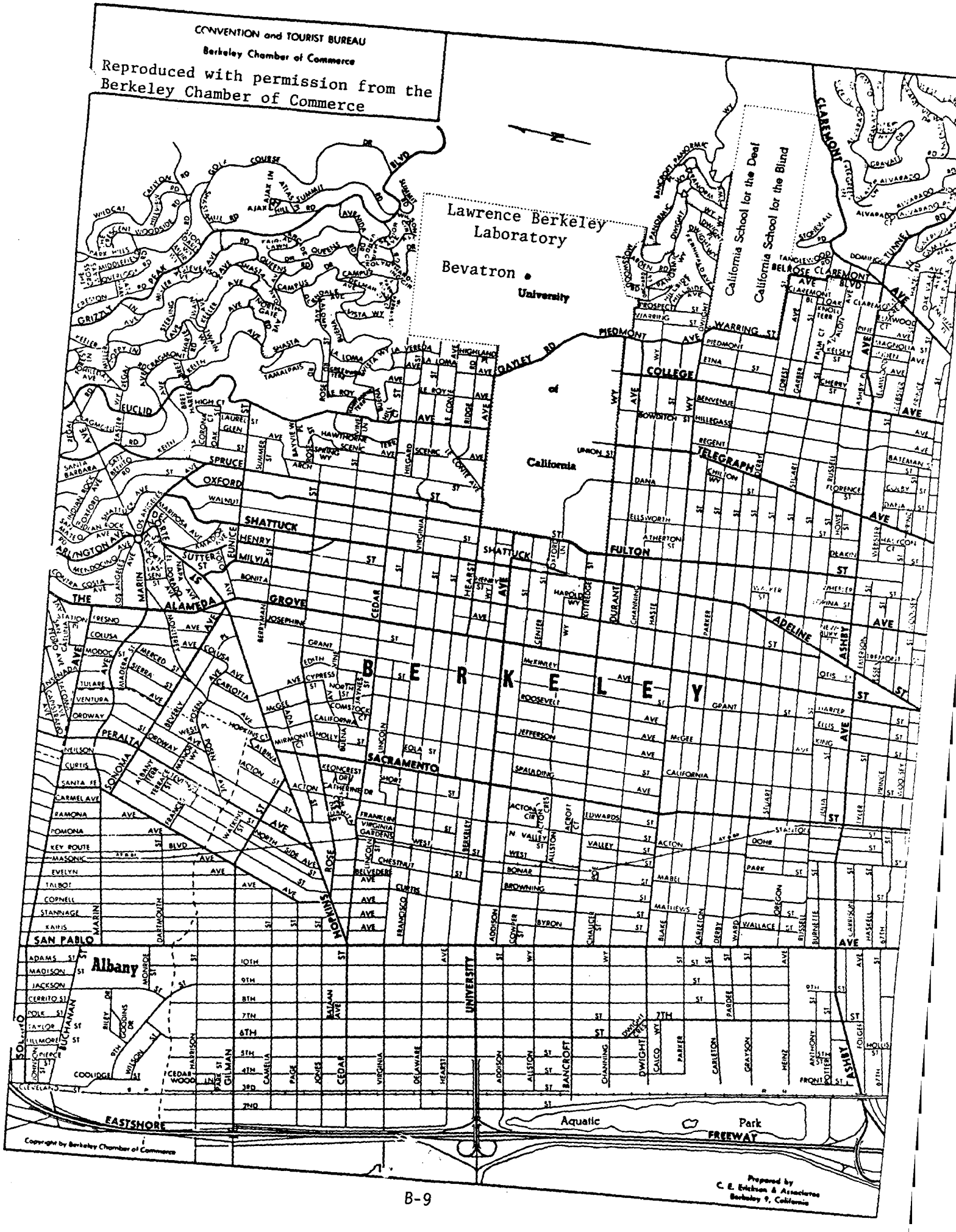
Turn left onto Oxford St. and, bearing right, take the first right turn onto Hearst Ave. and follow it up the hill to LBL (Hearst Ave. becomes Cyclotron Road before the entrance to LBL).

From the east end of University Ave. to LBL is about 1 mile.

(Note: Some time can be saved by using the local helicopter service to the Emeryville heliport, at the foot of Powell Street.)


LAWRENCE
BERKELEY
LABORATORY
BERKELEY
OAKLAND
SAN
FRANCISCO
OAKLAND AIRPORT
S.F. AIRPORT
LAWRENCE
LIVERMORE
LABORATORY
STANFORD
LINEAR
ACCELERATOR
CENTER
101
80
24
17
580
680
92


MARRIOTT INN
No. Berkeley Sta.
UNIVERSITY AVE.
HEARST AVE.
LAWRENCE
BERKELEY
LABORATORY
BERKELEY HOUSE
Berkeley Sta.
UNIVERSITY
OF
CALIFORNIA
B E R K E L E Y
SAN PABLO AVE.
SACRAMENTO ST.
SHATTUCK AVE
DURANT HOTEL
ASHBY AVE.
CLAREMONT HOTEL
Ashby Sta.
TELEGRAPH AVE.
CLAREMONT AVE.
TUNNEL RD.
To Lawrence Livermore Lab.
(approx. 40 mi.)
POWELL ST.
ADELINE ST.
BART
To San Francisco
O A K L A N D
80
13
24
580


CONVENTION and TOURIST BUREAU
Berkeley Chamber of Commerce
Reproduced with permission from the Berkeley Chamber of Commerce
Lawrence Berkeley Laboratory
Bevatron
University of California
California School for the Deaf
California School for the Blind
B E R K E L E Y
Albany
EASTSHORE FREEWAY
Aquatic Park
Copyright by Berkeley Chamber of Commerce
Prepared by C. E. Erickson & Associates Berkeley 9, California

UNIVERSITY OF CALIFORNIA
LAWRENCE BERKELEY LABORATORY
PATENT AGREEMENT

This agreement is made by me with The Regents of the University of California, a corporation, hereinafter called "University", in part consideration of my employment, and of wages and/or salary to be paid to me during any period of my employment, by University, and/or my utilization of University research facilities.

By execution of this agreement I understand that I am not waiving any rights to a percentage of royalty payments received by University, as set forth in the University Policy Regarding Patents hereinafter called "Policy". I further understand that I may, with the approval of the University, request a waiver determination by the U.S. Government on my identified inventions as set forth in 41 CFR 9–9.109–6, where applicable.

I agree that every possible patentable device, process, plant, or product, hereinafter referred to as "invention", which I conceive, make (first actually reduce to practice), or develop while employed by University, or during the course of my utilization of any University research facilities, shall be examined by University to determine rights and equities in accordance with the Policy, and I shall promptly furnish University with complete information with respect to each.

In the event any such invention shall be deemed by University to be patentable, and University desires, pursuant to determination by University as to its rights and equities therein, to seek patent protection thereon, I shall execute any documents and do all things necessary, at University's expense, to assign to University all rights, title and interest therein and to assist University in securing patent protection thereon. The scope of this provision is limited by California Labor Code section 2870, to which notice is given below, to the extent said Labor Code provision is consistent with federal law. In the event I protest the University's determination regarding any rights or interests in an invention, I agree: (a) to proceed with any University requested assignment or assistance; (b) to give the University notice of that protest no later than the execution date of any of the above-described documents or assignment; and (c) to reimburse the University for all expenses and costs it encounters in its patent application attempts, if any such protest is subsequently sustained or agreed to.

