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Lincoln Accelerator Laboratory

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MASSACHUSETTS INSTITUTE OF TECHNOLOGY

LINCOLN LABORATORY

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Group 63

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ABSTRACT

A complete technical description of the Lincoln Accelerator Laboratory is given. The primary purpose of the laboratory is to conduct radiation-effects studies for space vehicles and components. Particle fluxes up to 68 inches in diameter are provided in a solar-vacuum chamber. These can be either monochromatic electrons at any energy from 300 kev to 4 Mev; electrons distributed in a Van Allen energy spectrum from 40 kev to 4 Mev, or monochromatic protons at any energy from 50 kev to 4 Mev.

The general-purpose capabilities of the laboratory are described, equipment listed, and information concerning the facilities is given to enable the investigator to design his experiment for greatest convenience and compatibility.

Accepted for the Air Force
Franklin C. Hudson
Chief, Lincoln Laboratory Office

LINCOLN ACCELERATOR LABORATORY

INTRODUCTION

An accelerator facility having several unique capabilities is in operation at Lincoln Laboratory. Its primary function is to provide sources of electrons and protons at energies corresponding to those in the trapped-particle zones surrounding the earth. The facility's particle sources are electrostatic accelerators covering the energy range: 50 kev to 4 Mev. The design emphasis has been directed toward the simulation of satellite environment and the analysis of radiation effects on the materials and devices proposed for employment in satellites.

An electrostatic accelerator, however, is a very versatile tool; certainly the most versatile of all accelerators. This, coupled with the fact that Lincoln Laboratory's program of studies covers a wide range of disciplines, made it desirable to provide a general-purpose laboratory which experimenters in other fields could use conveniently and quickly.

I. DESCRIPTION OF FACILITIES

A. General

Accelerators have largely been designed by and for nuclear physicists whose experimental needs are best met by an intense, small diameter beam of particles at a single energy. When studies of the consequences of the earth's magnetically trapped particles began, experimentalists modified standard accelerator beams by a first-order expediency, viz. area scanning of the sort that takes place in a cathode ray tube. This was clearly necessary when an entire flight article was to be exposed; it is just as necessary in the study of individual devices since such articles must be irradiated in large arrays in order to obtain statistically meaningful results. The raster scanning of an intense beam over such an array may look all right mathematically, but it is extremely unsatisfactory physically. The short, intense bursts to which test objects are exposed do not relate well to the constant low-intensity flux of particles in the Van Allen belts.

This aspect of the problem - the need to obtain uniform, continuous, large area fluxes of electrons and protons - has been solved in the present facility by means of a rather elaborate beam-handling system that employs six magnetic lenses and four sections of axial magnetic field to spread mono-energetic particles over areas up to 160 centimeters in diameter.

There is yet another serious problem that has tended to make laboratory data relatively useless as a predictive factor, or even as a guide, in the design of long-lived satellite electronics. The trapped particles incident on a satellite have energies distributed over a range of several orders of magnitude. In the lowest part of the energy range, the particles generate ionization in the devices; in the upper part they create lattice defects in the material as well as ionization. Over the range there is tremendous variation in the site of deposition of ionizing energy; the mechanism of ionization; the immediate and long-term effects on devices of the ionization; the effects of geometrical, chemical and mechanical design of the devices; and the effects of various operating modes of the devices and their subsequent deterioration. In spite of all this, the present universally practiced method of testing and reporting on the radiation response of devices and materials is exposure to an arbitrarily chosen single-energy flux of particles -- and raster scanned at that. It is one of the major purposes of the LAL to bring this most unsatisfactory state of affairs to an end. By judicious use of scattering and absorption in tantalum plates and cones, any desired spectrum of particles can be generated from a monochromatic beam. The radiation response of a device or a circuit can then be measured at any given degree of hardness of the exposure spectrum; the naturally-occuring range of spectra is reasonably limited. It will be necessary to define the most widely applicable ground rules before comparative measurements can be standardized, but the results will be well worth the effort. It is, of course, clear that physical analysis of the mechanisms involved will require point-by-point exposure to monochromatic fluxes at various energies within the spectral range.

Whenever solar cells or complete satellites are being studied, a close simulation of solar spectrum and intensity is necessary -- concurrent with the particle flux. This is provided by means of a 30-kilowatt xenon solar source as described in Section C-3 below. Correct thermal equilibrium is achieved by means of the liquid-nitrogen cold shroud lining the interior of the 78-inch environmental chamber.

B. Beam-Handling Equipment

In what follows it will be useful to refer to the general laboratory floor plan in Figure 1 for the relative placement of equipment.

A particle beam exiting from the K-4000 accelerator is 42 3/4 inches (108.6 cm) above the floor. Taking its forward direction as "zero degrees" it is seen that the switching magnet can direct the beam to the left by 0°, 33°, 45°, 66° or 90°. Semi-permanent installations are seen along the 45° and 0° axes; these are the environmental chambers and the air-scattering facility, described below in Sections C and D, respectively.

Three dual quadrupoles can be seen in Figure 1: one in the 0° leg ahead of the switching magnet, and two others in the 45° leg ahead of the vacuum chambers. The two sets in the 45° leg set the foci and angles of divergence of the vertical and horizontal components of the beam as it enters the chambers. The exposure area can be made any desired size and shape for electrons; at the higher proton energies the maximum dimension is 160 cm. in the 78-inch chamber.

The dual quad in the 0° leg diverges the beam in both vertical and horizontal so that it fills the aperture of the first quad in the 45° leg. It does this while placing a crossover (compression) point at the center of curvature of the switching magnet in order to avoid excessive interception.

When low-energy electron beams are focussed in this manner the required magnetic field gradients are quite small. In order to avoid instability and non-uniformity due to stray fields and quadrupole assymetry, a solenoidal field is employed along the vacuum pipe and through the first two sets of quadrupoles. This results in Brillouin focussing which is adjusted to a strength sufficient to swamp stray fields while permitting the quadrupoles to affect the beam but at substantially higher field strengths.

The switching magnet also serves as an analyzing magnet. When positive ions are produced in the terminal of an electrostatic accelerator, many unwanted species are extracted as well. The desired ion is then selected by means of the magnet.

C. Environmental Chambers

Plan and elevation views of the vacuum chambers are shown in Figures 2 and 3. The first chamber has an outside diameter of 48 inches; the second, 78 inches. When complete satellites or test objects whose maximum dimension exceeds 36 inches are irradiated, the 78-inch chamber is used. This chamber is on pneumatic tires and is rolled out of the vault into the exterior laboratory area where experiments are mounted in it. This permits operation of the accelerator for other experiments during large-chamber set-up time (which is usually lengthy).

The large chamber will shortly be fitted with a spin-and-attitude mount as described in Section III-E. Together with the xenon solar source (III-G) and the cold shroud (III-E), the 78-inch chamber provides a reasonable close simulation of the thermal-vacuum environment in earth orbit. Particle fluxes of electrons or protons can be distributed in energy as indicated in Section II or they can be provided as uniform and monochromatic over the energy ranges given in Section II.

The 48-inch chamber is employed alone whenever the cold shroud and/or volume of the 78-inch chamber are not required. Large experiments are mounted on the threaded posts indicated by the number 14, in Figure 2. Experiments up to about 15 inches in diameter are mounted on the portable end - dome shown in place in Figure 4 and indicated in more detail in Figures 5 and 6. Two domes and several detachable 16- inch mounting flanges are available. Common practice is to send an experimenter either a dolly-mounted dome or a flange; he then mounts his own experiment, providing any required electrical feed-thrus on the flange. When his experiment is scheduled it is less than an hour's job to "button it on" and hook it up to his instrumentation located in the "data area" indicated in Figure 1. As time goes on many different flange configurations will accumulate and it should become unnecessary to fabricate one for each experiment. A 10-inch square array providing 100 four-contact TO-5 transistor sockets is under construction.

The size, shape and uniformity of the beam is measured by lowering a 24-inch square scintillating screen (Ag-activated CdS) into the center of the chamber. The screen is viewed by closed-circuit television through one of the quartz ports on the input dome and is provided with grid lines to facilitate dimensioning. The size of the beam at any other plane in the chamber(s) is then known from geometrical considerations. Dosimetry and spectrometry are done with faraday cups, solid state and scintillation detectors in the normal way.

When adjustments or repairs require access to the experiment in the chambers, they can be brought up to atmospheric pressure and pumped back down to 10^{-6} torr in less than 40 minutes. Ultimate vacuum is 2×10^{-7} torr. A mass spectrometric vacuum analyzer is permanently attached to the chamber for identification and quantitative measurement of outgassing constituents or virtual leaks in test objects. Its specifications are given in Section IV-A-12.

D. Air-Scattering Facility

Whenever experiments can be done at atmospheric pressure it is very convenient because access to them is promptly available without a vacuum-cycling delay. An "air-scattering facility" is provided for such experiments.

