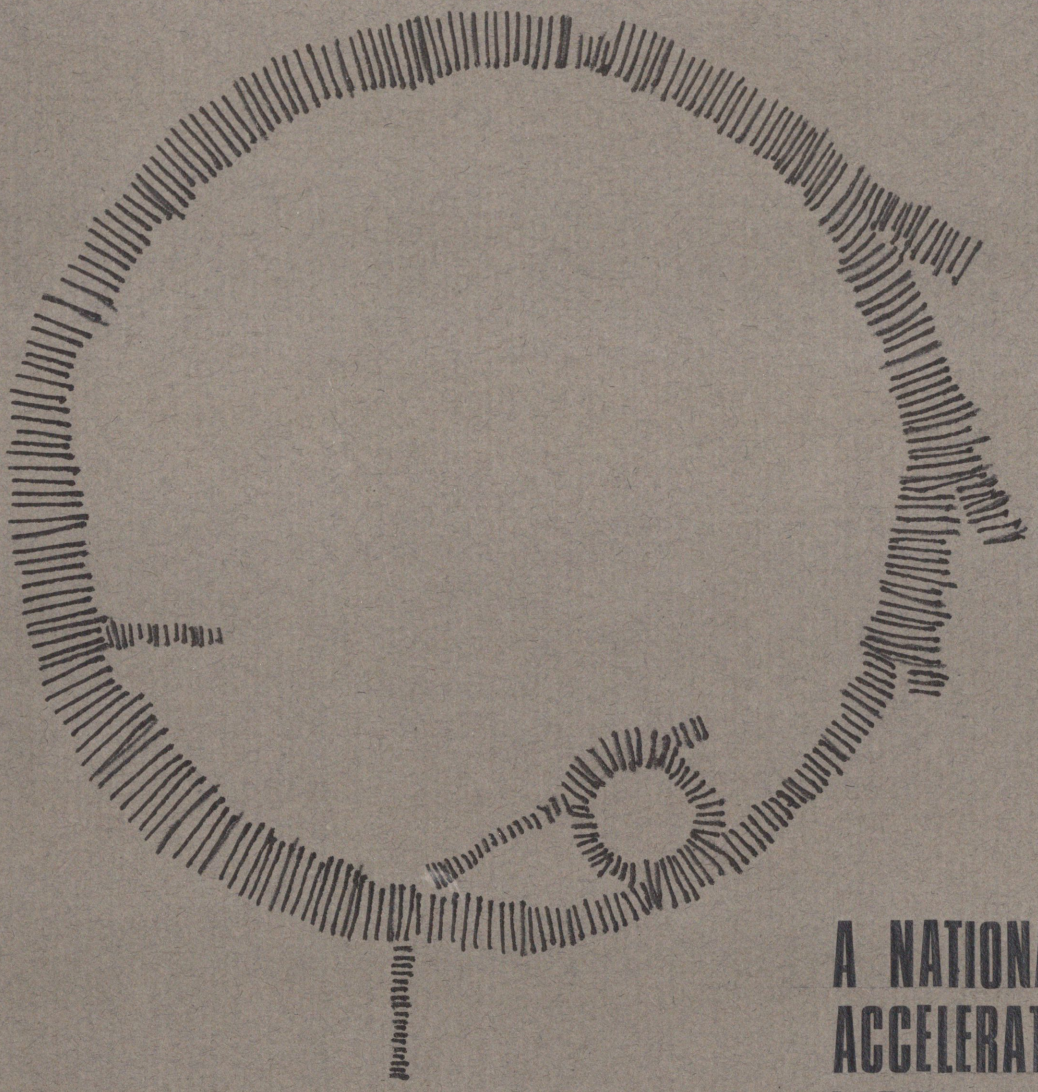
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A NATIONAL ACCELERATOR LABORATORY

A NATIONAL ACCELERATOR LABORATORY FOR RESEARCH OF HIGH ENERGY PHYSICS

located in the Jocko Valley of Western Montana

by Robert C. Strand

Part 1. Undergraduate thesis submitted to the School of Architecture at Montana State University as partial fulfillment of the requirements for the degree of Bachelor of Architecture.

Bozeman, Montana March, 1967

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FOREWORD

The purpose of this thesis study of a National Accelerator Laboratory is to investigate problems posed by a large industrial complex, including utilities, transportation, and basic functions or processes unique to the industry involved.

Montana has submitted a site in the Missoula-Arlee area, based on Atomic Energy Commission requirements for a high energy physics research laboratory. As a hypothetical design problem, I will develop the Arlee, Montana, site following Atomic Energy Commission program requirements and a design study done by the Lawrence Radiation Laboratory of Berkeley, California. This paper will discuss the function of an accelerator laboratory and outline a building program for its construction.

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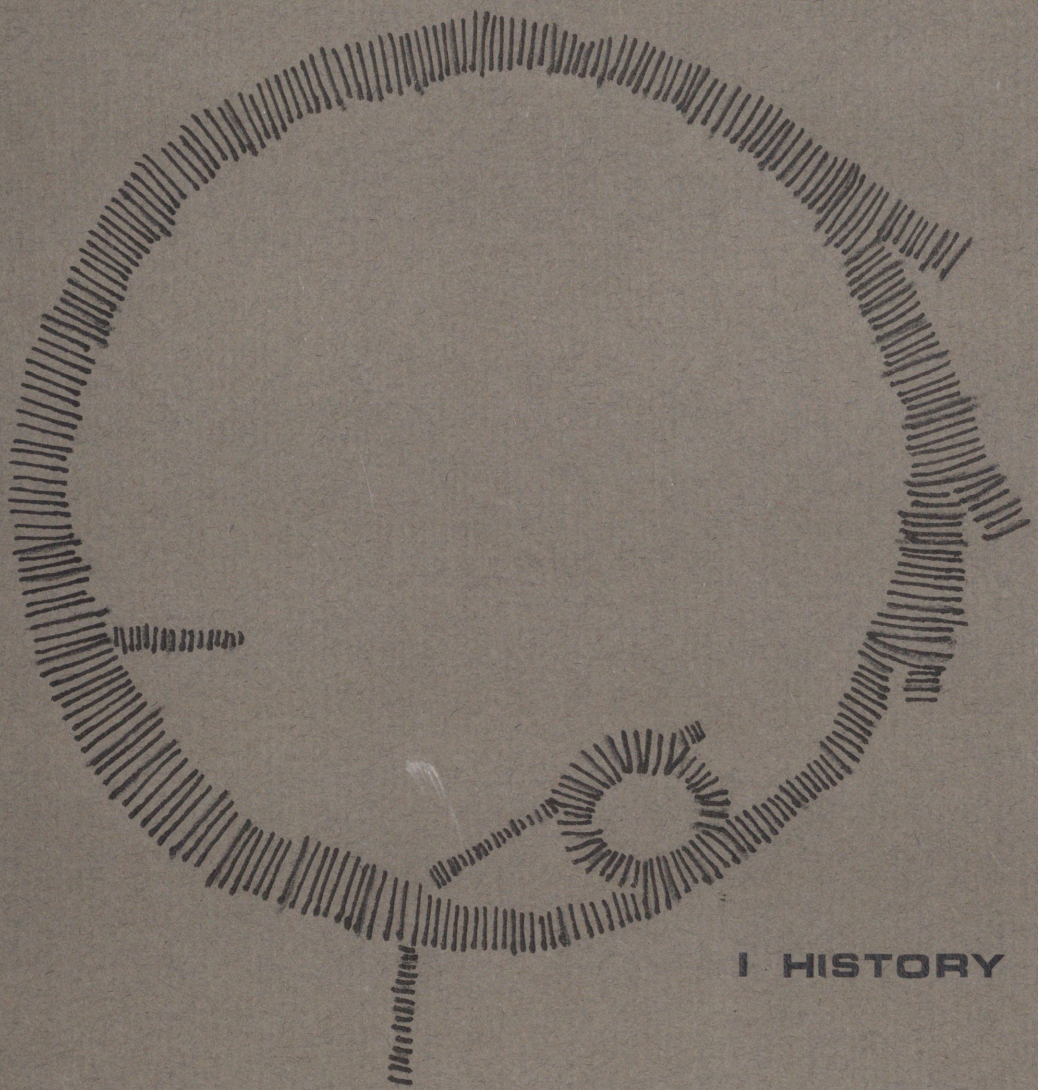
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1 HISTORY

The identification of x-rays by Wilhelm Roentgen in 1895 and the discovery of radioactivity in a sample of pitchblende by Henri Becquerel in 1896 paved the way for the sophisticated study of high energy physics carried on today. From the earliest discoveries at the turn of the 19th century, scientists have been involved in the advancement of knowledge of radioactive materials.

RADIATION

Early experiments located three forms of natural radiation from materials such as radium and uranium. These radiation forms, called alpha, beta, and gamma rays derived

their names from the first three letters of the Greek alphabet. Further experiments proved the alpha and beta rays to be actual particles. These particles, under further examination proved to be electrically charged. The alpha particles were positively charged and the beta particles negatively charged.

Experiments by Ernest Rutherford, in 1909, proved the alpha particles to be charged nuclei of helium atoms. Figure I-1. " . . . they made this discovery by collecting alpha particles from the decay of radon gas in a vacuum chamber and then sending an electrical discharge through them. This would add electrons to the alpha particles. [Figure I-1b.] What they observed was the optical spectrum characteristics of helium." (10:2) Beta particles, with their negative charge, were finally identified as electrons.

The important factor in these discoveries was the existence of positively and negatively charged particles which was to become the basis of accelerator design for high energy studies.

THE FIRST ACCELERATORS

Since radioactivity could only be studied in its natural form, there was a gap in knowledge that could only be closed

by devising experiments to control the intensity, direction, and energy of natural radiation. The first machines to provide this control were called accelerators.

The earliest machines operated by ionizing a gas such as hydrogen (ionization gives the hydrogen atom a positive charge by stripping away its electron, leaving a positively charged proton). Figure I-2. The proton was 'accelerated' in an electrical field. The energy of this acceleration was measured in relation to the power of the electric field. A proton accelerated across a potential of 1,000 volts would have an energy of 1,000 electron volts (1,000 ev). Accelerated across a potential of 1,000,000 volts, the proton would have gained 1,000,000 electron volts or 1 Mev.

Potential differences up to 10,000 volts were easily achieved, but higher energies were desired. Additional energy could be imparted to particles by using additional units of 10,000 volts in consecutive gaps, increasing the energy by 10,000 electron volts with each gap. "Another way was to charge a bank of condensers to 10 kv (10,000 volts) in parallel and then discharge them in series. If v was the voltage to which each condenser was charged and there were n condensers, then the final voltage available for accelerators was nv." (10:4)

The ultimate aspiration of these early accelerator

designers was to devise the first real nuclear experiment with accelerated particles. The following experiment was conducted by John D. Cockroft and Ernest A. Walton, using a machine of the latter design described above.