I shall do all things necessary to enable University to perform its obligations to grantors of funds for research or contracting agencies as said obligations have been undertaken by University, including the University's obligations regarding patents and technical and scientific records under Contract No. DE-AC03-76SF00098. (Contract-98) with the U.S. Government. With reference to Contract-98 I agree to abide by and fully perform the terms of Clause 35 of said contract, excerpts of which are set forth on the reverse side of this agreement, as they may be amended from time to time, to the extent applicable to me, and further agree that I will report all such inventions to the Director, Lawrence Berkeley Laboratory (LBL), or his designee. To protect the patent interests of the University and the Government, I agree not to publish any information regarding scientific or technical developments made or conceived in the course of or under Contract-98 without prior approval obtained from the Director, LBL, or his designee for this purpose.

University may relinquish to me all or a part of its right to any such invention, if, in its judgment, the criteria set forth in the Policy have been met.

I agree to be bound hereunder for and during any periods of employment by University or for any period during which I conceive, make (first actually reduce to practice), or develop any invention during the course of my utilization of any University research facilities.

In signing this agreement I understand that the law, of which notification is given below, applies to me, but that I am still required to disclose all my inventions to the University.

NOTICE

This agreement does not apply to an invention which qualifies fully under the provisions of Labor Code section 2870 of the State of California, to the extent said Labor Code provision is consistent with federal law. Said Labor Code provision provides that:

Any provision in an employment agreement which provides that an employee shall assign or offer to assign any of his or her rights in an invention to his or her employer shall not apply to an invention for which no equipment, supplies, facility, or trade secret information of the employer was used and which was developed entirely on the employee's own time, and (a) which does not relate (1) to the business of the employer, or (2) to the employer's actual or demonstrably anticipated research or development, or (b) which does not result from any work performed by the employee for the employer. Any provision which purports to apply to such an invention is to that extent against the public policy of this state and is to that extent void and unenforceable.

In any suit or action arising under this law, the burden of proof shall be on the individual claiming the benefits of its provisions.

Employee/Guest Name: _____
(Please Print)

Employee/Guest Signature: _____ Date: _____

Witness Signature: _____ Date: _____

Excerpts from Clause 35
Contract No. DE-AC03-76SF00098

(b) *Allocation of principal rights.* (1) Assignment to the Government. The University agrees to assign to the Government the entire right, title, and interest throughout the world in and to each Subject Invention, except to the extent that rights are retained by the University under paragraphs (b) (2) and (c) of this clause.

(e) *Invention identification disclosures and reports.* (1) The University shall establish and maintain active and effective procedures to ensure that Subject Inventions are promptly identified and timely disclosed. These procedures shall include the maintenance of laboratory notebooks or equivalent records and any other records that are reasonably necessary to document the conception and/or the first actual reduction to practice of Subject Inventions, and records which show that the procedures for identifying and disclosing the inventions are followed.

(f) *Publications.* It is recognized that during the course of the work under this contract, the University or its employees may from time to time desire to release or publish information regarding scientific or technical developments made or conceived in the course of or under this contract. In order that public disclosure of such information will not adversely affect the patent interests of DOE or the University, patent approval for release or publication shall be secured from Patent Counsel prior to any such release or publication.

NOTE

At LBL, patent related duties and functions have been delegated by the Director to the LBL Patent Department. Employees are therefore requested to contact LBL Patent Department for processing of patent matters. Similarly, any questions relating to the DOE and University regulations and policies relating to patents and inventions should be directed to the Patent Department.

Revised: September 1984

PLEASE USE TYPEWRITER

PARTICIPATING GUEST INFORMATION

LAWRENCE BERKELEY LABORATORY, BERKELEY

☐ RENEWAL ☐ NEW GUEST ☐ FORMER GUEST ☐ FORMER EMPLOYEE
☐ ON RENEWAL, CHECK IF NO CHANGE OR ADDITION IN THE SECTION

GUEST NUMBER:

1 NAME (Last) (First) (Middle Name or Initial) TELEPHONE NO. IN S.F. BAY AREA

ADDRESS IN S.F. BAY AREA (Number and Street) (City) (Zip Code)

CALIF.

PERMANENT ADDRESS (Number and Street) (City) (State) (Country or Zip Code)

LABORATORY CONTACT (Name) (Department) PAYROLL ACCOUNT NO.

2 REASON FOR VISIT (Facility to be used, nature of experiment, description of activity).

WILL BE WITH LABORATORY FROM: TO: | LAB. PHONE | BUILDING | ROOM

NOTE: FOR EXPERIMENTERS USING THE BEVATRON, CYCLOTRONS OR HILAC: | 8000 SERIES ACCOUNT NO.

3 IF MEMBER OF GROUP, NAME OF GROUP LEADER | IF NO 8000 ACCOUNT, WILL ONE BE ESTABLISHED? ☐ YES ☐ NO

4 IF FILM BADGE IS REQUIRED, PLEASE GIVE BIRTH DATE: SOC. SEC. NO.

5 ☐ U.S. CITIZEN ☐ OTHER | IF "OTHER" PLEASE SPECIFY

6 FROM (Name of University, Institution, Company, etc.) | DEPARTMENT

ADDRESS (Number and Street) (City) (State) (Country or Zip Code)

ARE YOU AN EMPLOYEE OF THE ABOVE ORGANIZATION? ☐ YES ☐ NO | YOUR STATUS IN THE ABOVE ORGANIZATION IS ☐ STUDENT ☐ SCIENTIST ☐ ENGINEER ☐ OTHER _____

7 DURING YOUR STAY AT LBL WILL YOU RECEIVE ANY FINANCIAL SUPPORT THROUGH A GOVERNMENT AGENCY, FELLOWSHIP, GRANT, SCHOLARSHIP, ETC? ☐ YES ☐ NO – IF YES, PLEASE GIVE NAME(S) OF SOURCE(S) OF FUNDS AND ADDRESS(ES) BELOW.

THE LAWRENCE BERKELEY LABORATORY IS UNABLE TO PROVIDE WORKER'S COMPENSATION BENEFITS IN THE EVENT OF A WORK-INCURRED INJURY TO A PARTICIPATING GUEST, THAT IS, ONE WHO IS NOT ON THE PAY ROLL OF THE LABORATORY. Whom should the Laboratory contact to ascertain whether or not you are covered for Worker's Compensation benefits? In the event of an injury while working at the Laboratory this information would be needed. (Do not fill out Section 8 unless you are sure. See Section 10 below for person to notify in case of emergency.)

8 NAME | TELEPHONE NO.

ADDRESS (Number and Street) (City) (State) (Country or Zip Code)

9 IF COVERED BY A MEDICAL OR HEALTH INSURANCE PLAN, PLEASE GIVE NAME AND CARRIER

10 PERSON TO NOTIFY IN CASE OF EMERGENCY (Name) RELATIONSHIP | TELEPHONE

ADDRESS (Number and Street) (City) (State) (Country or Zip Code)

I hereby agree to abide by all rules and regulations of the Lawrence Berkeley Laboratory and the University of California as set forth in their respectively approved policies and procedures.