Electrons are brought out of the vacuum system through a 2-mil titanium window into an exclosure 36 inches square by 9 feet deep. It is necessary to enshroud the facility in order to contain the electrons injected into it because free electrons would rapidly degrade organic materials in the vault and also might constitute a health hazard.

The facility appears on the 0° leg in Figure 1; as an artist's sketch in Figure 8, and to the right in the general photograph in Figure 9.

After passing through the titanium foil, the beam gradually increases in diameter due to a combination of foil scattering and multiple scattering in the air. For example, a half-inch beam at 1.5 Mev expands to nine inches after about 12 inches travel. The diameter is inversely proportional to energy and directly proportional to distance from the window. Accurate beam profiles throughout the usable energy range will be sent to all holders of this report when mapping has been completed.

Experiments are mounted on carts with 3/8-inch aluminum table tops, 36 inches wide by 24 inches deep. When an experimenter wishes to use the air-scattering facility, a spare cart is sent to his laboratory where mechanical and electrical arrangements can be made and tested. When all is ready he rolls the cart down to LAL and into any one of four positions in the facility. This is, of course, intended to reduce accelerator down time to a minimum.

When a spectrum is desired, foil scattering can be used to provide it. An interesting feature of such an arrangement is that the spectrum becomes harder the greater the distance from the window. To avoid contamination of the spectrum at the experimental planes by back-scattered particles from the end closure plate, a canted section of aluminum honeycomb is mounted on the last cart to serve as an absorber.

A glass port in the input face of the enclosure permits television viewing of scintillating screens or experimental phenomena.

E. Experimental Areas

The 0° target area can be cleared almost as far as the south wall by disassembling the air-scattering facility and retracting it along an overhead conveyor. This area affords the shortest-length cabling to external instrumentation through the maze shown going under the west wall at that point. It is available, therefore, when this is an important consideration.

Energy-stabilizing equipment is attached to the 33° port when protons are being used along the 45° axis; the 66° port serves this purpose when protons are brought out at 90°. These ports can be used for small experiments, however, when other ions are needed at those angles.

It can be seen in Figure 1 that a generous area is available for experiments on the 90° axis. This area is the most accessible for large equipment since the access from the 8 x 8 foot shield door in the north wall is unimpeded.

Roughing and holding vacuum manifolds (10^{-3} torr) extend throughout the experimental area, as well as water cooling (44°F) and various other mechanical and electrical facilities as specified in Section IV.

II. SUMMARY OF CAPABILITIES

There are two configurations in which the basic accelerator (KN/S-4000) may be operated. One is exclusively for electron acceleration and is called the "negative configuration"; the other provides either full positive-ion or partial electron capability and is called the "convertible configuration". It takes from 2 to 4 days and complete disassembly of the accelerator to change from one configuration to another. When in "convertible configuration" it takes a few minutes to convert from positive-ion operation to limited electron operation.

A. Routine Capabilities in Negative Configuration

Those capabilities that are available with less than one hour setup time are:

1. Electrons in Vacuum

(a) Monochromatic beam energy
(300 kev)* - 4 mev ± 2 kev

(b) Monochromatic beam flux - maximum

$$\frac{8 \cdot 10^{15}}{D^2} \quad \text{electrons/sec/cm}^2$$

*Numbers appearing in parentheses are subject to change as improvements are made.

where D is the diameter of exposure area in cm and
$1 \leq D \leq 165$ cm.

(c) Monochromatic beam flux - minimum

$$\frac{(10^{10})}{D^2} \text{ electrons/sec/cm}^2$$

(d) "Spectral beam" range of exponent

Equipment is being developed to provide electron fluxes over the entire chamber area as follows:

$$\begin{aligned} \text{integral flux} &= (5 \cdot 10^6)\,E^{-3/2} \text{ electron/sec/cm}^2 \\ &= (5 \cdot 10^7)\,E^{-1} \text{ electron/sec/cm}^2 \\ &= (5 \cdot 10^8)\,E^{-1/2} \text{ electron/sec/cm}^2 \end{aligned}$$

where flux is for all electrons with energy > E,
E is given in Mev,
and ($10 \text{ kv} \leq E \leq 4$ Mev)

(e) "Spectral beam" flux

The maximum flux is given above. Minimum controllable flux can be made (six) orders of magnitude less than maximum.

2. Electrons in Air

(a) Monochromatic beam energy
(300 kev) - 4 Mev ± 25 kev (spread)

(b) Monochromatic beam flux - maximum

$$\frac{4 \cdot 10^{14}}{D^2} \text{ electrons/sec/cm2}$$

where D is the diameter of the exposure area in cm. and
$1 \leq D \leq 100$ cm.

(c) Monochromatic beam flux - minimum

$$\frac{(4 \cdot 10^8)}{D^2} \text{ electrons/sec/cm}^2$$

(d) Energy spread goes from ±25 kev for D < 10 cm to as much as ±80 kev for D = 100 cm.

3. Photons in Air

(a) At a distance of one meter from a copper target, a flux of approximately 10^5 roentgens per hour can be put through an area 50 centimeters in diameter.

(b) The energy spectrum of the photons is as shown in Figure 10.

(c) Softer spectra are obtained by lowering the original monochromatic electron beam energy; the intensity will decrease as the 3.4 power of beam energy.

B. Routine Capabilities in Convertible Configuration

Those capabilities that are available with less than one hour setup time are:

1. Protons in Vacuum

(a) Monochromatic beam energy
(50 kev) - 4 Mev (±2 kev)

(b) Monochromatic beam flux - maximum

$$\frac{2.4 \cdot 10^{15}}{D^2} \text{ protons/sec/cm}^2$$

where D is the diameter of the exposure area in cm. and $0.3 \leq D \leq 165$ cm.

(c) Monochromatic beam flux - minimum

$$\frac{(8 \cdot 10^{12})}{D^2} \text{ protons/sec/cm}^2$$

2. Positive Ions in Vacuum

With 2-4 days' notice, the KN/S-4000 can be set up to provide any four of the following ions with less than one hour delay when switching from one type to another.

(a) Monochromatic beam energy
(50 kev) - 4 Mev ± (2 kev)

(b) Monochromatic beam flux
The fluxes listed in the table are maxima. It is not yet known what minima can be achieved.

Element	Atomic Weight	Flux x D^2	Range in Diameters (cm)
H	1	$2.4 \cdot 10^{15}$	0.3 - 165
He	4	$8 \cdot 10^{14}$	0.2 - 40
Li	6 or 7	$3.2 \cdot 10^{13}$	0.2 - 25
B	11	$1.6 \cdot 10^{13}$	0.2 - 15
N	14	$3.2 \cdot 10^{14}$	0.2 - 10
O	16	$1.6 \cdot 10^{14}$	0.2 - 10
Ne	20	$6.4 \cdot 10^{14}$	0.2 - 8
A	40	$3.2 \cdot 10^{14}$	0.2 - 4
Kr	84	$1.6 \cdot 10^{14}$	0.2 - 2
Xe	131	$1.6 \cdot 10^{14}$	0.2 - 1
Cs	133	$3.2 \cdot 10^{13}$	0.2 - 1

3. Electrons in Vacuum

(a) Monochromatic beam energy
(1.5 Mev - 3.0 Mev ± 6 kev)

(b) Monochromatic beam flux - maximum

$$\frac{(8 \cdot 10^{14})}{D^2} \quad \text{electrons/sec/cm}^2$$

where D is the diameter of exposure area in centimeters and $1 \leq D \leq 165$ cm.

(c) Monochromatic beam flux - minimum

$$\frac{(8 \cdot 10^{12})}{D^2} \text{ electrons/sec/cm}^2$$

(d) "Spectral beam" range of exponent and flux

The development goal is to provide (one-tenth) the flux given in II-A-1-d at 10 kev $\leq E \leq$ (3 Mev).

4. Electrons in Air

(a) Monochromatic beam energy
(1.5 Mev - 3.0 Mev ± 30 kev (spread)

(b) Monochromatic beam flux - maximum

$$\frac{4 \cdot 10^{14}}{D^2} \text{ electrons/sec/cm}^2$$

where $1 \leq D \leq 100$ cm.

(c) Monochromatic beam flux - minimum

$$\frac{(4 \cdot 10^{12})}{D^2} \text{ electrons/sec/cm}^2$$

(d) Energy spread goes from ±25 kev for $D < 10$ cm to as much as ±80 kev for $D = 100$ cm.

5. Photons in Air

At a distance of one meter from a copper target, a flux of approximately $(4 \cdot 10^3)$ roentgens per hour can be put through an area 50 centimeters in diameter. The maximum energy in the photon spectrum is (3.0 Mev).