". . . they achieved the artificial transmutation of lithium. The reaction was as follows:

$$_1H^1 + {}_3Li^7 \longrightarrow {}_4Be^8 \longrightarrow {}_2He^4 + {}_2He^4$$

That is, the nucleus of a lithium-7 atom, denoted $_3Li^7$, when bombarded with protons ($_1H^1$) formed an excited beryllium-8 nucleus ($_4Be^8$), which subsequently disintegrated into two helium nuclei ($_2He^4 + {}_2He^4$)." (10:4,5)

"The accelerator developed by Cockroft and Walton for their transmutation experiments filled a need so successfully and proved so versatile that it was very widely copied." (1:66) These experiments provided the first glimpse into the structure of the atom and a realization to scientists of the forces binding matter together. There could be no question about the value of these experiments - they were opening an entirely new dimension of study.

The first accelerators lacked sophistication of design, but more importantly, they lacked power capabilities. The next successful accelerator was the Van de Graaff electrostatic generator designed by Robert Van de Graaff in 1931. Figure I-3.

Limitations of Van de Graaff machines involve engineering problems. However, by various improvements

in materials and design, the Van de Graaff accelerator can be used to provide energies as high as 36 Mev (million electron-volts). This can be accomplished by using many machines in a tandem operation. The future use of these accelerators will be primarily for injection of particles into much larger accelerators.

CYCLOTRONS

Ernest O. Lawrence of the University of California proposed the first cyclotron. The purpose of his design was to achieve higher energy levels than had been previously possible. Accelerators already mentioned moved particles in one stage, Lawrence's design included many small accelerations to reach a large sum of energy. "The unique aspect of the cyclotron proposal was that a magnet was to be used to send the particles into a circular path, in order to keep the dimensions of the system small." (10:7) Figure I-4.

A particle continues to accelerate until it reaches a centrifugal energy causing its path to correspond with the radius of the cyclotron. At this point it emerges toward an external target.

The cyclotron can accelerate particles to a very high

energy, but there is a limit to its capabilities based on the relativity theory which indicates an increase in particle mass as its energy increases.

". . . if the mass of a proton in a fixed frequency cyclotron increases sufficiently, it will no longer gain enough additional speed in each half orbit to make up for the fact that it is traveling in a wider arc. Therefore it will not reach the gap between the dees in time to receive the usual push from the alternating voltage. In fact, it will arrive so late that it will actually be decelerated instead of accelerated." (10:8,9)

The following mathematical analysis of cyclotron operation indicates the problems imposed on "fixed" frequency accelerators by the relativistic theory.

"If a charged particle of mass 'm' and charge 'q' moves in a uniform magnetic field, where the magnetic field strength is 'H', with a velocity 'v' which is perpendicular to 'H', it will describe a circular trajectory whose radius 'R' is given by the expression:

$$R = \frac{MV}{QH} \qquad \text{I.}$$

The time it will take the particle to make one circular

orbit will then be the circumference of the orbit divided by the velocity, or

$$T = \frac{2\pi R}{V} \qquad 2A.$$

Substituting equation 1 for 'R', we get

$$T = \frac{2\pi M}{QH} \qquad 2B.$$

The time for one orbit is therefore independent of the velocity and the radius and depends only on the mass, charge, and magnetic field.

It follows also that 'T' will increase if 'm' increases. Therefore the fixed frequency remains satisfactory only so long as the mass of the particle is constant, or nearly constant.

The relativistically correct expression for 'm' is:

$$M = \frac{M_o}{\sqrt{1 - V^2/C^2}}$$

where 'm_o' is the "rest mass", that is, the mass of zero velocity, 'v' is the particle velocity and 'c' is the velocity of light. Once the term

$$\sqrt{1 - V^2/C^2}$$

differs appreciably from 1, the proton begins to arrive late at the gap." (10:33,4)

Although the above factor limited the capabilities of

cyclotrons to energies below 10 Mev, they were an important source of information on proton interactions. They produced radioactive isotopes and elements not known to exist. Knowledge derived from cyclotron experimentation was influential in the developments of the early atomic bombs. "Plutonium element 94, a fissionable material used in atomic bombs, was first obtained by bombarding uranium-238 with deuterons in the University of California cyclotron built by Lawrence. For development of the cyclotron, Lawrence received the Nobel Prize in Physics in 1939." (10:10)

SYNCHROCYCLOTRONS

To overcome the slowing-down of particles as they approach the speed of light, scientists developed a radio frequency (R.F.) power supply whose frequency would decrease at a rate coincident with slower proton revolutions. This became the basis for the design of the synchrocyclotron.

> "To do this, a machine was designed which operated in a pulsating manner, protons being accelerated in bursts. Unlike the fixed-frequency cyclotron which can accelerate a continuous stream of particles, the new machine, the synchrocyclotron, has to push one group of protons through the entire cycle, from the initial highest frequency to the final lowest one, before it can begin accelerating a new group.
>
> The rapidity with which synchrocyclotrons can repeat whole cycles, known as the repetition rate, is naturally very important and is often stated along with

> maximum energy and other parameters when defining their characteristics. The rates vary from 60 to 300 per second. The acceleration of particles in bunches necessarily reduces significantly the average beam intensity obtainable from the accelerator." (10:11)

Synchrocyclotrons are huge machines having gross power requirements and costing several millions of dollars. Figure I-5.

The synchrocyclotron provided, for the first time, energies capable of exposing facts about the atom only theorized before. There is no theoretical limit to the energy capabilities of a synchrocyclotron, but there is a definite economic limit. The design of a synchrocyclotron requires a huge electromagnet, and as the energy requirements increase, so does the radius of the magnet. To reach energies in the billion electron volt range (Bev) with this type of accelerator is not feasible from a cost standpoint.

PROTON SYNCHROTRONS

To achieve Bev energies scientists developed a new technique. They created the proton synchrotron "in which the magnetic field rises in step with the momentum of the particles being accelerated. This keeps the particles moving in a circle of virtually constant radius rather than in the widening spirals of cyclotrons and synchrocyclotrons.

The advantage is that it eliminates the entire center section of the magnet, with resultant cost savings." (10:15) See figure I-6.

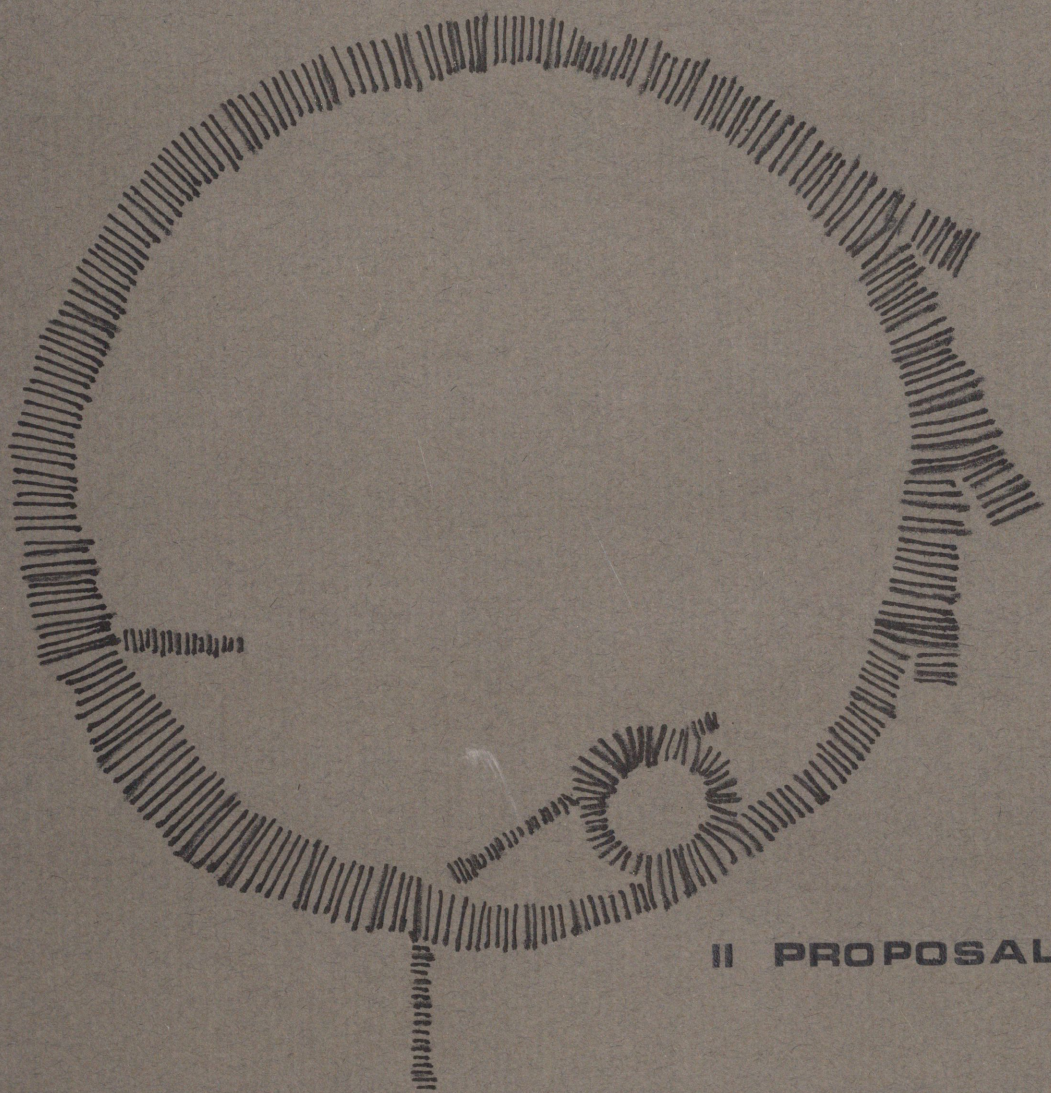
The synchrotron is essentially a large doughnut-shaped ring of magnets. The particles to be accelerated are injected by a linear accelerator (pre-acceleration is necessary to start this type of accelerator) into a vacuum tube traversing the magnetic path. The magnetic field then rises as the particle is accelerated by crossing one or more gaps of radio frequency fields.

The synchrotron is the key to accelerators in the high energy range (Bevs). A synchrotron at Brookhaven National Laboratory (33 Bev) is "capable of producing particles such as the Ω^- (omega minus) meson whose existence had been predicted on theoretical grounds but which had never been observed until 1964." (10:17)

The size of these machines stagger the imagination. The synchrotron at Brookhaven National Laboratory discussed above, has a circumference of "about one-half mile, and consists of an 18-foot-square tunnel covered by earth for shielding. To pre-accelerate and inject the beam there are a 750 kev Cockroft-Walton generator and a 110-foot long, 50 Mev linear accelerator. The main bending and focusing magnets for the accelerator consist of 240 units, each

weighing about 20 tons. About 14,000 tons of concrete shielding were used in the target building, and over 2,000,000 linear feet of power and control cables were used in the construction of the machine." (10:17)

Table I-1 shows the existing accelerators of a 200 Mev or greater energy range. The United States is now designing a proton synchrotron capable of accelerating particles to an energy level of 200 Billion electron volts.