11 INFORMATION PREPARED BY | SIGNATURE OF GUEST | DATE

REMARKS:

MEDICAL INFORMATION FOR PARTICIPATING GUESTS OF THE LAWRENCE BERKELEY LABORATORY BERKELEY, CALIFORNIA

DATE _____

Name _____
Last First Initial

From _____
(Name of Institution, Company, etc.)

Will be working at LBL from _____ to _____
Date Date

Date of last Physical Examination: _____

Industrial ☐ Private ☐

Name, Address and Telephone Number of physician who would have medical information in case of emergency.

_____

_____

_____

Please list any health condition (diabetes, heart trouble, etc.) or medication (digitalis, allergy to penicillin, etc.) that would be important to a physician treating you for a sudden illness or injury.

_____

_____

_____

THIS INFORMATION IS NECESSARY IF YOU ARE INJURED OR BECOME ILL WHILE AT THE LAWRENCE BERKELEY LABORATORY. IT WILL BE HELD IN CONFIDENCE BY OUR MEDICAL DEPARTMENT.

(PLEASE FOLD THIS SHEET IN HALF, STAPLE IT AND DROP IT IN LBL MAIL. IT IS PREADDRESSED)

RL-3766 (Rev. 8/76) 7600-68177

LAWRENCE BERKELEY LABORATORY
BEVATRON/BEVALAC PROPOSAL FOR BIOMEDICAL OR BIOPHYSICS EXPERIMENT

EXP. NO.	CATEGORY

1. Submission Date: _____

Fifteen (15) copies required - a separate set for each experiment.

2. Title of Experiment (60 typewriter spaces or fewer):

3. Principal Investigator: (Include institution, address and telephone number.)

4. Participating Investigators: (Include telephone numbers and addresses if different from P.I.)

5. Abstract: Provide an abstract of your proposal. Include rationale, hypothesis, specific aims, methods, and significance.)

6. Instructions for Research Proposal Preparation. Proposals are evaluated by the Biomedical Program Advisory Committee (PAC), based on scientific merit and relevance to overall goals of the Bevalac Biomedical Program.

Adherence to the sectional outline described below provides for inclusion of information sufficient for peer review of your proposal. Brevity and clarity are essential since the total submission should not exceed 7 single-spaced pages. Applicants must bear in mind that the information content of the proposal must be such that PAC members can reconstruct and visualize your clearly delineated project in its entirety. The following are among the questions considered during peer review. Does a high probability exist that a significant new contribution to knowledge will be forthcoming? Is the rationale sound and a logical extension from a critical evaluation of current literature? Are the experimental design and methods such that reliable data from replicated experiments will be available for interpretation? Where supporting preliminary results are presented, is the statistical evaluation appropriate, and is the interpretation correct?

SECTIONAL OUTLINE:
Objective and AIMS.

A. State the overall objective or long-term goals of the research proposed in a few sentences, and describe the specific aims.

B. Background: Review critically, yet succinctly, the most significant previous research that bears most directly on development of the rationale/hypothesis with which the proposed project is concerned.

C. Rationale: Describe the logical sequence that led to formulation of the hypothesis tested. Why should heavy charged particles be used in the experiment proposed?

C.1. Preliminary Results: Present succinctly illustrative preliminary results (not considered in the background section) obtained by the P.I. or collaborators that bear directly on the research proposed. The absence of preliminary results in no way penalizes the applicant.

D. Experimental Design and Procedures: Describe the experimental design, including doses, appropriate controls, sample sizes, replications, and procedures to be used. Cite references to procedures freely, but be convincing with regard to the matter that all procedures relevant to the experiments proposed are fully in hand. Indicate how data forthcoming will be evaluated statistically.

E. Significance: Specify the hypothesis(es) tested and the potential contribution to knowledge from the experiments proposed.

DATA SHEET

PROPOSAL FOR BEVATRON/BEVALAC
BIOMEDICAL OR BIOPHYSICS EXPERIMENT

Pertinent Data

It is the policy of the Biomedical Scheduling Committee to implement approved proposals so that investigators are not faced with runs in which only incomplete data are obtained. However, investigators must realize that unforseen interruptions in beam availability will occur, and if this happens during a particular run, the investigator is not automatically entitled to an extension of time during that running period. Therefore, attention should be paid to the minimum number of dose points, samples, etc., that will satisfy experimental needs. This approach by investigators will help when problems in beam time availability occur.

7. Time Projections:

   a. Which ions and accelerated energies?

   b. How many hours for each ion? Total hours requested in this proposal: ___. Note: Time charged is the total of actual irradiation time, dosimetry time, set up time and waiting time if the beam is ready before the experimenter is ready to begin.

   c. How is this time to be divided during the various runs? (For the present assume only one ion per run)

   d. Is the time devoted to one run to be further subdivided? If so please indicate:

   e. Indicate the total period of time you would like to see this experiment completed within.

   f. Please indicate specific calendar months during which you want to run.

8. Beam Characteristics:

   a. Target size: _____ cm.

   b. We will attempt to provide ± 10% uniformity over the target size. If this is not satisfactory, state requirements and justify: _____

   _____

   _____

   If multiple samples are to be placed on our sample translator or areas of the target are to be spared, the collimated field dimension is _____ cm.

9. Experimental Design:

a. Nature of Sample and/or Apparatus: _____

_____

b. Size of Sample and/or Apparatus: _____

c. Type of experimental conditions (i.e., oxygenated, hypoxic, etc.:

_____

_____

d. Dose levels per experimental condition: _____

_____

e. Number of samples per dose level:

Minimum _____

Maximum _____

f. Sample Replacement Time: _____

g. Dose Rate

Desired: _____

Minimum Acceptable: _____

10. Readiness:

a. How many days or weeks lead time? (To order animals, grow tumors, etc.) _____

b. Experiment start time constraints: (How many hours warning time is required before irradiation starts? How many hours will the samples hold if the beam suddenly becomes unavailable?) _____

_____

_____

11. Hazardous equipment or material you will use:

NOTE: The design, operating procedures and operating mode of all hazardous equipment (equipment using flammable gases, pressure devices, etc.) must be approved by the LBL Safety Committee. (See UCRL 17928).

_____

_____

12. Animal Husbandry and Cell Culture Requirements:

a. Equipment: (e.g. caging, food, microscopes, hoods, incubators, special gas cylinders, etc.)

b. Space: (e.g. animal holding, storage, etc. Include length of time required.)

c. Support: (e.g. transportation, animal handling, personnel, shop facilities, etc.)

13. Dosimetry Requirements:

14. Other Special Requirements:

15. Submitted by:

16. We would appreciate receiving reprints of any publications resulting from this experimental work.

INSTRUCTIONS FOR FILLING OUT BEVATRON EXPERIMENTAL PROPOSAL FORMS

Your experiment will be placed in one of the following categories by the Program Advisory Committee:

Category	Objective
0	Fundamental Dosimetry
I	Cancer Therapy Potential
II	Diagnostic and other Medical Applications
III	Fundamental Radiological and Chemical Effects
IV	Fundamental Biological Effects
V	Exploratory Studies
VI	Space Biology

Items 1-2 Self-explanatory.

Item 3 The named person(s) must be able to answer questions relating to the experiment and be responsible for the experiment.

Item 4 Please list all scientific and graduate student participants in the experiment. Include the following information: Name, degree, title telephone number.

Item 5 Self-explanatory.

Item 6 Self-explanatory.

Items 7-8 See User's Handbook for currently available particles and energies, dose rates, and beam size information.