C. Capabilities Requiring Specific Preparation

Delays cannot be predicted for these capabilities since preparation is effected by delivery times of isotopes or minor equipment as well as normal setup of permanent facility equipment.

1. High-Energy Protons

Various reactions are available; the 17.8 Mev protons from $D(He^3, P) He^4$ is one example.

2. Gamma Rays

Reaction	Mev Avg. Energy	Sec^{-1} Max Yield
$He^3 (p, \gamma) He^4$	21.6	10^6
$Li^7 (p, \gamma) Be^8$	15, 17	10^6, 10^6
$C^{13} (p, \gamma) N^{14}$	10	10^5
$B^{11} (p, \gamma) C^{12}$	11.8, 16.6	10^6, 10^5

many others, all (p, γ)

3. High-Energy Electrons

Yields of 10^6 - 10^8 electrons/sec at energies up to 12 Mev from $B^{11} (d, p) B^{12} \rightarrow C^{12} + \beta^-$.

4. Optical Spectroscopy

A recent technique worth mentioning is the excitation of optical transitions by accelerating the atoms of interest (c.f. Sec. B-2), passing the beam through a thin foil to excite electronic states by coulombic interaction and observing the light emitted during de-excitation as a function of distance travelled beyond the shock foil. The relaxation time is very precisely related to the distance travelled by the atoms from the foil since the velocity is quite uniform and known.

It has been found that $\sim 0.4\ \mu$amp or more is needed for spectroscopic analysis.

5. Trace Determination and Assay

Many reactions permit the quantitative determination of abundance of a particular element in a sample. An example derives from the reaction

C^{12} (d, n)N^{13}. A sample whose abundance of carbon is unknown is bombarded with deuterons. C^{12} is converted to N^{13} which then decays by positron emission with a half life of 10.2 minutes. The subsequent 0.51 Mev annihilation photons are easily detected and distinguished from background. Calibration is effected with a sample of pure carbon or one whose content is known.

Most elements have reactions either with particles or photons which allow similar assay.

6. Neutrons

At 4 Mev the Be^9 (d, n) B^{10} reaction produces 5.5×10^9 neutrons per second per microamp of deuterons. Thus yields of over 10^{12} n/sec are available at the beryllium target.

Since neutron facilities abound, however, a proposed experiment would have to be of a compelling nature before the headaches associated with such operations could be accepted.

D. Capabilities Projected for the Future

1. Increased Basic Energy

The basic electrostatic generator has been run for prolonged periods at 5.5 MV. Modifications in cathodes and sources will be undertaken as time goes on to increase the energy capability of the machine as a particle accelerator.

2. High Fields

An electrostatic field strength of fair magnitude can be produced by charging an insulated hollow sphere in the 78-inch vacuum chamber by means of a 4 Mev proton beam. The beam would be directed through a small hole in the sphere, trapping secondaries inside. Ultimate field strengths would therefore depend almost entirely on the surface conditions of the sphere and its surroundings.

3. High-Energy Heavy Ions

An attractive technique for the production of ions with energies greatly in excess of 4 Mev would be the use of the two accelerators in tandem. The 400 KV accelerator would produce singly or doubly-charged ions in its standard RF source and accelerate them to an efficient energy level for foil or gas stripping. The resulting multiply-charged ions would then be focused into the 4 MV accelerator set for negative terminal potential. Experiments would then be conducted in the 4 MV terminal with ions having energies of Z x 4 Mev where Z is the charge level accomplished in the final stripping.

This capability is being actively pursued at the present time but has not yet been demonstrated.

III. EQUIPMENT

A. KN/S - 4000 Accelerator

1. Electrons

(a) 300 kev - 4 Mev
(b) 10^{-4} μ amp - 10^{3} μ amps
(c) ±3 kev energy stability

2. Protons

(a) 50 kev - 4 Mev
(b) 1 μ amp - 300 μ amps
(c) ±2 kev energy stability

3. Quick-Conversion Electronics

(a) 1.5 Mev - 3.0 Mev
(b) 1 μ amp - 100 μ amps
(c) energy stability not established as yet

B. AN/S - 400 Accelerator

1. Electrons

(a) 50 kev - 400 kev

(b) 0.1 μamp - 50 μamps

(c) energy stability $\approx$ ±2 per cent

2. Protons

(a) 50 kev - 400 kev

(b) 1 μamp - 150 μamps

(c) energy stability $\approx$ ±2 per cent

C. Beam-Handling System

1. Analyzing and Switching Magnet

(a) Ports at 0, 33, 45, 66 and 90 degrees

(b) Flux density 13,000 gauss

(c) Mass-energy product: 12 at 45°, 4 at 90°

(d) Field stability: 1 part in 10,000 in 8 hours

2. Quadrupoles

(a) Two-sections

(b) Four-inch aperture

(c) Mass-energy product 12 at 60 inches

(d) Maximum pole field 1600 gauss

D. 48-inch Vacuum Chamber (see Figure 4)

1. Ultimate vacuum:	(2.10^{-7} torr)
2. Time to reach 10^{-6} torr:	(40 minutes)
3. Mounting posts:	1-inch, 8 threads-per-inch tapped holes, 2 inches deep. Threaded portion of experimenter's equipment must be flat or slotted along length to provide pump-out path for threads. See Figure 2 for positions.
	Load Capacity: 200 lbs per post

4. Experiment-staging dome: See Figure 5 for dimensions. Experiments mounted on and cantilevered from 16-inch port on dome centerline. Data leads available to connect to experimenter - provided feedthrus are listed in Section IV B and paragraph 6 below.

5. Ports: Three 16-inch, four 9-inch and four 6-inch ports are available in positions indicated in Figure 2.

6. Feedthrus Available: Two coaxial liquid nitrogen 3/8-inch lines; six octal headers with 5-amp capacity per pin; two 40 KV high voltage bushings; two twin-pipe fluid lines, 3/8-inch I. D.; three headers supplying four BNC coaxial feedthrus each.

7. Remote-controlled positioners:

(a) Motor-driven rod mounted at an angle of 70-degrees from the vertical. Positions along a radius from wall of 48-inch chamber to the central axis. Position remotely indicated. No signal leads provided. Thirteen inches from face of back flange.

(b) Motor-driven rod as above, but located symmetrically opposite, positionable along the entire diameter of the chamber, and containing an RG-58 coaxial signal lead.

E. 78-inch Environmental Chamber (see Figures 2 and 3)

1. Ultimate vacuum: $2 \cdot 10^{-7}$ torr

2. Time to reach 10^{-6} torr: < 40 minutes

3. Mounting posts: Mechanically the same as Section D-3. (See Figure 2 for locations)

4. Ports: Two 9-inch as shown in Figure 2. Only one available to experimenter for feedthrus.

5. Spin Table:

(a) Load capacity: 500 lbs.

(b) Spin rates: Up to 10 rpm

(c) Reciprocation:

(d) Attitude: ±30 degrees from vertical

6. Cold Shroud

(a) Inside surface has a $\alpha/E \cong 1$

(b) Effective (Stefan Boltzmann) temperature seen by:

an object on spin table $\approx$ 200°K

an object 12 inches from back wall $\approx$ 150°K

(c) Liquid nitrogen feedthrus exist to enable local shrouding of small objects where necessary.

F. Air-Scattering Facility

1. Energy range:	50 kev - 4 Mev electrons
2. Exposure diameter:	1 cm - 100 cm
3. Flux range:	up to total of 2×10^{14} electrons/sec over the total exposure area
4. Width of experimental area:	35 inches
5. Length of experimental area:	84 inches
6. Height of experimental area:	38 inches

G. Xenon-Arc Source

1. Spectrum:	See Figure 11
2. Exposure diameter:	20 cm - 150 cm
3. Radiant flux:	≈ 2 cal/cm^2/sec - 0.05 cal/cm^2/sec

IV. FACILITIES

A. Instrumentation

1. RCL Model 20631 Pulse Height Analyzer

(a) 400 channels

(b) 10^5 counts per channel

(c) Digital stripper

(d) Coincidence input option

(e) Outputs: Oscilloscopes with Polaroid camera; typewriter; punched tape

(f) Inputs: Positive Pulses

5 volts (1250 Ω)

15 volts (3750 Ω)

60 volts (15,000 Ω)

Negative Pulses

10 volts maximum peak

10 millivolts nominal

1300 Ω

2. Detectors

(a) Lithium-drifted silicon with depletion layers of 1 mm, 2 mm and 4 mm.

(b) Silicon surface barrier transmission-type with 500μ depletion layers and 100 to 300 mm^2 area.