II PROPOSAL

The need for experiments in high-energy particle physics was anticipated in the middle 1950's. When strong-focusing proton synchrotrons came into operation at CERN (European Organization for Nuclear Research) and Brookhaven National Laboratory, New York, plans for higher energies became feasible. (I:68) In 1962 the Lawrence Radiation Laboratory submitted proposals to the Atomic Energy Commission requesting authorization to conduct studies for an accelerator in the range of hundreds of Bevs. Their request was "considered in the context of the national

---

Note: This proposal and subsequent building program is based largely on a design study performed by the Lawrence Radiation Laboratory under contract with the United States Atomic Energy Commission, published in June, 1965.

program in high-energy physics by a scientific advisory panel appointed by the General Advisory Committee to the Atomic Energy Commission and by the President's Science Advisory Committee." (5:I-2)

The following recommendation was given concerning the Lawrence Radiation Laboratory request:

> "Construction by the Lawrence Radiation Laboratory of a high energy proton accelerator of approximately 200 Bev energy, with construction authorization at the earliest possible date. This accelerator should be a major national facility, and in its planning, consideration should be given to the convenience of users groups and visiting scientists from other parts of the country." (5:I-2)

With authorization, Lawrence Radiation Laboratory proceeded with a design study of a 200-Bev proton accelerator.

The authorization for this study is based primarily on scientific justification, which is indicated in a report issued by the Atomic Energy Commission in January, 1965, intitled, "Policy for National Action in the Field of High Energy Physics." Portions of this report are quoted below:

> "Proton energy is the single most important parameter to be extended. Research carried out during the last fruitful years at the 30-Bev Brookhaven and CERN machines has been very fruitful but has raised important questions that can be answered only by higher energy experiments.
>
> "The strong interaction probabilities vary rather slowly with proton energy. Likewise, the energy available for secondary particle production and the

energy of the secondary particles rises slowly as the primary proton energy is raised. For these and other reasons, a substantial factor of increase in accelerator energy is needed over the 33 Bev now available at Brookhaven and the 70 Bev expected from the Soviet accelerator under construction at Serpukhov (estimated completion date, 1966).

"There are now clear needs for a proton machine following the conventional alternating gradient synchrotron (AGS or proton synchrotron) design but having an energy of hundreds of Bev. These needs can best be met by the immediate design and construction of an AGS in the 200-Bev range, followed by a super-high-energy accelerator (600 to 1000 Bev) at a later date.

"The number of machines of highest energy is necessarily small, while the number of high energy physicists is increasing. The two-step approach toward the highest energy will make this undesirable situation less severe. Having two higher energy accelerators rather than one also has the advantage that the second one would have a higher energy than could be achieved if only one machine of say about 500 Bev energy were provided.

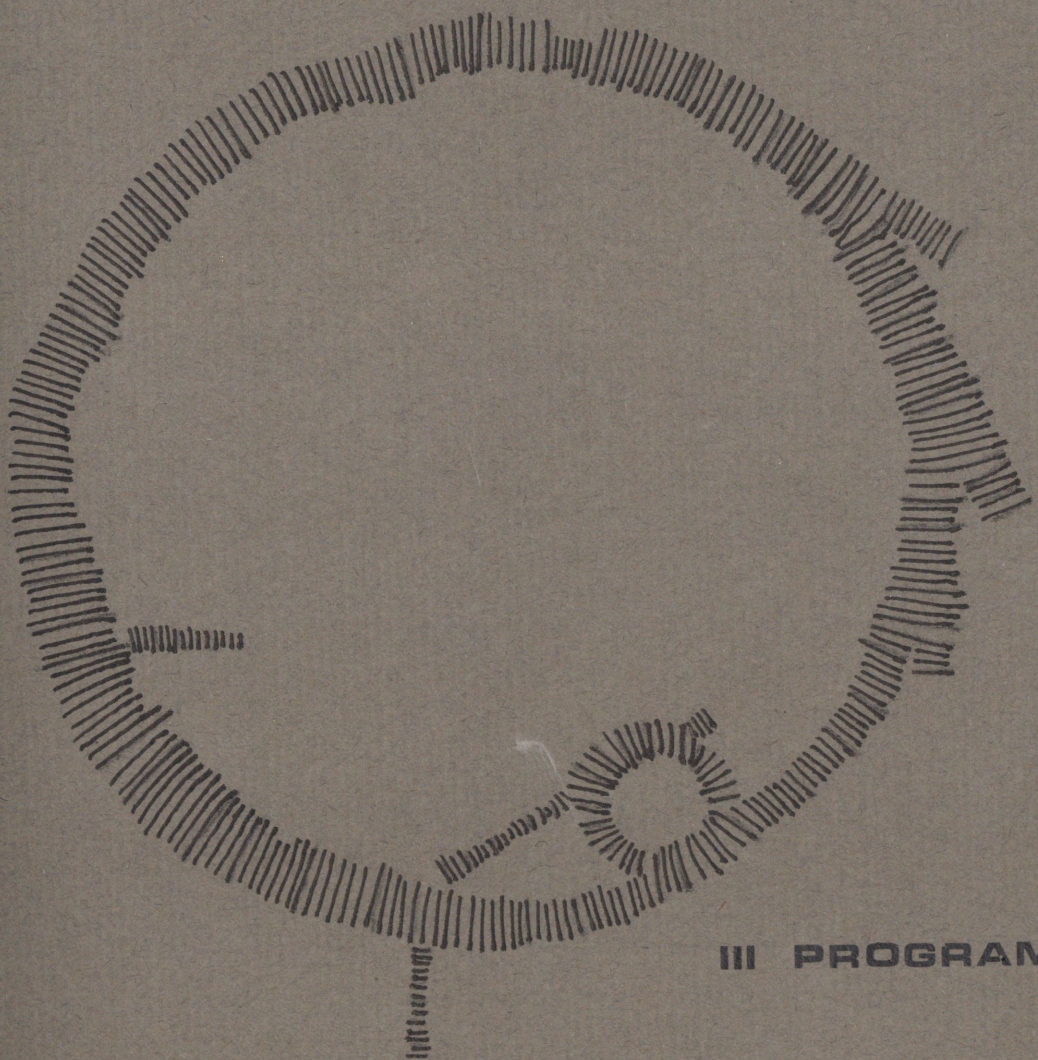
"Although it is important to see how the first accelerator fits into the long-range plan which includes the higher energy second accelerator, the first (200 Bev range) accelerator is, and must be, justified on its own merits. The decision to authorize the 200 Bev machine should be made on the basis that higher energy is needed now and can be provided by extension of existing accelerator technology and without regard to the eventual design and construction of a 600-to 1000-Bev machine which may require new approaches, and certainly requires a much more detailed engineering approach." (12:I-45)

Many people have emphasized that no practical applications of particle physics can be envisaged. This complaint could have been raised against earlier frontiers of physics, when no application of electricity, atomic

structure, and nuclear physics had been forecast. Yet, these areas of research have completely reshaped the world we live in today. Although it is too early to predict applications of particle physics, the past indicates the necessity for research in this area. The following quotation from the Lawrence Radiation Laboratory study indicates their feeling towards this project.

> "Elementary-particle physics has very great intrinsic importance. It seeks to answer the most fundamental questions about the ultimate nature of matter and about the forces acting in matter. In seeking these answers it touches profound questions about the nature of space and time. From experiments at higher energies and associated theoretical work could come a synthesis of knowledge comparable in scope and effect to the great and far-reaching advances of relativity and quantum mechanics.
>
> Scientific research has become a brilliant part of civilization, not only because of its many technological applications, but also because of its contributions to the culture of society. Perhaps the greatest intellectual advances of the century have come in the deeper understanding that science has given us of nature in all its facets. Elementary-particle physics seeks, in concert with other branches of science, to deepen still further this understanding." (5:II-7)

It is hoped that the study of particle physics will have many applications to technology that cannot be dreamed of today. If returns on research investments of the past can be equalled by returns on research investments of the future, this project will be invaluable to our technological advancement.



III PROGRAM

The following summation describes the general components of the 200 Bev accelerator. See figure III-1. The function of this accelerator follows the principle discussed in accelerator history under the heading of "Proton Synchrotrons".

Protons generated from an ion source are accelerated to an energy level of 750 kev in a Cockroft-Walton preinjector. These particles are then accelerated to a higher energy level of 200 Mev in a linear accelerator. At 200 Mev, the protons are injected into an 8 Bev injector synchrotron. At this energy, they are transferred to the main synchrotron in seven pulses and stored in orbits around the main accelerator ring. The protons are then accelerated to full energy - 200

Billion electron volts. The particles are extracted to either of two external experimental areas, or observed in one internal experimental area.

The main synchrotron is approximately 0.8 of a mile in diameter with a circumference of 14,230 feet. The ring contains 12 straight sections for injection, acceleration, and experimental uses. The protons circulating around the accelerator are contained within a vacuum chamber of elliptical shape which passes between the poles of a continuous magnet system that bends the proton orbit in a circular path. There are 528 primary magnets controlling the proton beam. Three radio-frequency stations provide acceleration and a motor-generator unit provides direct-current power. A central control building monitors the operation.

The function of the main accelerator, the injection system, the control building, and experimental areas will be covered in detail in the subsequent program. Consideration will also be given to support facilities and future expansion.

MAIN SYNCHROTRON

The main synchrotron is an alternating gradient proton

synchrotron with an effective energy capability of 200 Billion electron volts. The synchrotron forms a circular ring of 2,265 feet average radius containing a continuous system of accelerating magnets controlled by a radio frequency system located in three structures on top of the accelerator ring. The proton beam is circulated between the poles of the magnet system in a continuous tube placed under a high vacuum. The accurate alignment of the beam is controlled by a survey system located in 96 points around the main ring.

Figure III-2 shows a typical ring cross section, giving the location of some of the acceleration equipment to be discussed in this section. The main ring enclosure has the following nominal dimensions:

Length (feet)	Width (feet)	Height (feet)	Gross Area sq. ft.
14,230	19	16.7	434,400

The entire ring is placed under 25 feet or more earth shielding. This shielding is shown in figure III-28.