Item 9 A brief description is all that is necessary. Upon approval, a complete description, including sketches, drawings and photos would help to insure proper mating of target material to our irradiation benches.

Item 10 Self-explanatory.

Item 11 Self-explanatory.

Item 12 Self-explanatory.

Item 13 Normally provided by LBL unless you wish to provide your own dosimetry. Any special requirements from LBL?

Item 14 Please list special requirements for your experiment, e.g. cables, power, water, gases, etc. See User's Handbook for what is normally supplied.

Include a brief curriculum vitae of the Principal Investigator.

Payment for Services Rendered

Guest scientists who plan to house animals, need special supplies or support, or who will require more than a modest amount of machine shop work, are requested, following approval of their experiment, to submit a purchase order to LBL in an amount estimated to cover the required services. The purchase order should be sent to Administrative Services, Bldg. 930, Rm. 413, Lawrence Berkeley Laboratory, 1 Cyclotron Road, Berkeley, CA 94720. The normal services are listed in the User's Handbook.

Please send the completed proposal to the Accelerator Research Coordination Office, Bldg. 51, Rm. 208, Lawrence Berkeley Laboratory, 1 Cyclotron Road, Berkeley, CA 94720. Telephone No. - commercial (415)486-5185 or FTS 451-5185.

 | EXP. NO. | CATEGORY

LAWRENCE BERKELEY LABORATORY
BEVATRON/BEVALAC

EXTENSION REQUEST FOR
BIOMEDICAL OR BIOPHYSICS
EXPERIMENT

Fifteen (15) copies required - a separate set for each experiment

1. Date _____

2. Institution _____

3. Group _____

4. Person in charge or group spokesman (name, address, telephone number):

5. CHANGE OF EXPERIMENTERS (list those who have joined or left your group)

6. Title of Experiment (60 typewriter spaces or fewer):

7. JUSTIFICATION FOR EXTENSION REQUEST (300 words or fewer):

8. Time and ion requests. List desired hours for each ion, energy and run. A biomed run consists of several shifts every two weeks. If your desired time during a run is to be subdivided please indicate how (e.g. 4 hrs. running, 24 hrs. wait, then 4 hrs. running).

	1st run/mo.	2nd run/mo.	3rd run/mo.	4th run/mo.
Relative date				
Ion				
Energy				
Time				
Total time requested				

9. PROGRESS REPORT

State your progress so far in this experiment. Please include answers to the following specific questions, and limit your discussion to two pages.

1. What were your research accomplishments during prior approval phases?

2. How many hours of Bevatron/Bevalac time have you used in this phase of the experiment?

3. How much progress has been made toward achieving the goals originally established for this work?

If there are any publications which have arisen directly from this experiment, please include 15 copies with this extension request.

REQUEST FOR BEVALAC BEAM TIME

1. DATE_____

2. PRINCIPAL INVESTIGATOR_____

3. CONTACT_____EXTENSION_____

HOME PHONE_____

4. INDIVIDUALS WHO WILL BE PRESENT AT THE BEVALAC DURING THE EXPERIMENT:

_____

_____

5. EXPERIMENT NUMBER_____

6. EXPERIMENT NAME OR DESCRIPTION_____

7. SET UP NUMBER_____

8. ION_____

9. ION ENERGY_____

10. PREFERRED DATE_____NUMBER OF HOURS REQUESTED_____

11. If using other than a standard setup please attach a brief description and be sure to contact a biomed bevalac operations physicist well in advance of the run.

12. ANY SPECIAL HOLDERS, COLLIMATORS OR ABSORBERS REQUIRED THAT ARE NOT IN YOUR POSSESSION_____

13. DO YOU REQUIRE X-RAY SUPPORT_____

14. SPECIAL REQUESTS_____

15. SCHEDULED FOR_____

16. SUMMARY OF RUN: TIME AND DATE RAN_____

HOURS CHARGED_____

PROBLEMS_____

_____

NOTE: All necessary setups will be available in the computer prior to the run. If the setup is not there, the experiment cannot be run. Last minute changes cannot be made, except by creating and installing a new setup file but is not recommended.

Doc. #0312A

LAWRENCE BERKELEY LABORATORY
ADMINISTRATIVE MEMO

POLICY AND PROCEDURE

27 October 1978 Volume IV - No. 25

PROTECTION OF HUMAN SUBJECTS

This is to call to the attention of all investigators the Policy Statement on Protection of Human Subjects, Volume II - No. 4, issued 26 April 1976, and to remind everyone that safeguarding the welfare, privacy and rights of persons taking part in any research project is of paramount concern. Any project at LBL, whether DOE or other source, which will in any way involve human subjects (including the use of questionnaires) must be reviewed for determination of risk and for approval. Determination of risk is not to be made by the investigator; it is made by the Campus Committee for Protection of Human Subjects upon submission by the LBL Human Use Committee, and approval is to be obtained prior to initiation of research. In addition, all such projects must be reviewed at least annually.

It is the responsibility of investigators to comply with the LBL procedure in a timely fashion. Copies of the "Procedure for Securing Approval of Projects Involving Human Subjects" were distributed to Division Administrators in August 1978, and the procedure is also included in the "Contract & Grant Manual", revised in August 1978, since most projects involving human subjects are funded by the National Institutes of Health. Copies may be obtained from the Contract and Grant Office, Building 50A, Room 4119, Extension 5131. Questions may be directed to the appropriate Division Administrator or the Contract and Grant Office or the LBL Human Use Committee, Donner Laboratory, Room 468.

Your explicit attention and cooperation will be appreciated.

Mark Owens, Jr.
Deputy Division Head
Administration Division

MO:jer

LAWRENCE BERKELEY LABORATORY

PROCEDURE FOR SECURING APPROVAL

OF

PROJECTS INVOLVING HUMAN SUBJECTS

No research activity involving human subjects may be undertaken unless our official institutional review board, the Berkeley Campus Committee for Protection of Human Subjects (CPHS) has (a) determined that no human subjects are at risk or (b) reviewed and approved the activity if human subjects are found to be at risk. In any case, the project is not to be conducted until certification has been made to the funding agency within the prescribed time limits. Reference should be made to the Policy Statement on protection of human subjects, issued 26 April 1976 (copy attached). The LBL Advisory Committee, now designated LBL Human Use Committee, makes all submissions for LBL to the Campus Committee for Protection of Human Subjects.

On 30 November 1976, DOE, then ERDA, adopted final regulations for the protection of human subjects which are essentially the same as the DHEW regulations. With the cooperation of the Berkeley Campus, LBL had already been in compliance with DHEW policy. When the arrangement with the Berkeley Campus was formalized, DHEW approved the LBL Assurance of Compliance in August 1977. A formal amendment has now been made to the DOE regulations so that DOE will accept the DHEW Assurance as evidence of compliance with DOE policy.

The following procedure shall be followed to request approval for use of human subjects in a research project:

I. In accordance with the attached Berkeley Campus Guidelines, dated 10 March 1978, the protocol with consent form as appropriate is to be submitted to LBL Associate Director for Administration who will forward the protocol to the LBL Human Use Committee. (Investigators in the Biology and Medicine Division may submit their protocols directly to the LBL Human Use Committee, and the latter will keep the Associate Director for Administration advised of actions.)