(c) Plastic scintillator: 2-inch right cylinder with well

(d) Sodium iodide scintillator: 3-inch right cylinder

3. Scalers

(a) 25 KHz

(b) 10^7 total

two available

4. Count-Rate Meter

(a) Up to 10^5 Hz with 0.5 per cent accuracy

(b) Time constants: 0.5, 2, 10, 40 secs

(c) Pulse height: Positive 0.25 - 10 volts

(d) Pulse width: 0.2 - 10 μsec

(e) Recorder output: 50 Ω, 0-10 millivolt

5. Keithley Direct Current Meters

(a) Five meters with 10^{-9} amp full scale sensitivity

(b) Two meters with $3 \cdot 10^{-6}$ volt full scale sensitivity

6. Faraday Cups

(a) Circular: $0.2\ cm^2$ area
(b) Slit: 2 mm x 28 cm — in air
(c) Gridded Cup: $1\ cm^2$ circular - in vacuum

7. Remote Temperature Measurement

(a) $-80^{\circ}C$ to $+180^{\circ}C$

(b) $\pm 0.5^{\circ}C$ accuracy at worst part of scale

(c) Variety of thermistor sensors

8. Closed-Circuit Television

(a) Portable radiation-resistant vidicon

(b) 1-inch focal length

(c) f 0.95

(d) Remote iris and focus control

9. Recorders

(a) Brown Inst. Co., 11-inch chart, 10 millivolt F.S.

(b) Varian potentiometer strip chart, 5-inch, 10 millivolt F.S.

10. Rotating Gaussmeter

(a) Full scales: 8,000; 16,000; 40,000 gauss
0.1 per cent full scale accuracy

11. Nuclear Magnetic Resonance Fluxmeter

(a) Six bands from 500 gauss to 19,000 gauss

(b) Measurement accuracy: 1 part in 10^5

12. Mass Spectrometer - Vacuum Analyzer

(a) up to 70 amu

(b) Maximum sensitivity: 10^{-10} torr partial pressure

(c) Scan Speeds: 30 sec, 120 sec.

B. Electrical

1. 208 volts, 3 φ, 4 wire, 80 KVA, 60 Hz
2. 440 volts, 3 φ, 4 wire, 130 KVA, 60 Hz
3. Direct-current supplies

(a) 6, 12, 18, 24 volts
10 amperes
batteries

(b) 0 - 130 volts
0 - 700 amps
full-wave rectified (3 φ)

4. Instrument ground system

(a) 24 banana plug sockets

(b) 6 battery-cable lugs

5. Control and power leads into experimental vault

(a) No. 18 in six groups of eight leads each

(b) No. 12 as required

(c) No. 8 as required

6. Signal Leads

(a) Thirty RG-8 coaxial, type N

(b) Twenty-eight shielded No. 20

photocurrent:	$<10^{-9}$ amp
pickup:	$<10^{-7}$ volt
leakage to ground:	$<10^{-10}$ amp
leakage between pairs:	$<10^{-10}$ amp