MAGNET SYSTEM. The main ring has been divided into 12 sections or 'superperiods' corresponding to 12 similar magnet groups. Figure III-3. Each superperiod contains 10 normal unit cells and one 'collins straight-section'. Each unit cell contains 4 primary gradient magnets which provide

the main bending and focusing of the particle beam to keep it within the circular vacuum chamber. Of the four magnets in each unit, two face toward the center of the ring providing radial focusing (F) and two face outward providing radial defocusing (D). The units group in an FOFDOD pattern with the spaces between like magnets 'O' used for placement of secondary magnets that provide small field corrections as needed or desired. Figure III-4.

The collins straight-section contains two short gradient magnets and two 'collins quadrupole' focusing elements. Between these magnets there is 112 feet of straight drift space. These straight sections are placed around the ring for specific purposes. The 12 straight sections (one per superperiod) have the following functional breakdown.

ASSIGNMENT OF LONG-STRAIGHT SECTIONS

Injection 1

Transfer station for 200 Mev injection synchrotron to main synchrotron.

R. F. Stations 3

Location of each of three radio-frequency galleries is directly overhead three straight sections.

Internal Target Area 1

The drift space of one section is used to locate an experimental area.

Extraction 3

Two straight sections are used for placement of components to extract the beam to an external experimental target. One more will be used for a future external target area.

Spares 4

Even unused sections provide economy of design (drift length of 112 feet without magnets). These may be used in future development.

The following list gives the total number of primary and secondary magnets, including their length.

PRIMARY RING-MAGNET EIEMENTS	NO. OF UNITS	UNIT LENGTH (ft.)
1. Normal gradient magnet (F&D magnets, 4/unit, 10 units/superperiod, 12 superperiods)	480	20.64
2. Short gradient magnets (two per/superperiod at each end of straight section)	24	7.8
3. Collins quadrupoles (2 per/superperiod at each end of straight section)	24	10.4

*SECONDARY RING-MAGNET EIEMENTS

*The following magnets, used for minor corrections, are located in spaces between primary magnets	NO. OF UNITS	UNIT LENGTH (ft.)
1. Trimming quadrupoles	120	1.7
2. Sextupoles	120	1.4

3.	Vertical closed-orbit deflectors	72	0.9
4.	Horizontal closed-orbit deflectors	72	1.1
5.	Vertical steering magnets	24	1.5
6.	Long horizontal steering magnets	6	3.6
7.	Short horizontal steering magnets	18	2.2
8.	Skew quadrupoles	24	1.1

RADIO-FREQUENCY SYSTEM. The radio-frequency (RF) system provides acceleration control. Radio frequency control is necessary to reach an energy of 200 Bev because of the relativity effect discussed in section I, Accelerator History. This control is common to all proton synchrotrons.

The function of the system is to change the frequency of acceleration pulses to correspond with the location of the particle beam (the beam is in seven groups or pulses). This keeps the particle beam in phase with magnet pulses, assuring continued acceleration when the particle beam approaches the speed of light.

The radio-frequency system is located in three RF galleries placed above three collins straight sections. Each RF gallery contains 14 radio frequency control cavities, giving a total of 42 cavities. Thirty-six are needed for acceleration; six are inactive spares in reserve. Figure III-5 shows the location of an RF station over the

accelerator structure, and figure III-6 shows the equipment arrangement of an RF station.

The RF galleries have the following nominal dimensions:

Length	Width	Height	Gross Area (sq. ft.)
200	25	22	3 @ 5000 = 15,000

The RF galleries should be located in areas of deep cut (site topography) so earth shielding can be easily incorporated.

VACUUM SYSTEM. The particle beam travels along the main accelerator path in a tube of elliptical cross-section. This tube is placed under a high vacuum. The purpose of the vacuum system is to reduce 'beam-loss'. Beam-loss is caused by scattering of proton particles (meaning discontinuation of the accelerated beam) because of interaction with other particles within the beam chamber. Such interactions are primarily gas-scattering interactions (air). By placing the chamber under a high vacuum, these problems become negligible.

The vacuum system operates in two parts. The initial roughing from atmosphere pressure is done by conventional oil-sealed mechanical pumps. The final vacuum system uses 'sputter-ion pumps'.

The initial roughing system consists of 36 pumping

stations occuring at 400 feet intervals around the accelerator ring. Each station includes:

1 - Mechanical pump (for initial evacuation)

1-- Turbomolecular pump (added evacuation to reduce load on high-vacuum system)

The high vacuum system utilized 283 sputter-ion pumps located within the accelerator enclosure.

The 36 pumping stations are located within utility penetrations located around the main ring. Figure III-7.

SURVEY SYSTEM. The survey system is necessary to adjust for physical variation of beam alignment due to construction inaccuracies, foundation settling, and environment variations. The survey system will be valuable in separating misalignment effects from other effects that cause beam discontinuity.

The primary network consists of 96 survey huts located on top of the accelerator fill. Figure III-8. These huts, shown in figure III-9, are interconnected with survey apparatus used to control beam alignment.

96 survey huts - nominal dimensions:

Length	Width	Height	Gross Area (sq. ft.)
10	8	9	96 @ 80 = 7,700

UTILITIES AND ACCESS STRUCTURES. The number of utilities and access points are dependent upon accelerator use and site conditions. Their type and location will vary with site conditions. The basic plan calls for 12 major utility buildings, and 23 minor utility buildings located around the accelerator ring. There will also be 6 vehicle access structures and one crane access structure. Some of the utility structures will also provide for vehicle access.

Utility Structures. Figure III-10 shows the basic equipment included in the utility structures. These utilities pass into the main accelerator as shown in figure III-11. The elevator shown will be used when the ring passes below existing grade. The utility structures use the labrinth passage for radiation attenuation because air ducts cannot be blocked with shielding. The buildings will be located at 400 feet intervals (three per superperiod). The utility buildings provide access of electrical power for accelerator activity and environment controls, water for magnet cooling, and air exchange for atmosphere control.

The utility structures have the following nominal dimensions:

Major Utility Buildings

Length	Width	Height	Gross Area (sq. ft.)
120	40	20	12 @ 4800 = 57,600

Minor Utility Buildings

Length	Width	Height	Gross Area (sq. ft.)
40	40	20	23 @ 1600 = 36,800

Vehicle Access Structures. Necessity for maintenance of accelerator components and dangers of radiation within the ring enclosure has led to the following access system. The system uses shielded manipulator vehicles traveling on railway tracks paralleling the accelerator magnets. Figures III-12, III-13, and III-14 show three types of vehicle entrances to the main ring. Type A and B are horizontal entrances, with type B designed for access downstream from the internal target area. Type C is a vertical entrance for areas cut into the site.

The accelerator requirements call for three type-A and C accesses, and one type-B access.

The type B vehicle access is also a crane access structure. The location of the cranes within the main ring is shown in figure III-15 and figure III-2. The main ring contains 10 cranes, each with a 20 ton capacity. These cranes are used for removal and installation of the massive magnet elements. Vehicle access structures type A and C have additional cranes as shown in figures III-12 and III-14.

The access structures have the following nominal dimensions:

Type A

Length	Width	Height	Gross Area (sq. ft.)
60	40	20	3 @ 2400 = 7,200

Type B

50	40	20	2,000

Type C

100	40	26	3 @ 4000 = 12,000

INJECTION SYSTEM

The function of the injection system is to provide pre-accelerated particles for the main synchrotron ring. The injection system must have an acceleration capability high enough to match the designed acceleration of the main ring (at point of injection). To achieve adequate injection acceleration, an initial preinjection force field of 750 kev is provided by a Cockroft-Walton machine. This is housed in connection with a linear proton accelerator that increases the particle beam's energy to 200 Mev. From the linear accelerator the beam is injected into a proton synchrotron with an 8 Bev capacity. The 8 Bev machine is similar to the main synchrotron ring with which it connects.

INJECTOR SYNCHROTRON

Because of the similarity between the 200 Bev ring and this 8 Bev injection ring, I will not dwell on function of the parts. The two systems work on the same principle of acceleration; the only difference is in the size and number of components.

The injector synchrotron forms a circular ring 324 feet in radius, located adjacent to and within the circumference of the main ring. See figures III-16 and III-17.

The injection ring has the following nominal dimensions:

Length	Width	Height	Gross Area (sq. ft.)
2033	19	19.1	74,000

The following program lists the basic components of the injector synchrotron.

MAGNET SYSTEM. The ring is divided into 16 similar superperiods, each contains a 'collins straight section' with a 30.6 feet drift space. Figure III-18. These sections have the following use pattern.

Injection 1

Extraction (figure III-19) 1

Acceleration 8

Experiment beam 1

Spares 5

Magnet elements	NO. OF UNITS	UNIT LENGTH (ft)
FD magnet blocks (FD, see magnet system - main ring)	48	12.77
Separate gradient magnets	32	7.67
Collins quadrupole	32	1.29

RF SYSTEM. (see vacuum schematic, figure III-20) Eight radio-frequency galleries are located on the surface of the ring shielding fill, 21 feet above the enclosure. These galleries have the following nominal dimensions:

Length	Width	Height	Gross Area (sq. ft.)
40	25	20	8 @ 1000 = 8,000

VACUUM SYSTEM. Figure III-20.

	NO. OF UNITS
Sputter-ion pumps - within ring enclosure	77
Forevacuum stations (same equipment as main ring stations)	6

SURVEY SYSTEM. (see figure III-8, main ring survey system) There are 32 survey huts located above the enclosure, each with the following dimensions:

Length	Width	Height	Gross Area (sq. ft.)
10	8	9	32 @ 80 = 2,560

UTILITY & ACCESS. There are 4 utility buildings located in a manner similar to the arrangement for the main ring. They have the following nominal dimensions:

Length	Width	Height	Gross Area (sq. ft.)
40	24	20	4 @ 960 = 3,840

Access - through utility and experiment beam tunnel, and also through an injector staging building. Figure III-21.

Staging building. This is the major access point for the injector synchrotron. See figure III-16 (major access). The staging building has the following nominal dimensions:

Length	Width	Height	Gross Area (sq. ft.)
120	80	50	10,200

LINAC & PREINJECTOR. The linear accelerator and preinjector are located in a single enclosure. Figures III-22 and III-23 show the physical configuration of these areas as they relate to the injector synchrotron. The composite units have the following dimensions:

Length	Width	Height	Gross Area (sq. ft.)
Linac enclosure			
500	50	43	
Preinjector building			
100	50	43	38,600

EXPERIMENTAL AREAS

Two external-beam areas and one internal-beam area will be provided in the initial construction. Of the two external areas, one is a "long external proton beam (EPB) area" with three target stations and the other is a "short EPB area" with one target station. At each target station there is a large magnet used to separate primary and secondary beams. Several experiments can be done with secondary beams simultaneously.

The experimental areas should be located at adjacent superperiods if possible to facilitate communications, transportation, services, etc. It is also desirable to locate the external areas on large level areas of the site because of the long run distance of the high energy beams.