II. In order to meet due dates, the protocol should reach the LBL Human Use Committee six weeks before the scheduled meeting date of CPHS. Advice of approval (certification form, HEW 596) is usually issued one week after the CPHS meeting. Certifications are due at the Agency (NIH, DOE) as follows:

   A. For NIH, within 60 days of submission of the proposal.

   B. For DOE projects, within 60 days of the submission of Budget Form 189 for the ensuing year; e.g., for the 189's to be

submitted 1 April 1979 for Budget Year 1981, the certification for a project to be conducted in FY 1980 should reach DOE before 1 June 1979.

C. For projects to be supported by other agencies, investigators should allow an appropriate time and verify due dates with the LBL Contract and Grant Office.

D. Human Subject protocols for active projects must be recertified annually, and it is the responsibility of the principal investigator to submit a progress report and the protocol for the ensuing year for review at the appropriate time to the LBL Human Use Committee.

III. In all cases, the original (signed by the principal investigator and the appropriate research division Associate Director, as Responsible Administrator) and seventeen (17) copies of the complete protocol, and two (2) copies of the proposal or DOE Form 189 should be submitted to the LBL Human Use Committee (via the Associate Director for Administration for all divisions except Biology and Medicine); however, six (6) copies of the proposal or Form 189 are needed when the project requires medical review. The LBL Committee retains one copy.

The LBL Human Use Committee meets as needed, and the investigator may attend the meeting at which his/her protocol is reviewed. The Executive Officer of the Human Use Committee may be contacted at Donner Laboratory, Room 459, extension 5507, for information on meetings and protocols.

IV. The CPHS will submit appropriate certification to the Agency with a copy to the LBL Human Use Committee. The CPHS will notify the principal investigator by letter of the approval/certification and of the expiration date of the approval, with copies to the responsible administrator and the LBL Committee. The LBL Committee will send copies of the certificate and approval letter to the Associate Director for Administration.

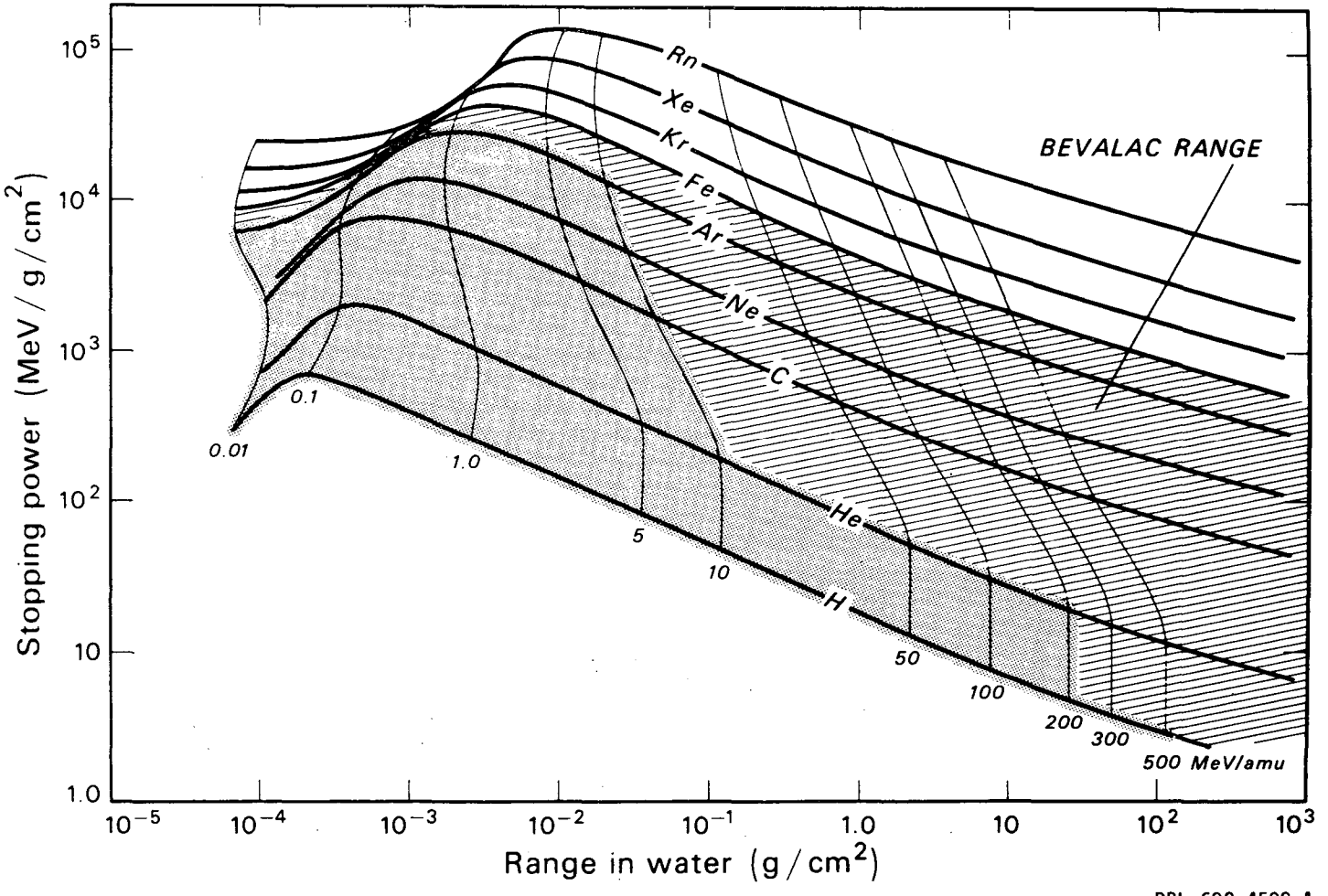
The LBL Human Use Committee has the responsibility of maintaining the complete file of protocols and certifications in accordance with the regulations of DHEW and DOE and of keeping the Associate Director for Administration advised of actions.

V. Special conditions are (but not limited to) the following; request for determination of a special condition should be addressed to the LBL Human Use Committee, allowing for the time frame in paragraph II.