C. Mechanical

1. Vacuum forepump lines (pressure $\cong$ 1μ)

   (a) 4-inch std. ASA flange

   (b) 3-inch std. ASA flange

   (c) 2-inch std. ASA flange

   (d) 3/4-inch rubber hose connections

2. Liquid Nitrogen

   (a) 100 liters per minute maximum

   (b) Various fittings from 1/4 to 1 inch

3. Chilled water (closed system)

   (a) 80 psi system pressure

   (b) 30 gpm at 44°F

   (c) 3/4-inch std. hose fittings

4. Compressed Air

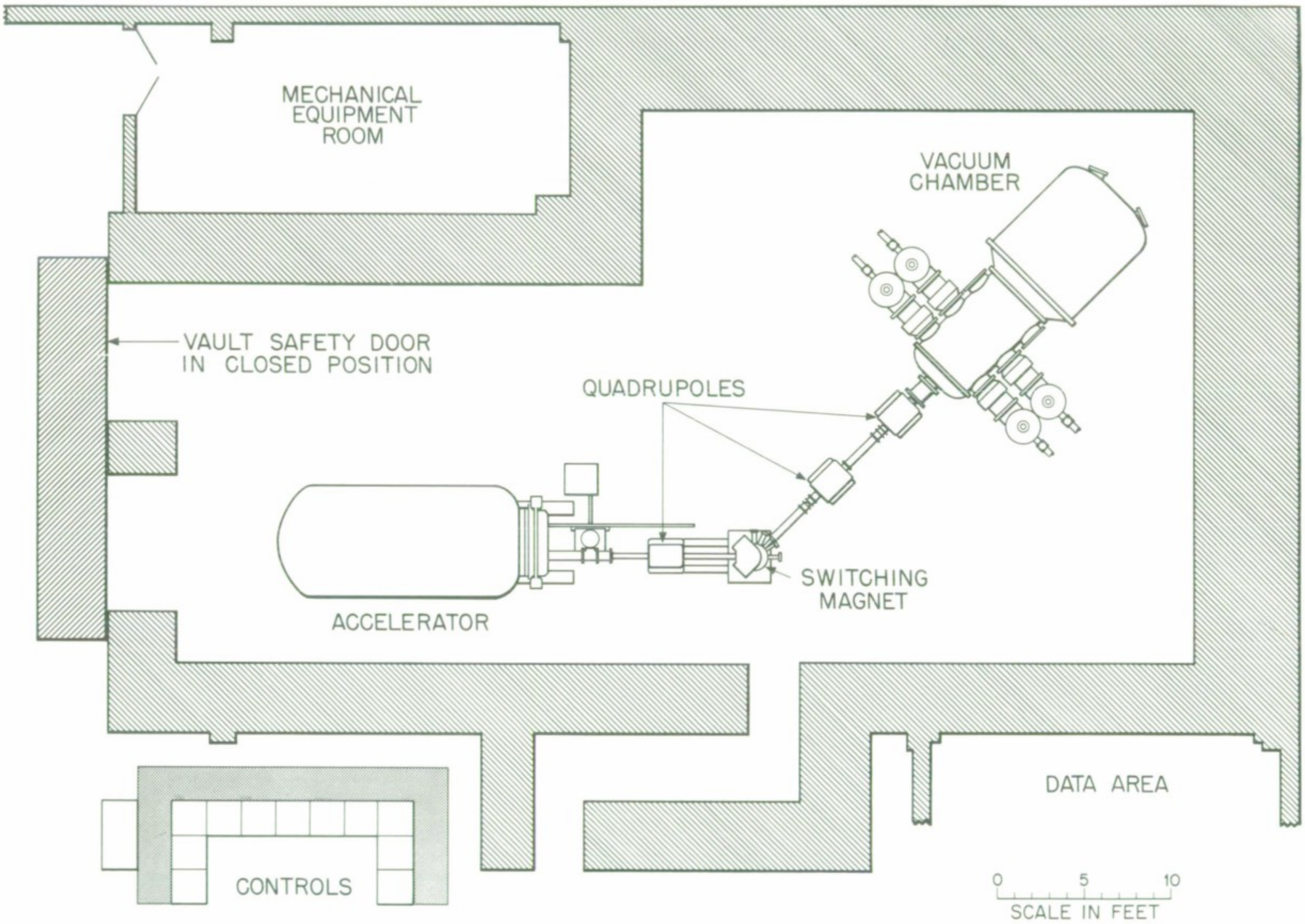
   (a) 100 psi

   (b) Various 1/4 and 3/8 Cu tubing fittings

V. ACCESS

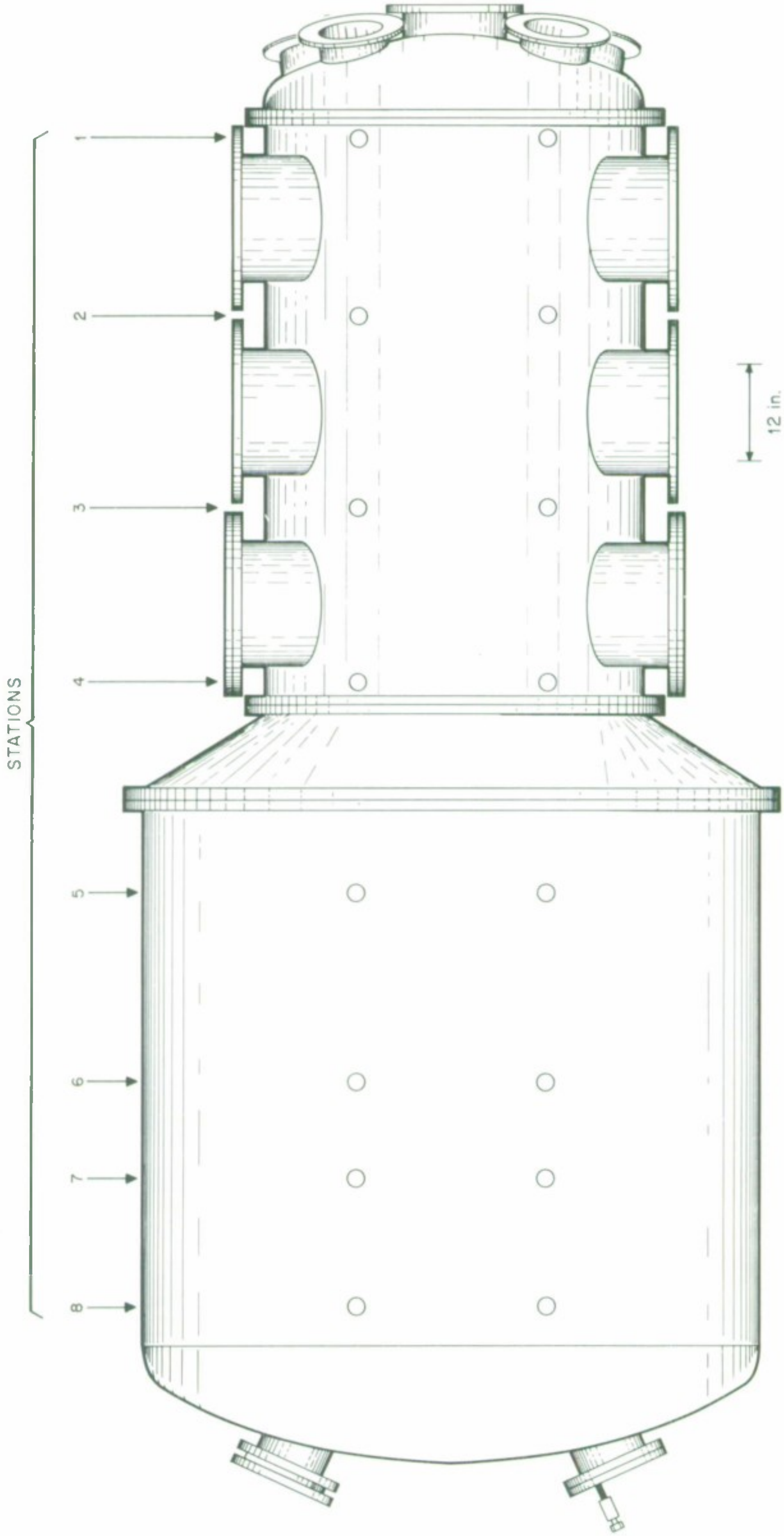
A. Objects whose greatest dimension does not exceed 80 inches and whose weight does not exceed 5000 pounds can be accommodated without special arrangements.

B. Advance notice and some preparation are required for objects weighing from 5000 to 13,000 pounds. Special rigging is required above 13,000 pounds.



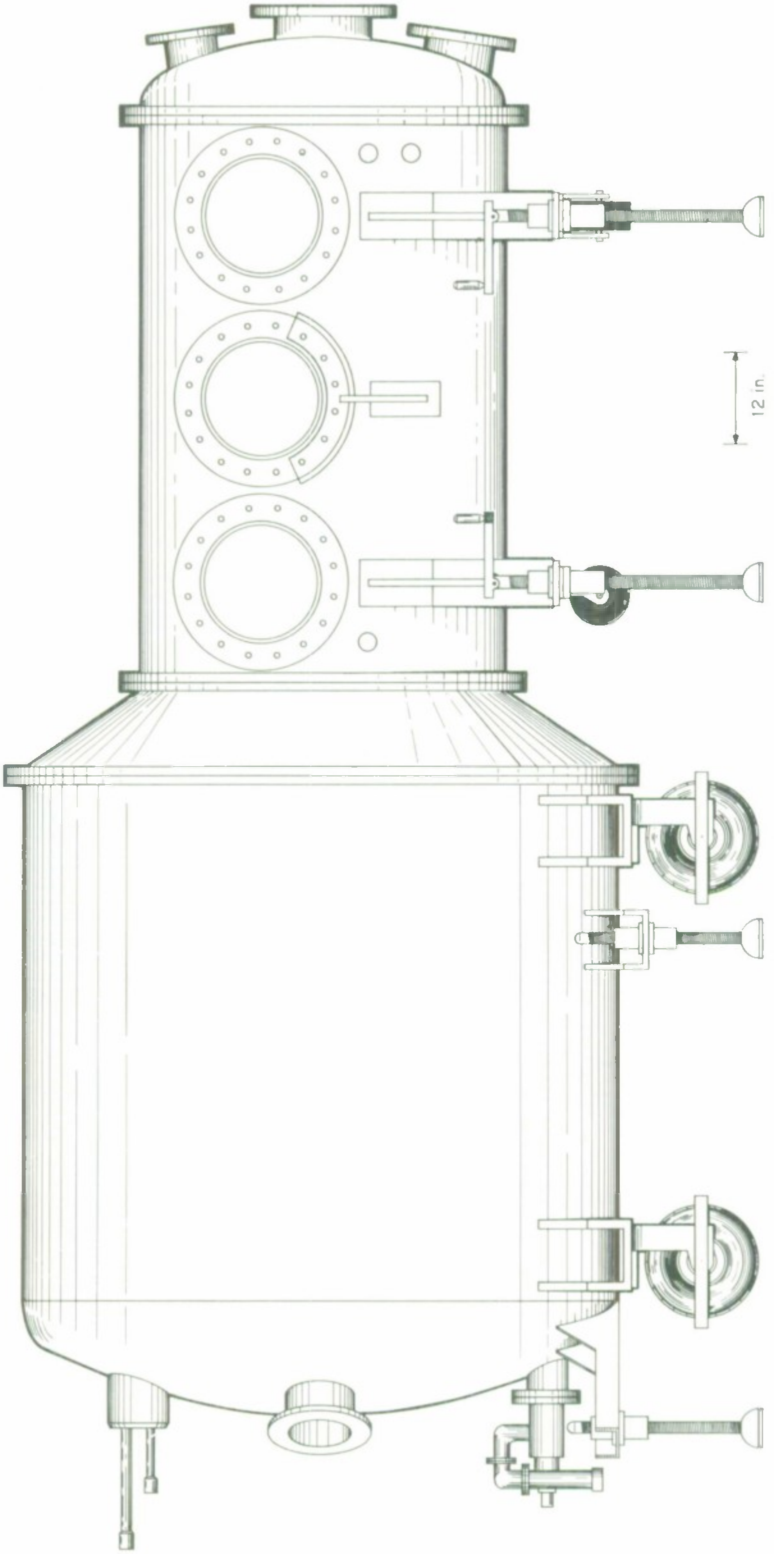
1. General Laboratory Floor Plan.