Figure III-24 shows the general configuration of an internal experimental area and two external experimental areas located in adjacent superperiods.

INTERNAL EXPERIMENT AREA. The internal experiment area is shown in figure III-25. This area is located along the main ring. Experimentation can be done here without changing the course of the particle beam. A target can be placed within the path of the accellerated beam, and the beam will pass through it many thousands of times in its normal circulation.

EXTERNAL EXPERIMENT AREAS. To reach the external experimental areas, the beam must be extracted from its normal path as shown in figure III-24. The external experiments differ from the internal experiments in that the beam passes through the target only once. From this single interaction, secondary particles are generated that are also experimented with and observed. The two external areas are shown in figures III-26 and III-27.

The experimental areas have the following nominal dimensions, not including uncovered areas.

Length	Width	Height	Gross Area (sq. ft.)
Internal Area			
400	200	67	83,000
Short External Area			
360	200	67	75,000
Long External Area			
420	200	67	87,000

The short EPB and the internal area each contain one-50-ton crane (194 feet span). The long EPB contains two 50-ton cranes (194 feet span).

RADIATION PROBLEMS

Radiation problems can be divided into three categories:

1. Shielding - danger of high energy radiation during operation of synchrotron.
2. Residual radioactivity - induced radioactivity from accelerator operation that continues after shutdown of synchrotron.
3. Radiation damage - breakdown of materials subjected to large doses of high energy radiation.

1. Shielding. Figure III-28 shows the approximate radiation level variations above the earth shielding that covers the accelerator components. Acceptable doses for personnel are in the range of .06 mrem/hour. The area of high radiation during accelerator operation is near the experimental stations. The shielding and location of various accelerator components are shown in figure III-29.

2. Residual radioactivity is caused by induced radioactivity in accelerator parts because of high energy interactions with the particle beam during acceleration operation. Although the radiation levels are lower, they last longer, and during periods when personnel must work in the accelerator enclosure. Air, water, and dust scraps

are the important materials to control. Ventilation will reduce the level of radioactive air to an acceptable level. Water used for cooling of accelerator components will also contain radioactive isotopes. The decay rate is such that the water can be discharged into streams within a few hours after accelerator shutdown. Dust, scraps, and chips should be controlled within the enclosure. Vacuuming of components, and proper clothing of personnel would reduce dust and scrap build-up with the accelerator ring.

3. Knowledge of radiation damage is important when choosing accelerator parts. Some components will have to be replaced periodically; this partly justifies the extensive access and crane system.

CONTROL CENTER

The size and complexity of the 200 Bev accelerator requires a large control system. There are approximately 20,000 monitoring and control functions that are processed at a central control center. The monitor and control signals are connected to the accelerator through utility structures at 400 feet intervals. In the control center, the data will be collected, stored in memory banks, and presented to operators in a usable form. Control signals

will be sent in a similar way, passing from the control center to the accelerator components.

Figure III-30 shows the location of the 58 data stations planned for the facility. They are arranged as follows:

Main ring	36
Motor-Generator Building	1
Injector synchrotron	8
Linear accelerator	3
EPB area (short)	5
EPB area (long)	5

The information will be transmitted from the data station to the central control computer by a time shared multiplex system. Figure III-31 shows a schmatic diagram of the computer system.

Communications between remote accelerator areas and the control center are furnished by closed-circuit television with an audio channel. Telephone communication will also be available at plug-in stations around the two synchrotrons and linear accelerator

The control building is located at the center of accelerator activity near the two synchrotron rings and the

linear accelerator. The control building has the following nominal dimensions:

Length	Width	Height	Gross Area (sq. ft.)
80	50	85	4 floors = 13,000

MOTOR-GENERATOR BUILDING

The motor-generator (M-G) building houses the main power supply for the 200 Bev accelerator. The M-G building contains the following equipment:

Two motor-generator sets, each consisting of:

1-alternator driving motor, 12,000 hp @ 1200 rpm.

1-alternator, 20 feet in diameter and 20 feet long.

The M-G building will be located near the center of the accelerator ring. The prime purpose of the motor-alternator sets is to supply and to store temporarily the energy required to excite the main magnets, thus preventing load fluctuations in the supply network.

To power the main accelerator ring the main power station is linked with 24 convertor stations located around the main ring (2 per superperiod). Figure III-32 shows a schematic diagram of this relationship.

The M-G building has the following nominal dimensions:

Length	Width	Height	Gross Area (sq. ft.)
270	85	40	24,000

The M-G building contains one 20-ton capacity crane (80 feet span).

SUPPORT FACILITIES

The following program, as submitted by the Lawrence Radiation Laboratory, will be used to relate the various support facilities to the overall site plan. These areas will not be designed in great detail, but consideration will be given to their physical form, their location, and their basic functions as related to the accelerator.

SUPPORT FACILITIES PROGRAM

	GROSS AREA (ft^2)
Resident Physics	
1. Operations and Development	21000
2. Theoretical Physics	17000
3. Bubble-Chamber Physics	19000
4. Counter Physics	16000
5. Computer Center	21000
	94000

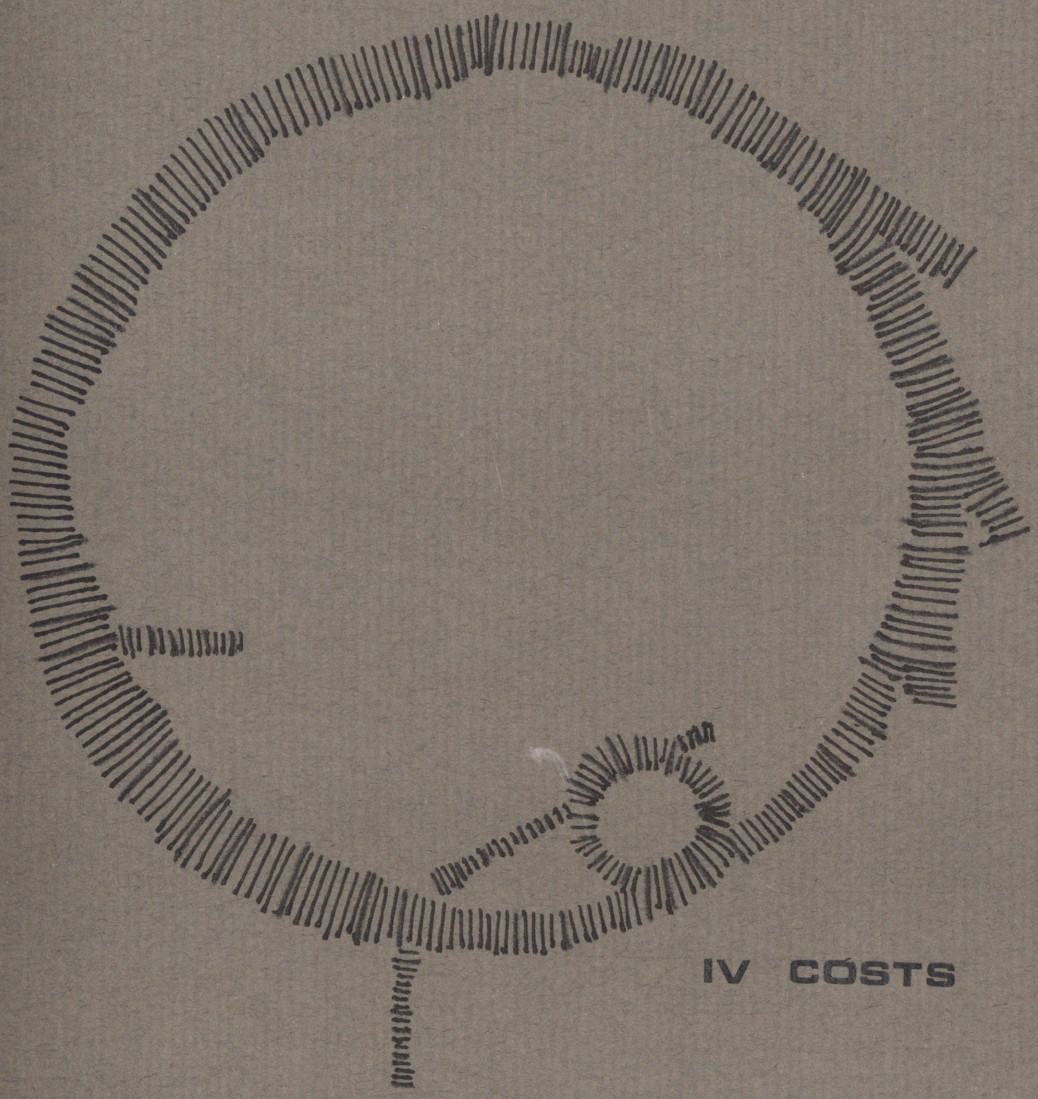
	Visitor Physics		
6.	Light Laboratory and Office	57000	
	Direct Support		
7.	Heavy Laboratory	26000	
8.	Mechanical and Plant Engineering	26000	
9.	Electronic Engineering	26000	
10.	Mechanical and Electronic Shops	108000	
11.	Craft Shops	37000	
12.	Film Processing	9000	
			232000
	Indirect Support		
13.	Administration	40000	
14.	Mechanical, Security, and Fire	8000	
15.	Plant Services	6000	
16.	Stores and Transportation	144000	
17.	Auditorium	10000	
18.	Cafeteria	14000	
19.	Housing	13000	
			235000
	Total		618000 (5:XV-4)

PARKING. Parking for 2500 cars will be required. The personnel parking relates closely to the support facilities and the

location of personnel during work periods. Table IV-1 lists accelerator personnel and their area of work.

FUTURE EXPANSION

Experience at many accelerators has shown the importance of flexibility in site arrangement to allow for future expansion. Future expansion of this facility has been anticipated as shown in figure III-33. The function of the areas shown will not be dealt with in this paper. However, space allotment for such future expansion will be considered in the site design.



IV COSTS

The cost estimates of the accelerator complex are taken from data presented by the Lawrence Radiation Laboratory. The estimates include engineering, design, inspection, and administration costs. Contingencies are rated at 25% for technical components and 15% for conventional facilities. (5:I-7)

Construction cost estimate summary	Millions of dollars
Accelerator housings and components	192.8
Experimental facilities	59.1
General plant and utilities	35.9
Total accelerator facility	$287.8

Estimation of cost escalation during construction (6–8 years) and funds for research equipment were added to the building budget to give a total of:

Total Authorization Summary	Millions of dollars
Accelerator facility	287.8
Escalation	19.7
Research equipment	40.5
Total	$348

CONSTRUCTION COSTS

The cost of construction can be broken into two categories: accelerator components and accelerator housings and auxiliary structures. The cost of components will not affect the physical aspects so they will not be discussed. The following cost list is concerned with the building construction of the accelerator laboratory complex.