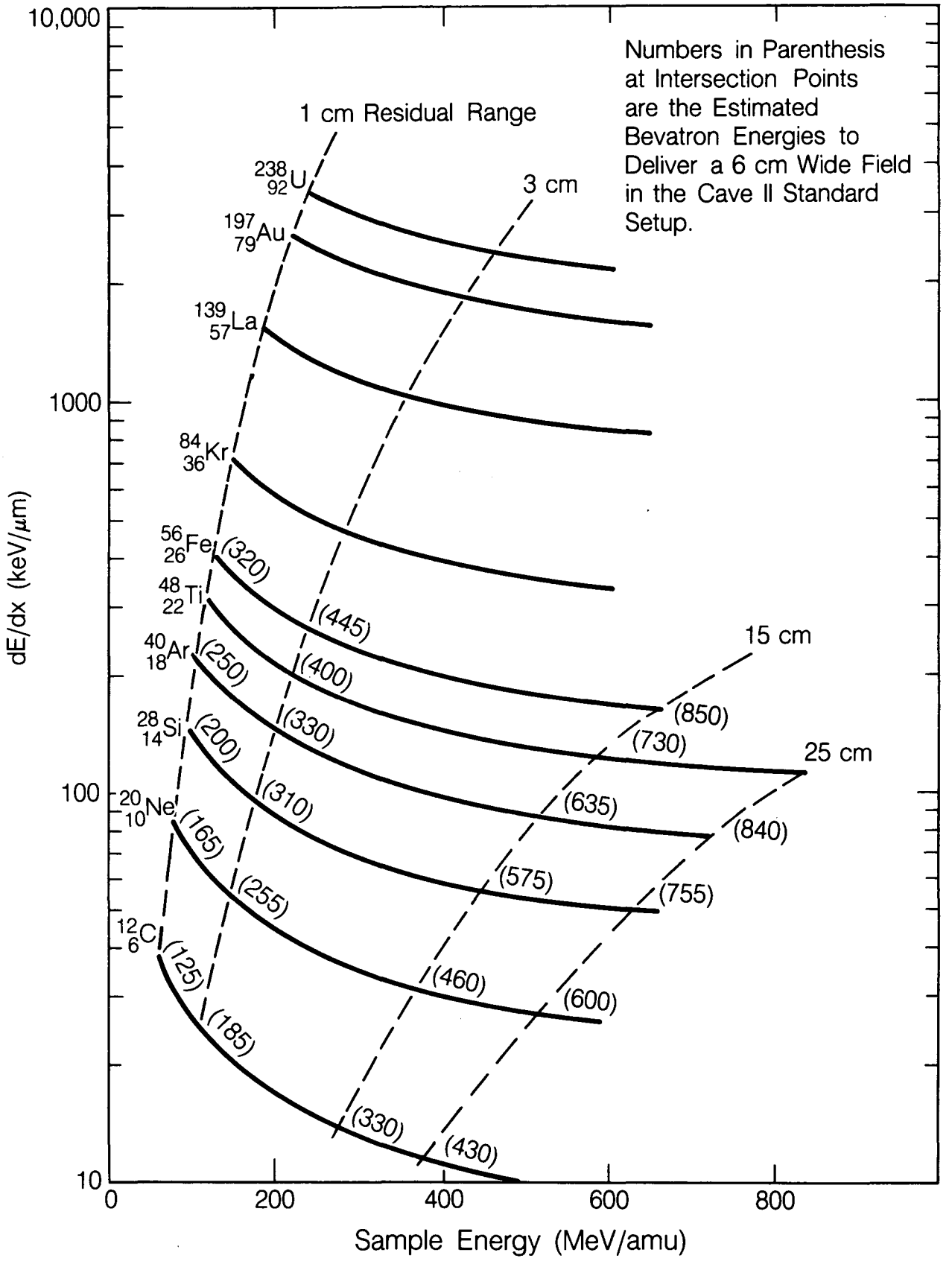
A. Where the precise involvement of human subjects cannot be delineated due to pending investigations of developments, an explicit statement must be given the LBL Human Use Committee. For example, NIH training grants may be in this category. Conditional certification may be made in such cases.

B. Collaborative projects require the approval of a responsible committee of the collaborating institutions, and this document must be appended to the LBL investigator's protocol. A project in which control of the subjects is shared by LBL with another institution or in which control of the subjects rests with one institution and analysis of fluids, tissues, etc., is carried out at the other is a collaborative project.

C. Projects which may involve use of radioactive drugs and/or Investigative New Drugs will require special approvals. The LBL Human Use Committee should be consulted before writing such a proposal. The investigator will be responsible for furnishing appropriate documents to the Committee.



DBL 682-4598 A


Numbers in Parenthesis at Intersection Points are the Estimated Bevatron Energies to Deliver a 6 cm Wide Field in the Cave II Standard Setup.
1 cm Residual Range
3 cm
15 cm
25 cm
238 92 U
197 79 Au
139 57 La
84 36 Kr
56 26 Fe
48 22 Ti
40 18 Ar
28 14 Si
20 10 Ne
12 6 C
(320)
(445)
(250)
(400)
(850)
(200)
(330)
(730)
(165)
(310)
(635)
(840)
(125)
(255)
(575)
(755)
(460)
(600)
(185)
(330)
(430)
10,000
1000
100
10
0
200
400
600
800
dE/dx (keV/μm)
Sample Energy (MeV/amu)

XBL 848-8609

TABLES OF RANGE, ENERGY, AND STOPPING POWER
(Actual energy, not accelerated Bevatron energy)

	ION ENERGY MeV/amu	RANGE cm water	STOPPING POWER keV/micrometer
CARBON	100	2.58	26.3
	125	3.81	22.0
	150	5.25	19.3
	175	6.87	17.4
	200	8.66	16.0
	220	10.20	15.1
	240	11.83	14.3
	260	13.55	13.7
	280	15.35	13.1
	300	17.23	12.6
	320	19.00	12.2
	340	21.00	11.91
	360	23.08	11.53
	380	25.20	11.27
	400	27.39	10.95
	420	29.63	10.74
	440	31.92	10.45
	460	34.26	10.29
	480	36.65	10.13
	500	39.07	9.89
	525	42.17	9.77
	550	45.32	9.62
	575	48.53	9.49
	600	51.79	9.27
NEON	100	1.54	73.2
	125	2.29	61.0
	150	3.15	53.8
	175	4.12	48.4
	200	5.19	44.4
	220	6.12	41.8
	240	7.10	39.8
	260	8.13	37.8
	280	9.21	36.4
	300	10.34	35.0
	320	11.40	34.0
	340	12.61	33.0
	360	13.85	32.0
	380	15.12	31.2
	400	16.43	30.4
	420	17.78	29.8
	440	19.15	29.2
	460	20.56	28.6
	480	22.00	28.2
	500	23.44	27.6

ION	ENERGY MeV/amu	RANGE cm water	STOPPING POWER keV/micrometer
	520	24.93	27.4
	540	26.43	27.0
	560	27.96	26.6
	580	29.51	26.2
	600	31.08	26.0
	625	33.06	25.8
	650	25.08	25.2
	675	37.1	25.0
	700	39.19	24.6
SILICON	100	1.10	143.4
	125	1.64	119.6
	150	2.25	105.3
	175	2.95	94.9
	200	3.71	87.1
	220	4.37	82.0
	240	5.07	77.80
	260	5.81	74.2
	280	6.58	71.1
	300	7.38	68.6
	320	8.15	66.6
	340	9.00	64.7
	360	9.89	63.0
	380	10.80	61.3
	400	11.74	59.6
	420	12.70	58.5
	440	13.68	57.1
	460	14.68	56.0
	480	15.71	55.2
	500	16.75	54.0
	520	17.80	53.5
	540	18.88	52.6
	560	19.97	52.1
	580	21.08	51.5
	600	22.20	50.7
	620	23.33	50.1
	640	24.48	49.6
	660	25.64	49.3
	680	26.81	48.7
	700	27.99	48.2
	725	29.37	47.9
	750	30.87	47.3
	775	32.39	47.0
	800	33.93	46.8
ARGON	100	0.95	236.8
	125	1.41	197.6
	150	1.95	174.0
	175	2.55	156.8
	200	3.21	144.0

ION ENERGY MeV/amu	RANGE cm water	STOPPING POWER keV/micrometer
225	3.92	133.6
250	4.69	125.6
275	5.51	118.8
300	6.38	113.2
320	7.04	110.4
340	7.78	107.2
360	8.55	104.0
380	9.34	101.2
400	10.14	98.8
420	10.97	96.4
440	11.82	94.4
460	12.69	92.8
480	13.57	91.2
500	14.47	89.6
520	15.39	88.4
540	16.32	87.2
560	17.26	86.0
580	18.21	84.8