3-63-5485

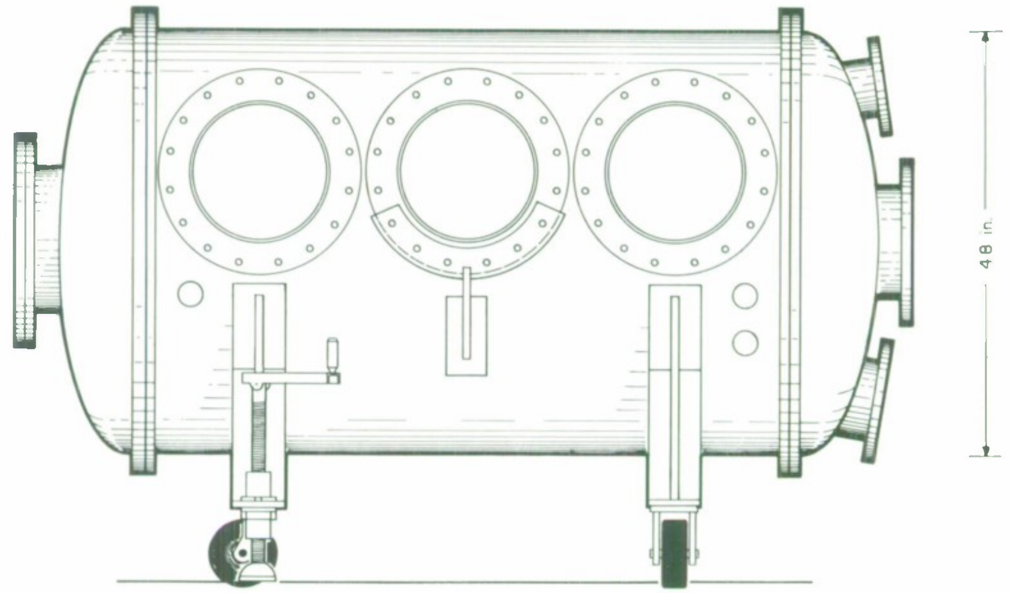


2. Chambers, Plan View.

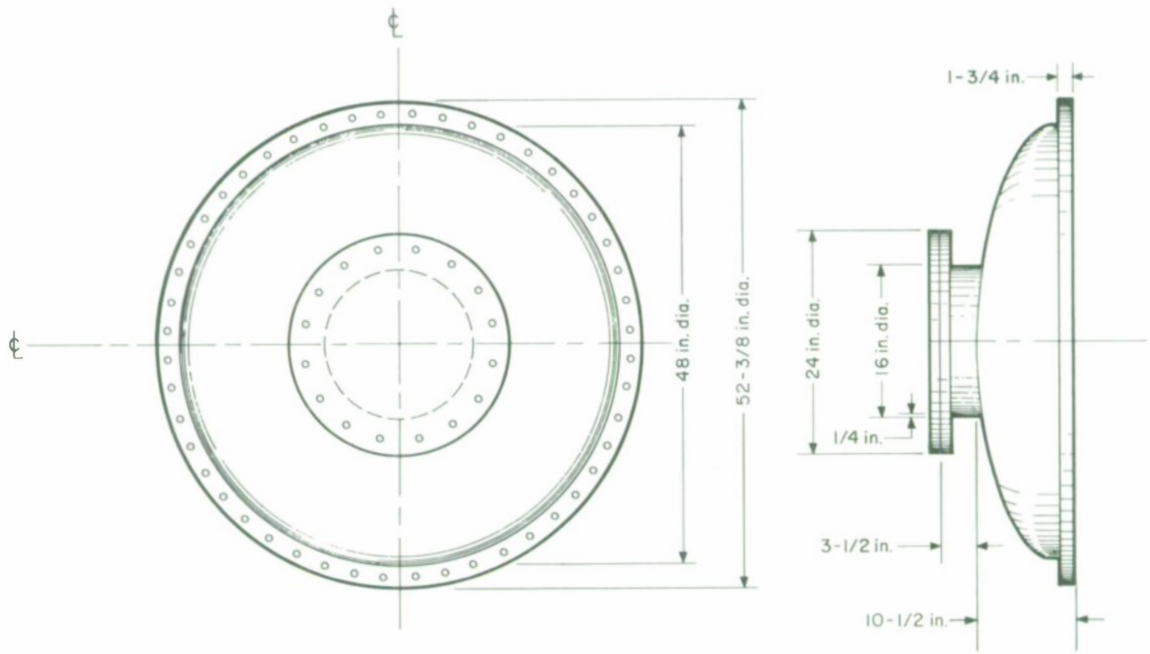
3-63-5453



3. Chambers, Elevation.

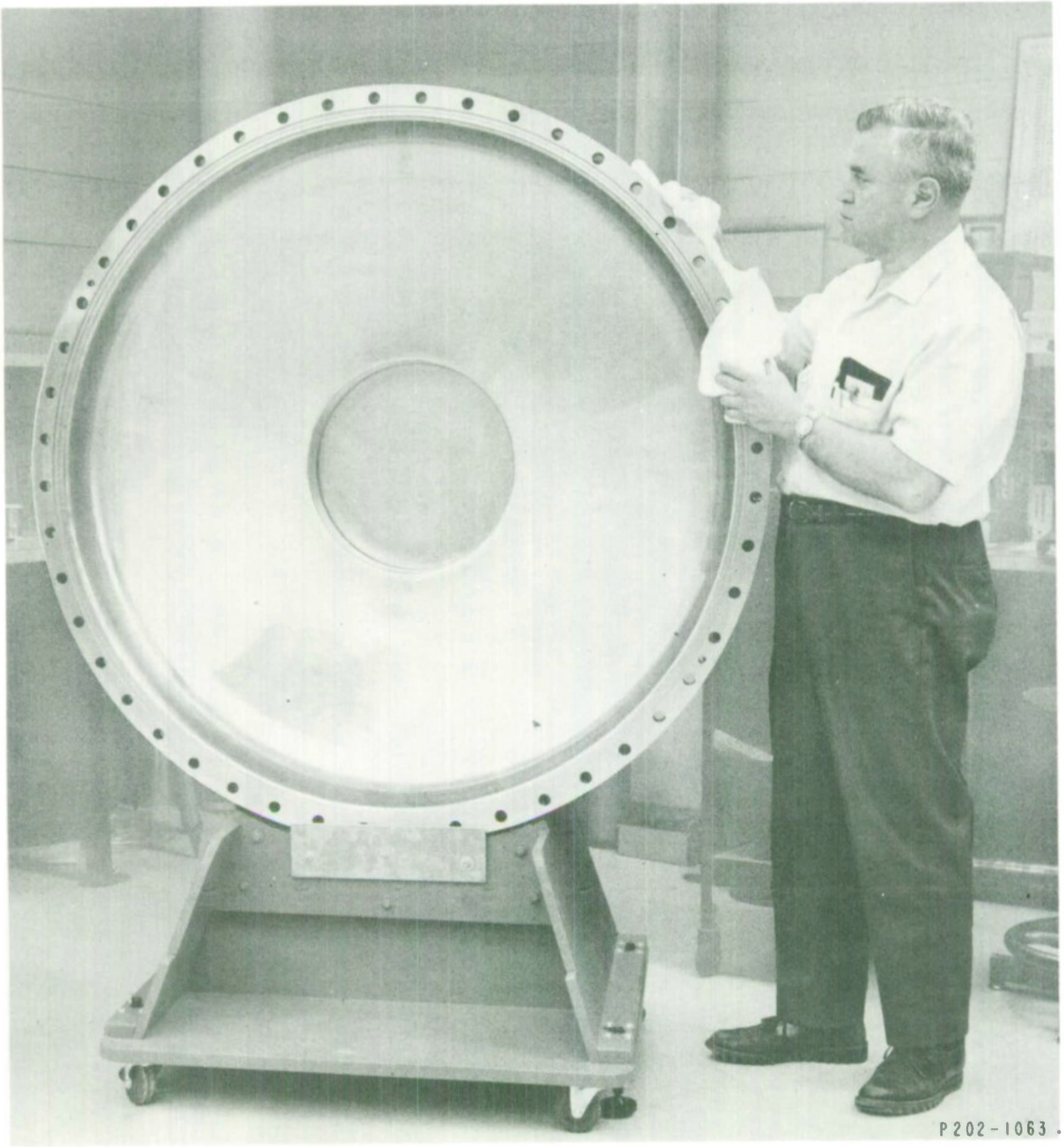


4. 48-inch Chamber with Dome (Elevation). 3-63-5456

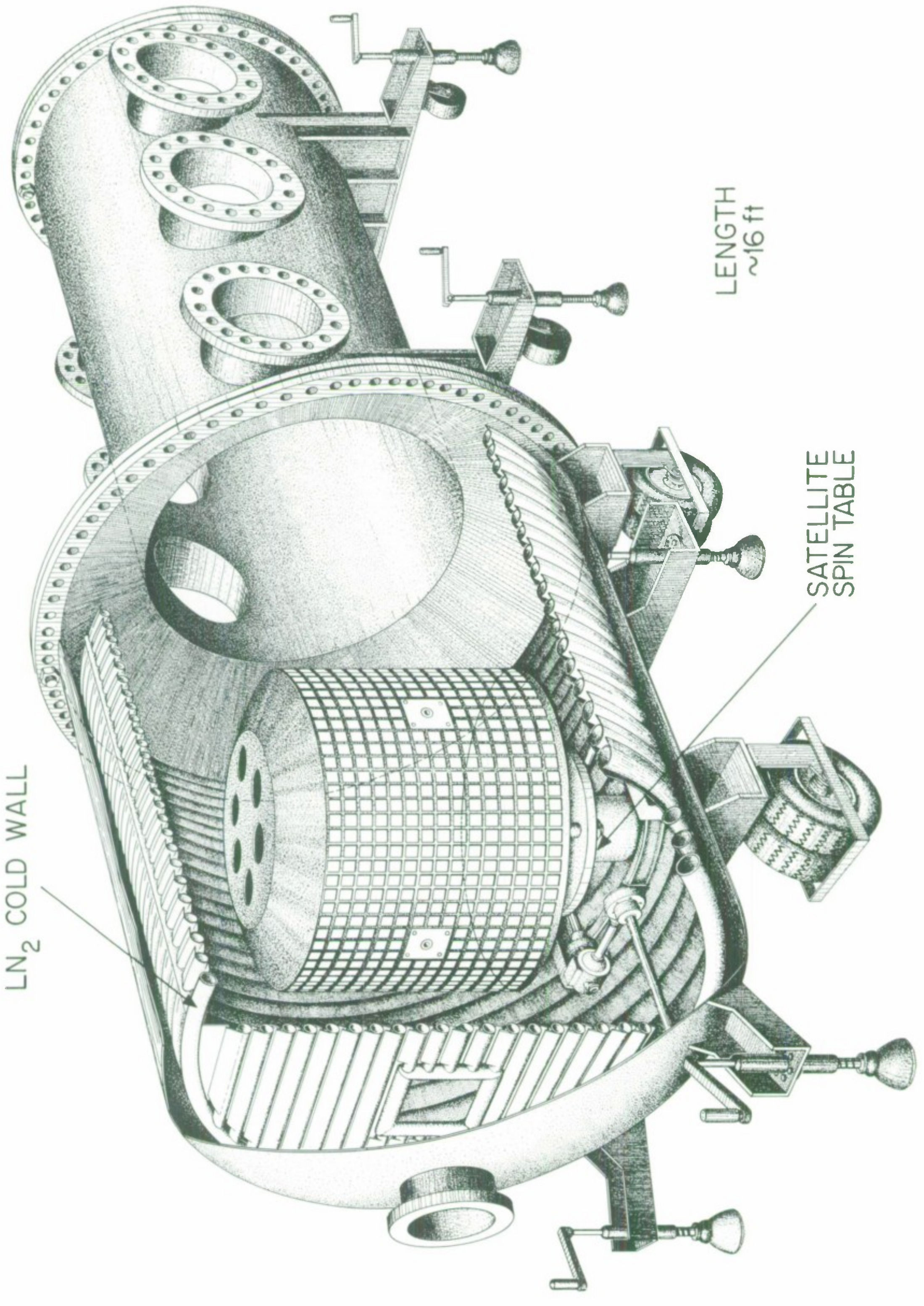


5. 48-inch Dome - Both Views.