Accelerator housings and auxiliary structures	Thousands of dollars
1. Main synchrotron	
a. Accelerator enclosure (including rf houses)	14770
b. Penetrations and auxiliary structures	
(i) Utility and control accesses	4820
(ii) Utility and vehicle accesses (Type C)	960

(iii)	Vehicle accesses (Types A and B)	610
(iv)	Survey houses	100
c.	Magnet foundation and support	4850
d.	Earthwork and yardwork	5330
e.	Utilities	
(i)	Inside enclosure	3770
(ii)	Outside enclosure	7310
f.	Air conditioning	520
g.	Enclosure cranes	290
h.	Motor-generator building and foundations	1030
		44360
2.	Injection system	
a.	Synchrotron enclosure	2680
b.	Penetrations and auxiliary structures	
(i)	Utility and control accesses	550
(ii)	Radio-frequency galleries	240
(iii)	Staging and access structures	400
(iv)	Survey	40
c.	Magnet foundation and support	720
d.	Earthwork and yardwork	1140
e.	Utilities	
(i)	Inside enclosure	1490
(ii)	Outside enclosure	1780
f.	Air conditioning	430

g.	Enclosure cranes	60	
h.	Magnet power supply building	100	
i.	Linear-accelerator housing	1740	
			11370
3.	Control building		410
	Subtotal, accelerator structures		56140

Experimental Facilities

1.	Short EPB		
a.	Experimental building (75000 ft^2)	1130	
b.	Outdoor paving and crane runway	160	
c.	Crane	220	
d.	Foundations for shielding and magnet	190	
e.	Earthwork and yardwork	170	
f.	Utilities		
(i)	Inside	1030	
(ii)	Outside	1810	
g.	Shielding		
(i)	Heavy concrete	500	
(ii)	Lead	50	
(iii)	Iron	440	
(iv)	Depleted uranium (or equivalent)	2530	
			8230

2.	Long EPB		
	a. Experimental building (87000 ft^2)	1330	
	b. Outdoor paving and crane runway	350	
	c. Cranes (2)	440	
	d. Foundations for shielding and magnet	630	
	e. Earthwork and yardwork	530	
	f. Utilities		
	(i) Inside	1200	
	(ii) Outside	2700	
	g. Shielding		
	(i) Ordinary concrete	50	
	(ii) Heavy concrete	2600	
	(iii) Lead	2730	
	(iv) Iron	3610	
	(v) Depleted uranium (or equivalent)	6610	
			22780
3.	Internal-target facility		
	a. Experimental building (83000 ft^2)	1260	
	b. Crane	220	
	c. Foundations for shielding	550	
	d. Earthwork and yardwork	90	
	e. Utilities (all inside)	1140	
	f. Shielding	4370	
			7630

4.	Injector-synchrotron experimental area		
	a. Experimental building (21000 ft^2)	220	
	b. Crane	190	
	c. Utilities	290	
	d. Shielding (beam backstop)	200	
			900
5.	Motor-generator building and foundation	890	
	Subtotal, experimental facilities		40430
General Plant and Utilities			
1.	Site development		
	a. Roads and parking	890	
	b. Railroad sidings	190	
	c. Fencing and guardhouses	180	
	d. Miscellaneous (substation pads and fences, etc.)	370	
	e. Site earthwork	390	
			2020
2.	Site utilities		
	a. Cooling towers	5240	
	b. Water system	760	
	c. Electrical system		
	(i) Main substation	460	
	(ii) Site distribution	2650	
	(iii) Communications, external-plant fire alarm, and area lighting	100	

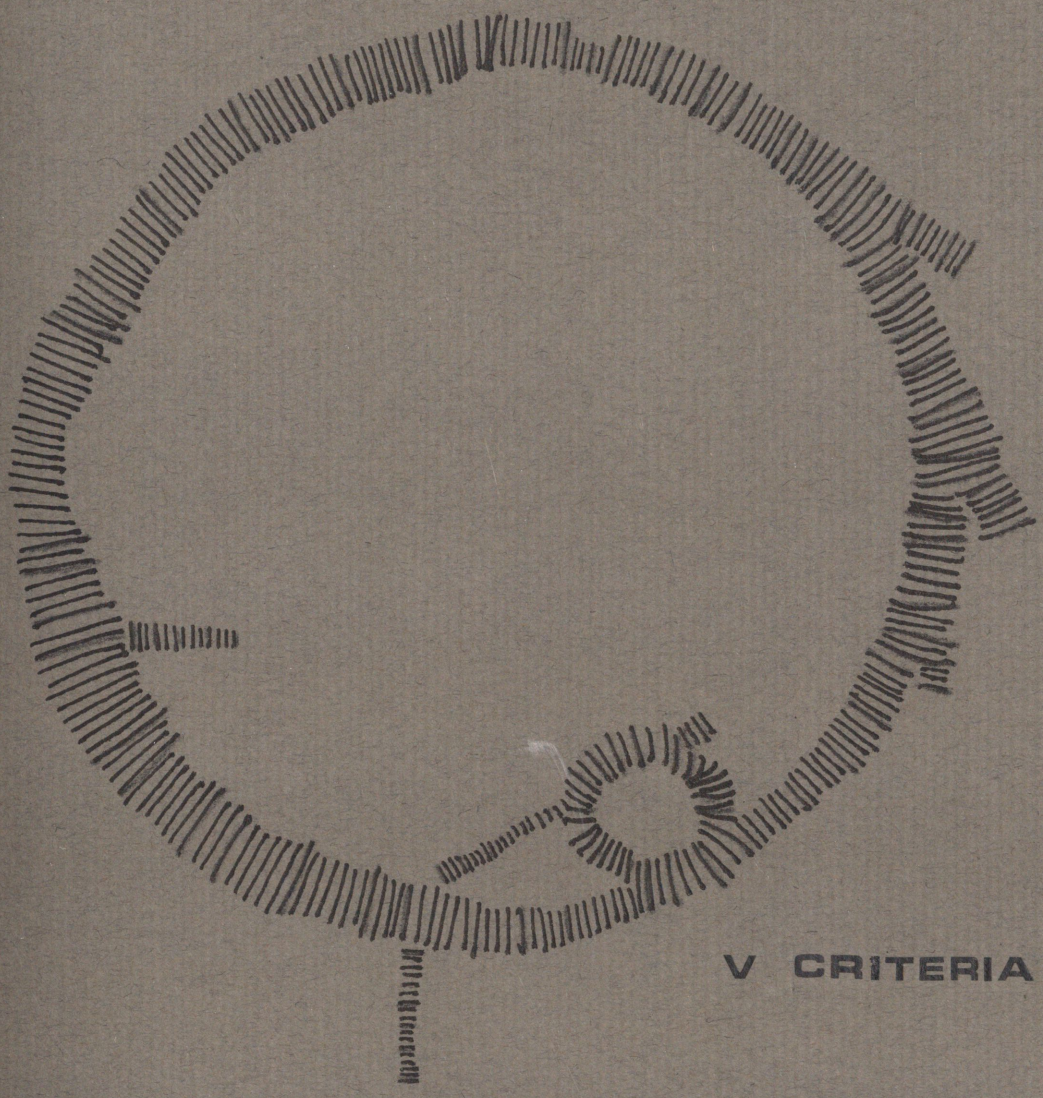
(iv)	Temporary construction power	50
d.	Sewage systems	
(i)	Storm drainage	470
(ii)	Sanitary sewers	460
e.	Industrial gas distribution	30
		10220
3.	Support buildings	
a.	Resident-physics offices and laboratories (94000 ft^2) (includes operation, accelerator development, and computer center)	2840
b.	Visitor physics offices and laboratories (57000 ft^2)	1720
c.	Direct-support shops and services (232000 ft^2)	6500
d.	Indirect support (235000 ft^2)	4100
		15160
	Subtotal, general plant and utilities	27400
	Total accelerator facility	123970

(5:XVI)

OPERATIONAL COSTS

The operational costs vary radically over the period of construction, therefore the cost data given here is

projected for the fiscal year 1977. This is a more stable indication of the yearly operational cost based on accelerator functions and staff salaries. Table IV-1, gives the estimated staff and their areas of study. Table IV-2 shows the estimated annual budget.



V CRITERIA

The following list of criteria has been formulated by the Lawrence Radiation Laboratory for their use in analyzing various proposed sites for the accelerator complex. The subsequent sections will describe the Arlee site, based on these criteria.

200 Bev Accelerator Laboratory - Site Criteria

(i) Necessary area--a minimum of 2500 to 3000 acres; more area is desirable.

(ii) Geologic conditions--substructure should have a load-bearing capacity and settlement characteristics adequate to ensure stable foundations for the accelerator

facility. Seismic history must be considered.

(iii) Topography--excessive variations in elevation will increase the costs of design, excavation, and construction.

(iv) Utilities--adequate electric power and water should be available at reasonable rates.

(v) Transportation--proximity to major transportation is desirable.

(vi) Climate--construction and operating time, costs, and convenience are benefited by mild climatic conditions.

(vii) Personnel availability--it is desirable to be close to an existing source of skilled personnel.

(viii) Industrial services--it is desirable to be close to sources of the many industrial services required in construction and operation.