TABLES OF NOMINAL LEAD ABSORBER THICKNESS vs ACTUAL MEASURED WATER EQUIVALENT THICKNESS

NOMINAL THICKNESS IN INCHES	ACTUAL WATER EQUIVALENT IN CM
CAVE I:	
1/64	0.26
2/64	0.52
4/64	1.06
8/64	1.94
16/64	3.92
CAVE II:	
1/64	0.31
2/64	0.54
4/64	1.10
8/64	2.14
16/64	4.18

MATERIAL IN BEAM LINE TO CAVES I AND II

AREA OR OBJECT	MATERIAL	THICKNESS INCHES	WATER EQUIV CUMUL. CM
BEVATRON EXIT WINDOW	Aluminum	0.020	0.108
F1 AREA			
SEM	Aluminum	0.00425	0.131
Plastic scintillator	Plastic	0.039	0.231
Scintillator box alum. foils	Aluminum	0.003	0.247
Wire chamber	Aluminum	0.010	0.301
	Gas	1.50	0.306
B0WC1 AREA			
Wire Chamber	Aluminum	0.010	0.360
(common to Cave I and II beam lines up to this point)	Gas	1.50	0.365
CAVE I BEAMLINE			
Exit window	Kapton	0.010	0.398
SEM	Aluminum	0.0453	0.643
B1WC1 wire chamber	Mylar (+gas) (water equiv.)	0.0197	0.693
Ion chamber 1	Kapton	0.005	0.710
Air path - IC1 to IC2	Air	129.00	1.080
Ion chamber 2	Kapton	0.005	1.097
Water column windows	Lucite	0.499	2.580
Air path - IC2 to IC3	Air	31.00	2.669
Ion chamber 3	Kapton	0.005	2.686
Air path to isocenter	Air	91.00	2.947
CAVE II BEAMLINE			0.365
B2WC1 AREA			
Wire chamber (retractable)	Aluminum	0.010	0.419
	Gas	1.50	0.424
CAVE II AREA			
Exit window	Mylar	0.010	0.457
Air path to first bench	Air	84.0	0.698
Ion chamber 1	Kapton	0.005	0.715
B2WC2 wire chamber	Mylar (+gas) (water equiv.)	0.0197	0.765
SEM	Aluminum (water equiv.)	0.0984	1.015
Air path to second bench	Air	160.0	1.474
Ion chamber 2	Kapton	0.005	1.491
Water column windows	Lucite	0.500	2.977
Ion chamber 3	Kapton	0.005	2.994
Air path to standard position	Air	40.00	3.109

APPENDIX E: COMPUTER OUTPUT

BRAGG CURVE PROCEDURE

EXPLANATION OF IONIZATION VS WATER ABSORBER SETTING DATA

The normal dialogue to obtain a BRAGG curve is shown on the next few pages and represents what the operator will see on the console.

The numerical data on the screen is described as follows:

COL. 1 Sequence number of point taken. Only 100 are allowed.

COL. 2 - Water absorber setting in cm. Currently, an initial curve is taken at 0.5-cm steps, and areas of specific interest (such as rapidly changing readings around the Bragg peak) are then filled in with smaller steps, 0.1 or 0.01 cm, for example.

COL. 3 - Ring 1. Relative ionization chamber readings. These numbers are the ratios of the readings from the 1-cm area of the downstream ion chamber divided by the reading from entire area of the upstream chamber, normalized to the first reading taken (normally 0 cm water absorber setting).

COL. 4 - Ring 1-7. Similar to Col. 2, but with the downstream chamber readings taken from the entire 17-cm area.

COL. 5 - EGG/ALL. Relative ionization on egg chamber compared to all rings upstream.

COL. 6 - SEM/IC2-R2. Reading on the secondary emission monitor compared to ring 2 on backup chamber.

BRAGG ROUTINE DIALOGUE

```
>;
>; I UNDERSTAND COMMANDS OF ONLY ONE LETTER.
>; THE COMMANDS ASSOCIATED WITH EACH LETTER ARE:
>; A
>; B    ***** BRAGG CURVE
>; C    ***** CALIBRATIONS
>; D    ***** DISPLAY
>; E    ***** EXIT
>; F    ***** FILE NAME CHANGE
>; G    ***** GO DO ONE EXPOSURE
>; H    ***** HELP
>; I    ***** ION CHAMBER CHANGE
>; J
>; K
>; L    ***** LOW LEVEL BEAM SPOT
>; M    ***** MULTIPLE EXPOSURES USING SAMPLE POSITIONER
>; N    ***** NOTES ON HOW TO RUN THE SYSTEM BY USERS
>; O    ***** OPERATOR CHANGE
>; P    ***** PRACTICE CHANGE
>; Q    ***** 'QUIPMENT TESTS
>; R    ***** RADIOTHERAPY EXPOSURE
>; S    ***** SET UP AN EXPERIMENT
>; T    ***** TUNE THE BEAM ON THE BENCH
>; U    ***** DYNAMIC-PANGE-SHIFTING EXPOSURES
>; V    ***** VOLTAGE PLATEAU
>; W    ***** SINGLE TARGET, MULTIPLE WOBBLER SETTINGS
>; X
>; Y    ***** HOW TO GET BIOLOGY DATA SHEETS OUT
>; Z
>;
>* ENTER YOUR NEXT "SUPER" COMMAND: [S]: B
>;
>; ***** B: BRAGG CURVE
>;
>* DAILY-CHECK-OF-DOSIMETRY. [Y/N]:N
>* AUTOMATIC BRAGG CURVE WITH THE WATER COLUMN. [Y/N]:N
>* MANUAL BRAGG CURVE WITH THE WATER COLUMN. [Y/N]:Y
>BRM BB
```

```
SLOW CUTOFF ON THE MONITOR CHAMBER IS SET AT : 60.00  RADS

ENTER DESIRED CUTOFF OF MONITOR CHAMBER (<CR> FOR CURRENT VALUE) : 60

PLEASE ENTER A LINE OF DESCRIPTION (80 CHARACTERS OR LESS)  :

RANGE CHECK

PRESS <RETURN> WHEN READY TO PULL THE BEAM PLUG (CTRL-Z TO EXIT)

    THIS BRAGG ROUTINE FOUND THERE IS NO SPIRAL RIDGE FILTER
    ON THE BENCH, INDICATING A SINGLE BRAGG PEAK.

    THE ESTIMATED PEAK IS LOCATED AT 30.87 CM

DO YOU WISH TO TERMINATE THIS BRAGG PROCEDURE (Y/N) . N

BEGINNING WATER EQUIVALENT POINT IS (CM): 0

ENDING WATER EQUIVALENT POINT IS (CM) : 35

STEP SIZE IS (CM) : .5
```

		RING 1	RING-7	EGG/ALL	SEM/IC2-R2
1)	0.500	0.987	0.989	0.000	0.997
2)	1.000	0.976	0.977	0.000	1.000
3)	1.500	0.962	0.966	0.000	1.002
4)	2.000	0.950	0.955	0.000	1.001
5)	2.500	0.944	0.944	0.000	0.998

```
THE BEAM HAS BEEN SWITCHED TO CAVE I TO TREAT A PATIENT, THE TREATMENT
SHOULD BE FINISHED IN ABOUT THREE MINUTES.

THIS PROCEDURE IS NOW WAITING FOR THE PATIENT TREATMENT TO FINISH


PRESS <RETURN> TO RESUME THIS PROCEDURE :
```