3-63-5452

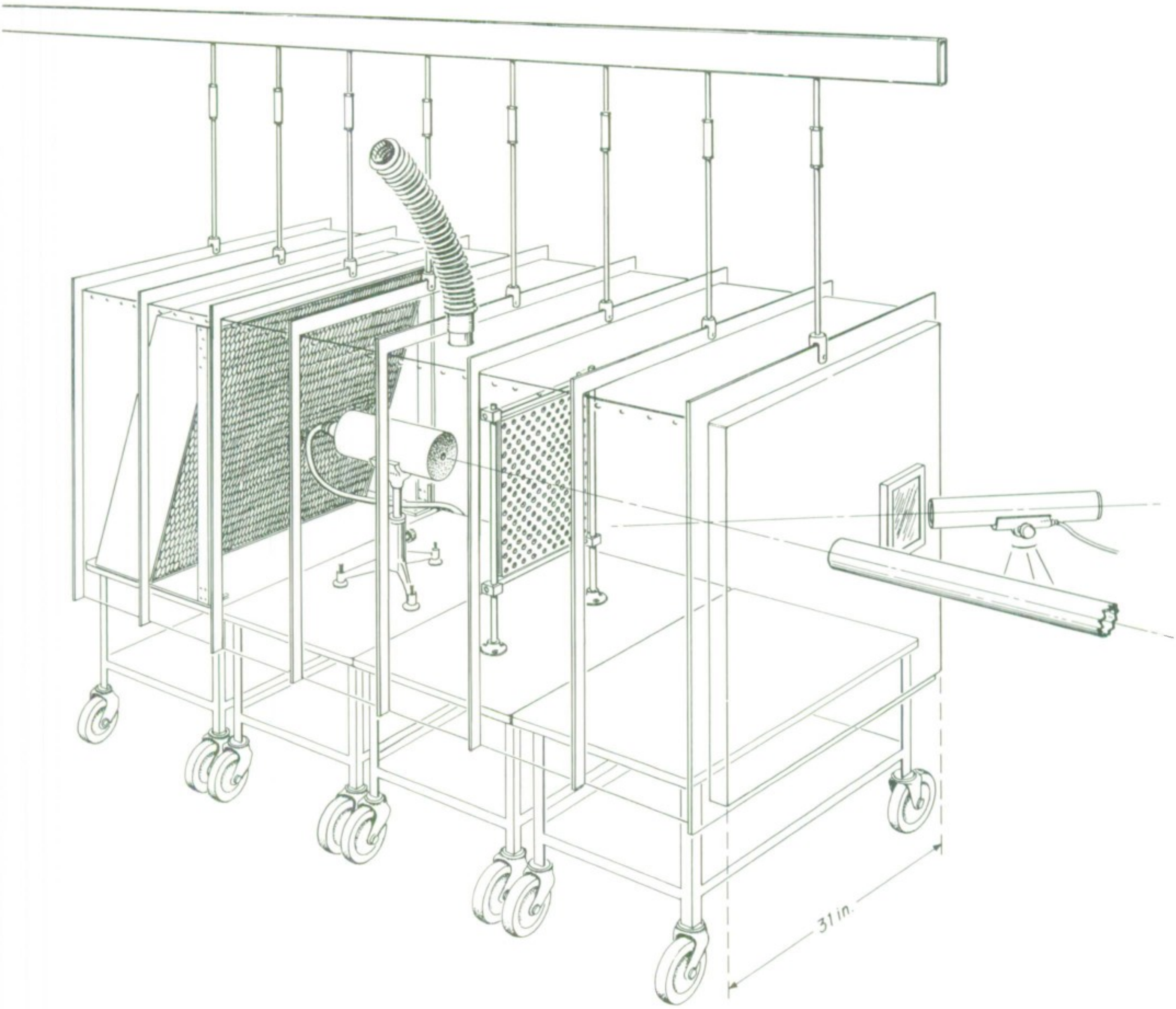


6. 48-inch Dome on Cart.