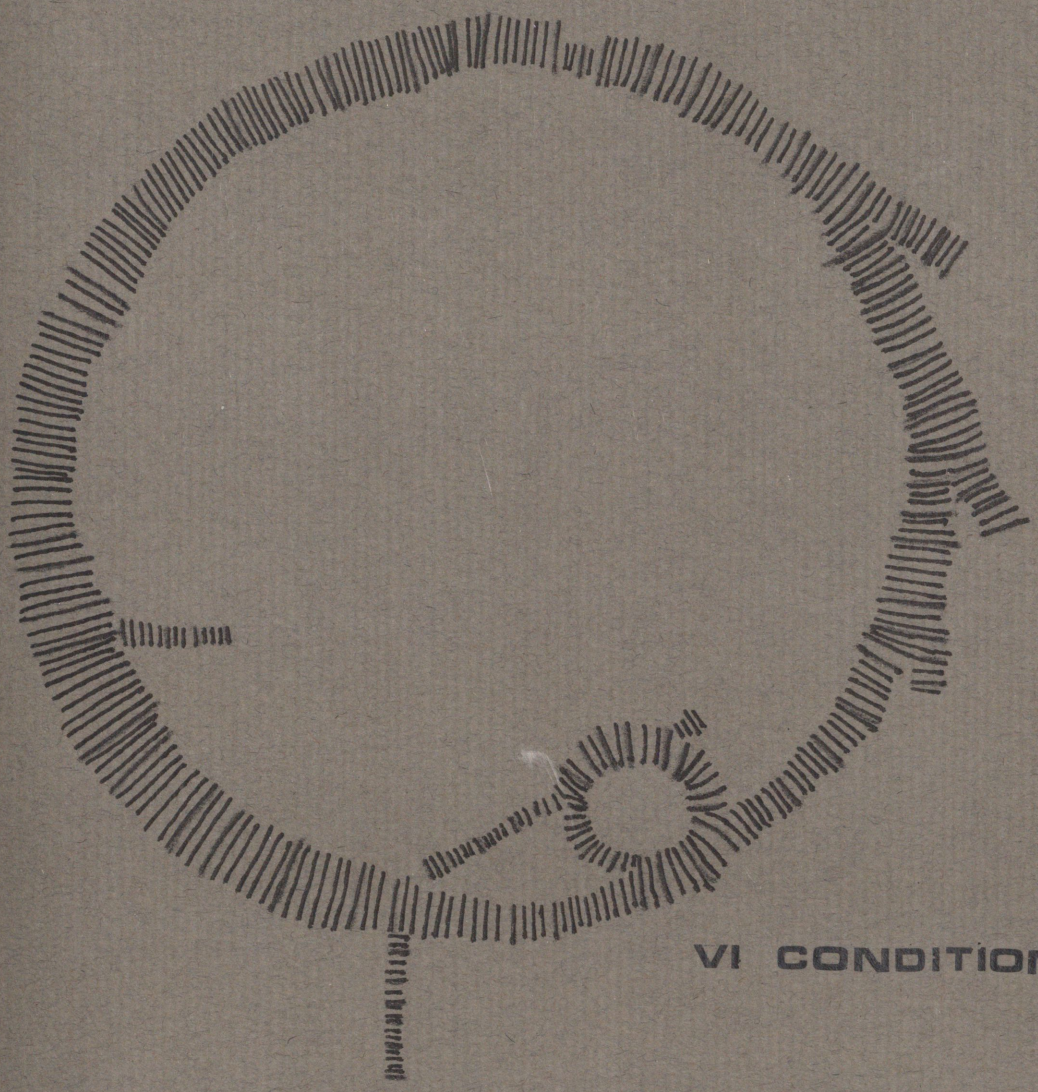
(ix) Proximity to a university--a nearby university can aid the program of the accelerator facility and will provide intellectual and cultural opportunities attractive to visitors and staff.

(x) Community services--desirable nearby communities will aid in the attraction and retention of personnel.

(xi) Existing facilities--buildings and utilities that are usable in the early stages of construction can be of

material assistance in meeting the construction schedule and in reducing first cost.

(xii) Local cost factors--local wage rates and living and materials costs can significantly affect the total cost. (5:XIV-2)



VI CONDITIONS

The proposed site occupies approximately 8,000 acres in the Jocko Valley of Western Montana. The valley is located in the southwest corner of Lake County, Montana, and has an average elevation of 3,100 feet above sea level with surrounding mountains reaching an elevation of 7,000 feet. See map, Figure VI-1. The community of Arlee, Montana, is located on the southwest perimeter of the site, and will be used as a reference point in relating the site to surrounding cities, universities, and research facilities.

RELATION OF SITE TO SURROUNDING FACILITIES

The closest related research facility is located on the campus of the University of Montana, which lies 27 miles to the south of the site. There is a small linear accelerator facility located on the University of Montana campus which would provide a valuable interchange of ideas between university staff and the accelerator laboratory scientific teams. (9) This campus would provide a continually changing nucleus of graduate students who would have need of the accelerator laboratory. Figure VI-2 shows the geographic locations (with approximate distances) of other universities and research facilities with respect to the University of Montana at Missoula.

PERSONNEL FACILITIES

The addition of the accelerator laboratory to the Missoula-Arlee area will necessitate changes in two categories of existing facilities at Arlee and Missoula. The first change involves housing of accelerator personnel. Various problems of commercial business expansion will be grouped in this category because of the obvious mixed cause-effect relationship. The second concern is in the area of cultural environment available for the laboratory personnel.

The housing of personnel will be spread out over a period of at least 6 to 8 years (the evenness of distribution is not determinable). Assuming an initial load of 800 to 1,000 people, many would seek housing in the Missoula area. Eventually, a portion of the personnel would move to the Arlee area. Others would remain in Missoula. The proximity of Missoula would, with its existing social and economic desirabilities, draw a large number of permanent residents from the laboratory staff.

Regardless of the Missoula urban center, 50-60% of the accelerator personnel would probably prefer to live adjacent to the Arlee site. This would indicate 1,000 to 1,200 homesites or a combination of homes and apartments. With this increase, there would be a corresponding business uplift in the Arlee community.

Cultural activities would always be close at hand on the University of Montana campus and in Missoula. Because of the short distance between Arlee and Missoula, social activities would have a minor effect on location of housing.

TRANSPORTATION

Highway and rail movement will be a primary design consideration to link Arlee with Missoula. Beyond this

point, air travel will be the major mode of transportation, with railway support to the site for freight supply.

The existing highway system will be modified in the proximity of the site, with possible improvement of the public system between Arlee and Missoula. The main line of the transcontinental Northern Pacific Railway which parallels the southwest border of the site will provide adequate passenger facilities in its existing state. Additional spur tracks will have to be added to the system to provide a proper freight facility at the site. The existing line does not carry freight traffic. Freight is now routed on a line to the south, but this condition could be altered when the accelerator facility is built. Freight traffic to the site would probably come out of Missoula.

Existing air travel will have to be expanded to provide adequate time schedules for arriving and departing of the personnel of the accelerator laboratory. Northwest Orient Airlines now serves Missoula with two east-west and two north-south flights per day. (11:6-15) This flight schedule will have to improve to meet the demands of the accelerator laboratory.

CLIMATIC CONDITIONS

The basic environment problems involve temperature variances and precipitation extremes. The temperature highs and lows cause physical discomfort, building construction problems, high heating and cooling costs, and possible interference of experiments done in unenclosed areas. The major precipitation problem is snowfall which causes difficulty in transportation and is also difficult to remove from the site if the quantity is great enough.

Figures VI -3 and VI -4 give detailed information regarding annual temperature and precipitation data. The site's location in a valley surrounded by high mountains greatly reduces the climatological problem. The mountains, located on the east and west sides of the valley, provide natural protection from the prevailing winds (from west to east in this area). The average wind velocity in the valley is only 6 miles per hour. (3:11) The mountain slopes receive most of the precipitation, bringing the annual valley snowfall average down to approximately 10 inches at any one time throughout the winter months. (7) The temperature problem is reduced (from a comfort standpoint) by the low relative humidity common to most areas of Montana.

SEISMIC ACTIVITY

Earthquake damage to a facility of this scope would be extremely disastrous in terms of dollar loss and research setback. Therefore, seismic activity should be considered in the initial site selection. The Arlee site is located in a relatively mild seismic activity zone. Figure VI-5. The technical explanation of Arlee's protective location is as follows:

> ". . . immediately southwest of Missoula is the huge Idaho Batholith, a massive igneous intrusion that was emplaced from 50 to 75 million years ago. This granite intrusive, which has a surface exposure of 16,000 square miles, is dome-shaped and its northeastern shoulder is believed to extend, at depth, under part or all of the Missoula-Arlee area.
>
> Rock structures resulting from post-Idaho Batholith crustal activity all bend around the Idaho Batholith, suggesting that since its emplacement, the Idaho Batholith has acted as a massive and stable buttress which has resisted and turned away the extensive deformation that characterizes much of the rest of the Rocky Mountain region.
>
> It is this Idaho Batholith which, as shown on Dr. Richter's map, is an area of high stability, higher than any other area in the Rocky Mountains and one of the most stable areas in the United States." (3:5)

At this point, the seismic problem is more a matter of predetermining earthquake probability rather than analyzing structural design.

POWER & WATER SUPPLY

REQUIREMENTS. A status report issued by the Lawrence Radiation Laboratory gave these requirements for water and power supply. (14:6)

Initial requirements of 200 Bev accelerator:

Water supply : 2000 gallons/minute

Power capacity : 200 megawatts

Future requirements:

Water supply : 4000 gallons/minute

Power capacity : 300 megawatts

WATER SUPPLY. An adequate water supply is available at the site. The Jocko River flows through the site, as do other small streams. There is also a small grouping of natural springs and an irrigation canal. If the total supply from these streams proved inadequate, wells could be drilled on the site.

The following information on water supply was contained in a paper prepared by the Montana State Highway Commission.

> ". . . information relative to stream flow of the Jocko River was made available from records of the U. S. Geological Survey Supply Papers #1316. These records indicate that minimum stream flow of the Jocko River is 24,684 gallons/minute, while maximum flow is 1,444,238 gallons/minute.
>
> Finley Creek, another stream located on the

> boundary of the site, carries a maximum flow of 232,478 gallons/minute and a minimum of 3,141 gallons/minute." (2:1)

Tests made by the Montana State Board of Health indicate a high degree of purity of all sources of water at the site. Table VI-1.

POWER CAPACITY. There are three existing power lines adjacent to the site. The Bonneville Power Administration controls one which has a 230,000 volt capacity. The other two are 161,000 volt lines operated by the Montana Power Company. Montana Power also has a 230,000 volt line under construction in the area of the site.

In a letter to Representative Arnold Olson, The Bonneville Power Administration indicated the following plans for future expansion of power lines in the Idaho-Montana area.