6)	3.000	0.919	0.919	0.000	0.993
7)	3.500	0.908	0.909	0.000	1.001
8)	4.000	0.904	0.908	0.000	1.000
9)	4.500	0.882	0.878	0.000	0.996
10)	5.000	0.875	0.875	0.000	0.996
11)	5.500	0.862	0.867	0.000	0.997

```
(The crash off button was pressed to suspend the procedure)

DO YOU WISH TO TERMINATE THIS PROCEDURE (Y/N)   N
```

PRESS <RETURN> TO RESUME THIS PROCEDURE :

55)	27.500	0.694	0.736	0.000	0.994
56)	28.000	0.700	0.752	0.000	0.998
57)	28.500	0.715	0.746	0.000	0.999
58)	29.000	0.741	0.768	0.000	0.997
59)	29.500	0.762	0.787	0.000	0.999
60)	30.000	0.801	0.826	0.000	1.001
61)	30.500	0.844	0.863	0.000	1.000
62)	31.000	0.913	0.930	0.000	0.995
63)	31.500	1.031	1.045	0.000	0.994
64)	32.000	1.560	1.511	0.000	0.995
65)	32.500	0.458	0.502	0.000	0.996
66)	33.000	0.431	0.474	0.000	0.999
67)	33.500	0.412	0.452	0.000	0.998
68)	34.000	0.387	0.429	0.000	0.997
69)	34.500	0.369	0.413	0.000	0.998
70)	35.000	0.350	0.395	0.000	1.003

WOULD YOU LIKE TO SPECIFY MORE SETTINGS (Y/N) . Y

BEGINNING WATER EQUIVALENT POINT IS (CM) : 31.5

ENDING WATER EQUIVALENT POINT IS (CM) : 32.5

STEP SIZE IS (CM) : .1

		RING 1	RING-7	EGG/ALL	SEM/IC2-R2
71)	31.500	1.029	1.034	0.000	0.999
72)	31.600	1.065	1.067	0.000	0.999
73)	31.700	1.115	1.114	0.000	0.998
74)	31.800	1.207	1.194	0.000	0.998
75)	31.900	1.326	1.300	0.000	1.001
76)	32.000	1.577	1.530	0.000	0.996
77)	32.100	1.687	1.653	0.000	1.001
78)	32.200	1.315	1.293	0.000	1.000
79)	32.300	0.672	0.700	0.000	1.000
80)	32.400	0.479	0.521	0.000	0.999
81)	32.500	0.460	0.501	0.000	1.002

```
WOULD YOU LIKE TO SPECIFY MORE SETTINGS (Y/N) . Y

BEGINNING WATER EQUIVALENT POINT IS (CM) : 32.0

ENDING WATER EQUIVALENT POINT IS (CM) : 32.2

STEP SIZE IS (CM) : .05

                                RING 1    RING-7     EGG/ALL    SEM/IC2-R2

82)       32.000     1.507      1.460     0.000      0.995
83)       32.050     1.639      1.584     0.000      1.001
84)       32.100     1.596      1.580     0.000      0.973
85)       32.150     1.599      1.550     0.000      0.996
86)       32.200     1.351      1.328     0.000      1.002

WOULD YOU LIKE TO SPECIFY MORE SETTINGS (Y/N) . N

DO YOU WANT TO ABORT PLOTS AND PRINTS (Y/N) . N

>;
>;
>;  <<<<<END OF BRAGG>>>>>
>;
>* ENTER YOUR NEXT "SUPER" COMMAND: [S]:
```

SAMPLE DATA SHEET

FILE NAME:LF:[225,201]454F600A.DAT;2

INVESTIGATOR: AINSWORTH OPERATOR: AINSWORTH 454F600A.DAT
AVISHAI 14:51:48 15-JUN-84 Z=36 A=56 E/AMU=600

SAMPLE NAME..... 1 OF 6 ..... DDD_ _

DESIRED FAST CUTOFF.....	22.00 RADS	
DOSE (IC.3.RA.1)	22.00 RADS	
WATER COLUMN LENGTH.....	0.00 EM	
DOSE RATE (RAD/MIN).....	112.50	
TIME-OF-DAY	14.51:48	
ELAPSED TIME (MIN)	0.20	
BEAM PULSES	4	
AVE PARTICLES/PULSE (AT IC1)	3.825E+07	
PARTICLES /CM**2 (AT IC3 RING 1)	7.278E+05	
IC1RA1/IC3RA1	7.41	
EGG DOSE/IC1RA1	0.000E-01	
EGG DOSE/IC3RA1	0.000E-01	
BEAM/BACKGROUND RATIO	1.12	
LEAD FOIL THICKNESS	0/64 CM	
TOP/BOTTOM BALANCE	0.00	0.00
EAST/WEST BALANCE	-0.01	0.00
SIGMA	2.30	2.29
DZERO	138.43	44.79
GOODNESS-OF-FIT	0.99	0.86

SAMPLE SET UP SHEET

```
BB.ID.01.AS.005  100N670S                    ;EXPERIMENT I.D.
BB.ID.01.AS.003  HOWARD                      ;INVESTIGATOR's NAME
BB.ID.01.AS.006  STANDARD SETUP              ;DESCRIPTION OF EXPERIMENT
BB.ID.01.AS.001  NEON                        ;HEAVY ION NAME
BB.XW.01.NM.001    10.000                    ;ATOMIC NUMBER OF ION (Z)
BB.XW.01.NM.005    20.000                    ;MASS OF ION (A)
BB.XW.01.NM.003   670.000          MEV       ;E/AMU IN BEVATRON
B2.SS.01.DX.002     8.000          64'S      ;REQUESTED LEAD
BB.IC.01.AS.001  MAGENT                      ;COLOR OF MONITOR CHAMBER
BB.IC.02.AS.001  YELLOW                      ;COLOR OF BACKUP CHAMBER
BB.IC.03.AS.001  YELLOW                      ;COLOR OF DOSE CHAMBER
BB.IC.04.AS.001  FW 327-ATG                  ;EGG CHAMBER SERIAL NUMBER
BB.ID.01.DX.001    60.000           MM       ;MAXIMUM SAMPLE DIAMETER
BB.CL.01.BL.001     2.000           CM       ;MON IC COL
BB.IC.01.BL.001     7.000           CM       ;MONITOR CHAMBER BENCH LOCATN
BB.MC.01.BL.001    22.000           CM       ;WIRE CHAMBER BENCH LOCATION
BB.CL.03.BL.001   436.000           CM       ;DOSE IC COL
BB.IC.02.BL.001   446.000           CM       ;BACKUP IC BENCH LOCATION
BB.WC.01.BL.001   455.000           CM       ;WATER COLUMN No. 1 BENCH LOCAT
BB.IC.03.BL.001   505.000           CM       ;DOSE IC BENCH LOCATION
BB.ST.01.BL.001   527.000           CM       ;SAMPLE HOLDER BENCH LOCATION
BB.ST.01.DX.006   770.000           .1MM     ;SMPL TRNSLTR Y-POSITN INITIA
BB.ST.01.DX.005  1290.000           .1MM     ;SMPL TRNSLTR X-POSITN INITIA
```