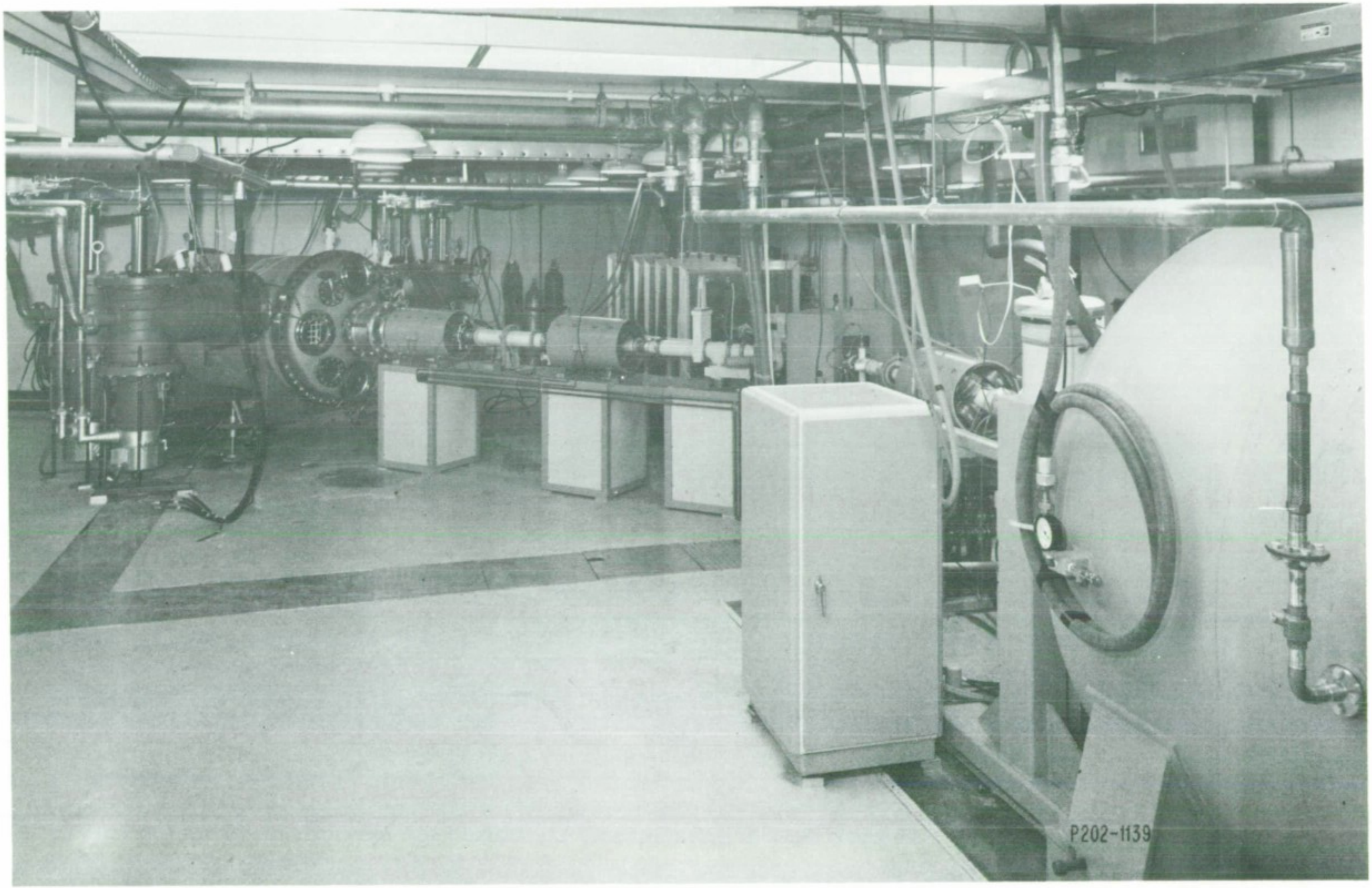


7. Artist's Sketch of Chambers.

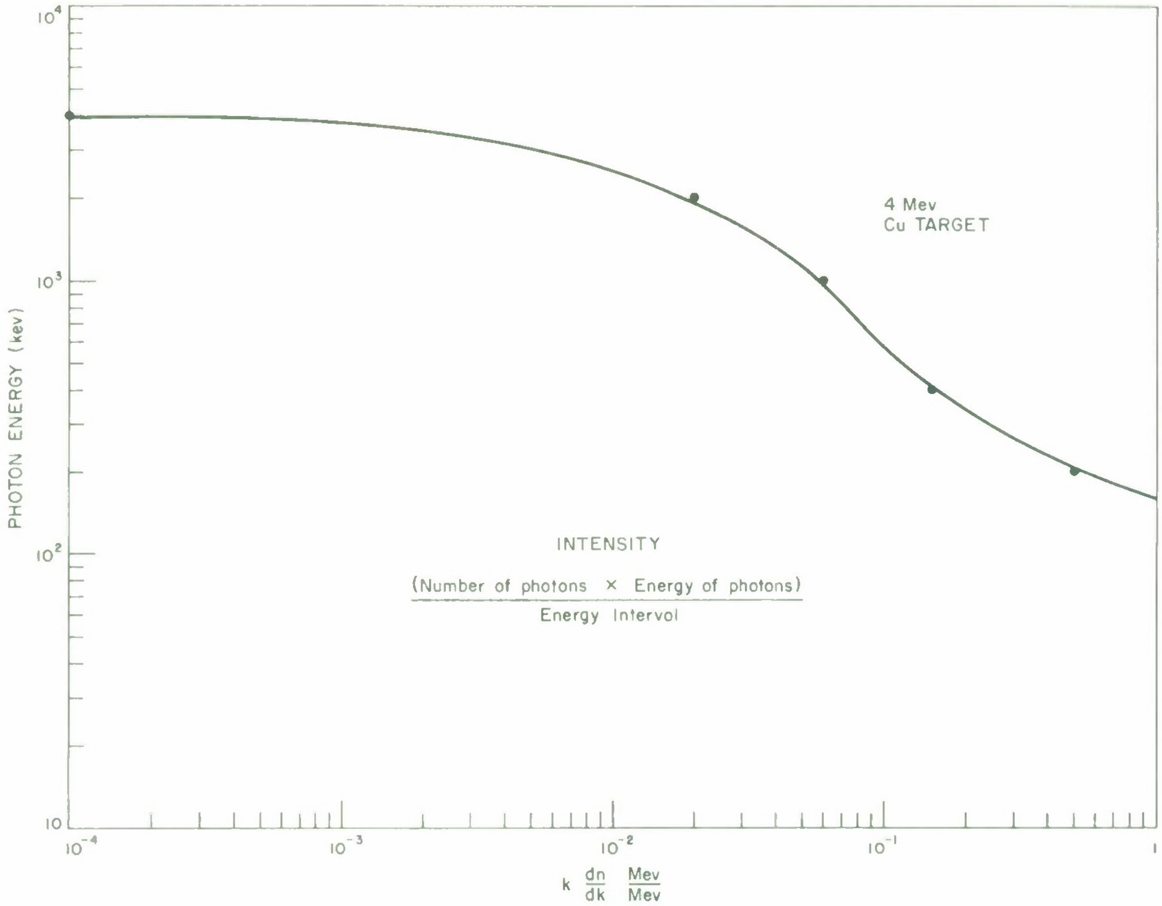
3-63-4603



8. Artist's Sketch of Air-Scattering Facility.

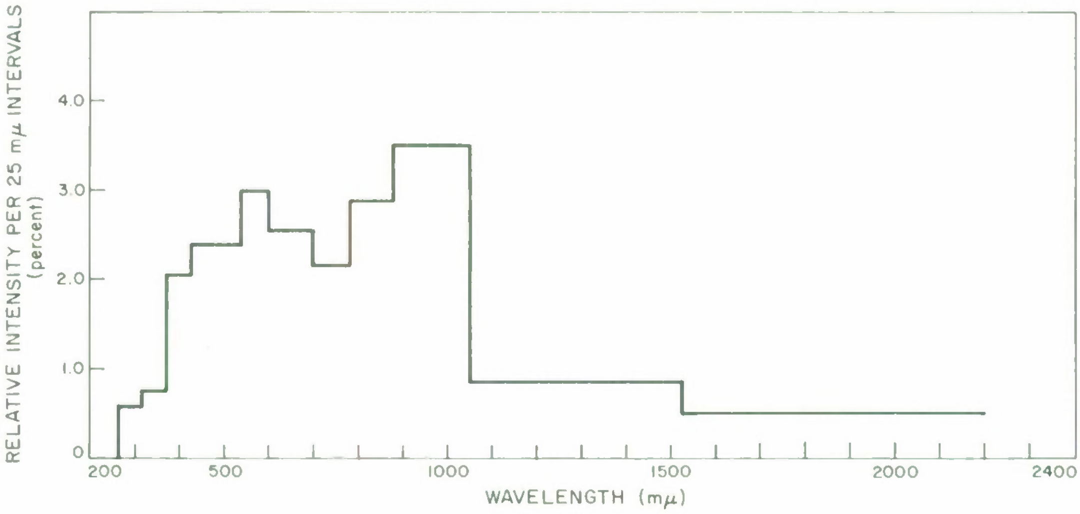


9. General Photo of Vault.



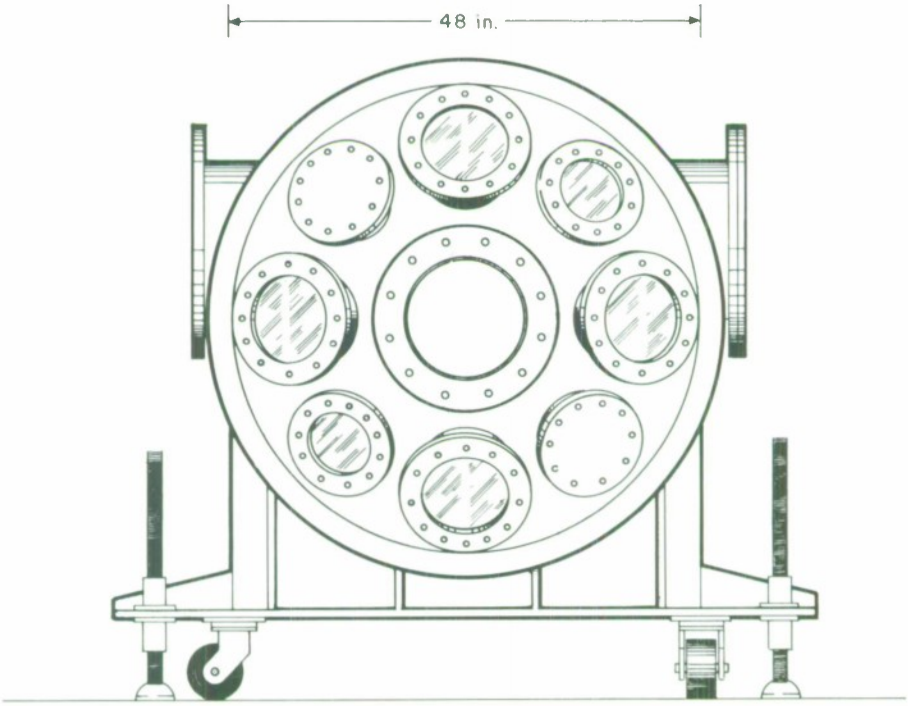
3-63-5431

10. Bremsstrahlung Spectrum at 4 MeV.



11. Xenon Arc Spectrum at 15 Kw.

3-63-5468



12. 48-inch Input Dome.

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13. ABSTRACT

A complete technical description of the Lincoln Accelerator Laboratory is given. The primary purpose of the laboratory is to conduct radiation-effects studies for space vehicles and components. Particle fluxes up to 68 inches in diameter are provided in a solar-vacuum chamber. These can be either monochromatic electrons at any energy from 300 kev to 4 Mev; electrons distributed in a Van Allen energy spectrum from 40 kev to 4 Mev, or monochromatic protons at any energy from 50 kev to 4 Mev.

The general-purpose capabilities of the laboratory are described, equipment listed, and information concerning the facilities is given to enable the investigator to design his experiment for greatest convenience and compatibility.

14. KEY WORDS

Lincoln Accelerator Laboratory   accelerators