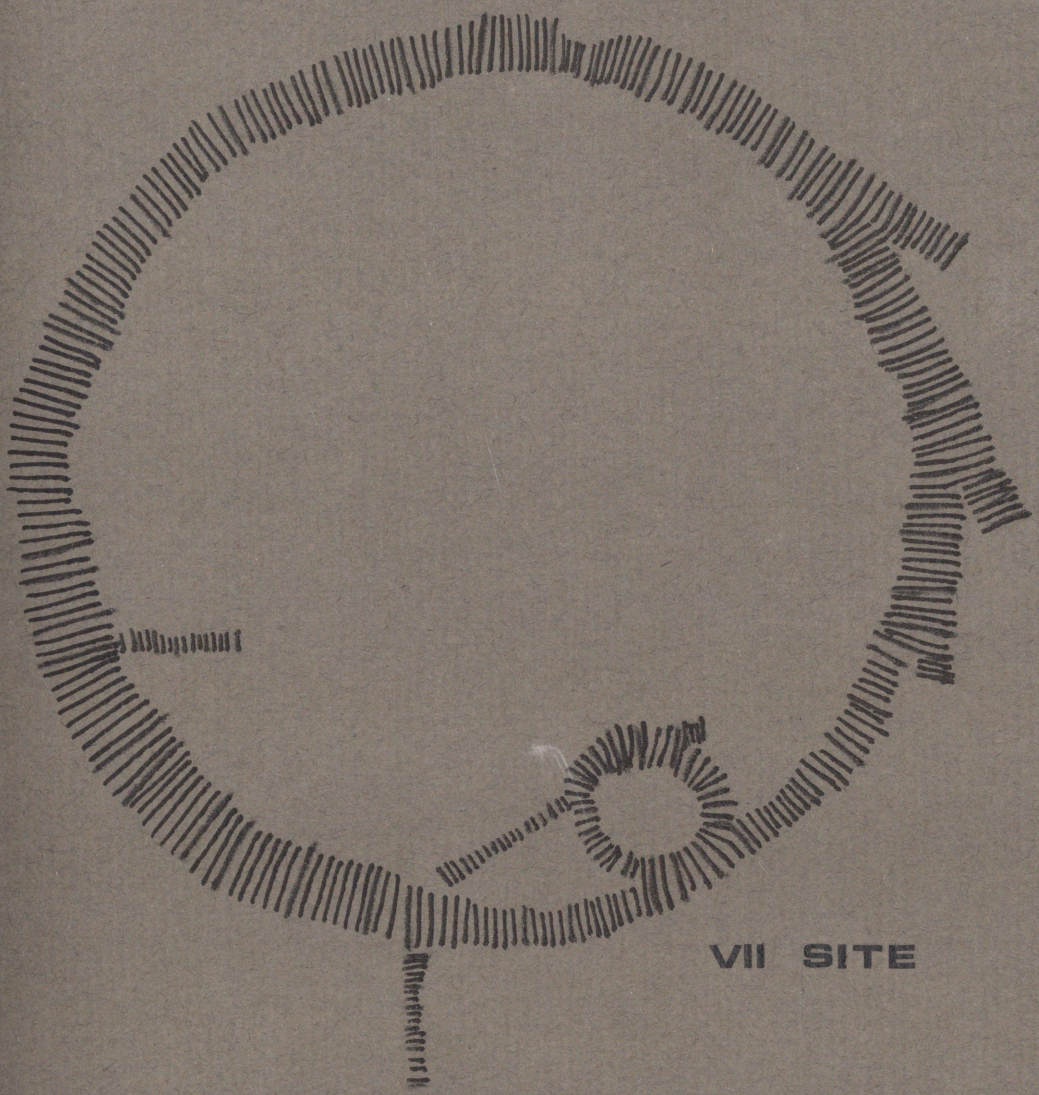
> ". . . the line from Dworshak [Idaho] to Anaconda could be routed close to Missoula; however, no decision has yet been made on a definite route. This line could be completed in 1969 or 1970 and would have a capacity of about 800 megawatts. About half of this capacity, or 400 megawatts, could be made available in the area around Missoula and could be used to serve a new large load that might develop in that area. If we knew in advance exactly where the load was located, the line probably could be routed close to the load so that service costs could be held to a minimum.

In addition, Libby Dam, according to its present construction schedule, will provide an additional power supply in the area of 315,000 kilowatts, beginning in 1973. This power could be made available to serve new loads in western Montana." (15:1)

The following quotation taken from a paper prepared by the Montana State Planning Board indicates an adequate power supply for present and future requirements.

"Bonneville Power Administration reports that, based on current load forecasts and scheduled additions to existing resources, there is available power to supply loads up to 700 megawatts in 1967, 1,100 megawatts in 1970 and 1,800 megawatts in 1973.

BPA can call upon hydroelectric resources located through out the Pacific Northwest and interconnected by means of high-voltage transmission lines, which not only tie together federal plants but are integrated with transmission systems of investor-owned and publicly-owned systems in Montana and adjoining states. The Northwest Power Pool, which includes all major generating utilities in the region, had 14,162,630 kilowatts of installed capacity as of 1964." (3:7)



VII SITE

The proposed site as indicated in figure VII-1, occupies an area of approximately 8,000 acres. This area is primarily farm land with the exception of the Jocko River drainage. Alfalfa is the basic crop, with a large percentage of the area in pasture land of native grasses. (7)

GENERAL TOPOGRAPHY

While appearing relatively level to the eye, the site slopes gently downward from an elevation of 3,360 feet at the southeast boundary to an elevation of 2,960 feet at the northwest boundary. This is a drop of 400 feet over a horizontal distance of 5½ miles, or an average slope of

1.38%. The variance of topography from the southwest to the northeast is more pronounced. Site profiles A, B, C, and D, (figures VII-2 and VII-3) show the existing topography in this direction.

SOIL PROFILE. A soil profile showing the type of material common throughout the valley is shown in figure VII-4. This soil profile is an approximation of conditions as described by John Farrel, who has drilled wells throughout the Jocko Valley, and a report on land conditions in the Jocko River Valley compiled by the Montana Highway Commission. (2,8)

Exceptions to this profile occur within the Jocko River drainage, and near the surrounding mountains where the bedrock comes near the surface and can be observed as rock outcroppings. Figure VII-5, and site profiles (figure VII-2 and VII-3) show the location of bedrock. Figure VII-5 also gives the soil characteristics of the site surface.

RIVER DRAINAGE. The topography undulation shown in the site profiles is caused by the Jocko River drainage. The river itself takes up very little area in the drainage channel. Verne Campbell of the State Fish Hatchery at Arlee, supplied the following information on the behavior of the Jocko

River. According to Mr. Campbell, the average width of the river is approximately 20 feet, with a seasonal variation in depth from 10 inches to 36 inches. Figure VII-6. There is not a major fluctuation from year to year, with the last flooding occurring in 1948, when the river overflowed its banks to a flood level of 2 feet. (7)

This drainage area contains the only concentration of trees on the site. These consist mainly of fir and poplar trees, with some fir trees reaching a height in excess of 70 feet. With this concentration of evergreens, there is a green belt of growth here throughout the year. Figure VII-7.

SITE FEATURES

ARLEE. The community of Arlee, Montana, is located within the site boundaries along the southwest perimeter. The town is extremely small, containing approximately 58 buildings, most of which are in bad physical condition. The highway through the valley divides the town and provides it with a main street where various small businesses are located. These include: a welding-blacksmith shop, a post office, two gas stations, a grocery store, and two bars. The community is comprised primarily of people of Indian descent. Figure VII-8.

HIGHWAYS & ROADS. There is one highway penetrating the site. This is a two-lane, asphalt paved, state-secondary that provides a north-south link between Missoula and Kalispell.

There are also many small gravel and dirt roads crossing the site. The only road that would have to remain is the gravel road that cuts the bottom half of the site in an east-west line. This road continues eastward to Seeley Lake and could be rerouted along the southern boundary of the site.

RAILROADS. The main passenger line of the Northern Pacific Railroad passes through the site as shown on the map.

FISH HATCHERY. The buildings and ponds for the State Fish Hatchery are located within the Jocko River drainage. There are six concrete storage ponds and a small breeding and hatching building. These buildings could be relocated or destroyed.

FARMS. Purchase of the site would include the acquirement of various farm buildings. These buildings, on the whole, are in poor condition and could be destroyed or removed from the site. There are approximately 50 farm buildings

within the site, not including buildings at Arlee or the fish hatchery.

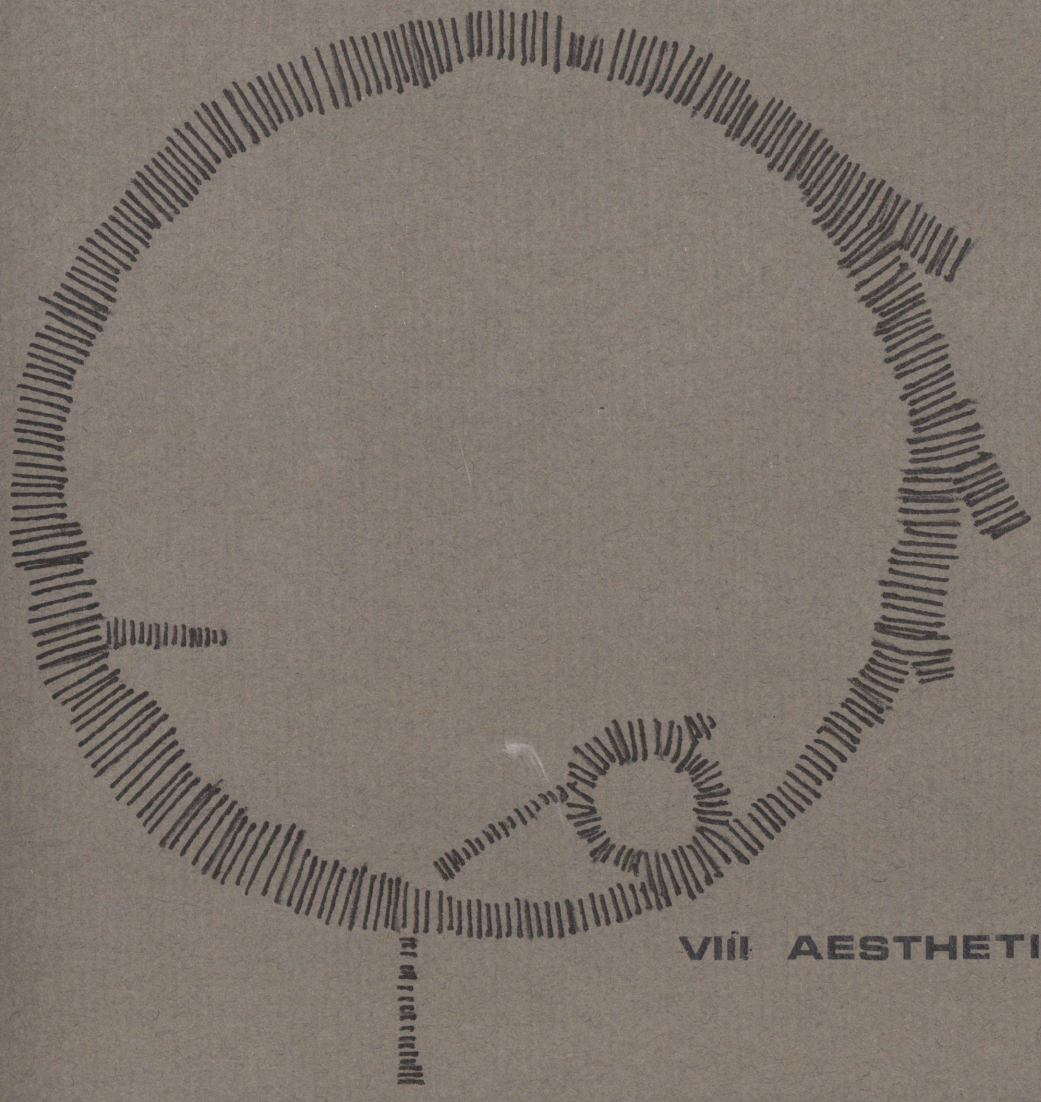
UTILITIES. See figure VII-9 for description of existing power and water utilities.

VIEWS

SITE VIEWS. Views within the site include the items covered throughout the site analysis. I have divided these views into three categories which are labeled positive (indicating a value to the site from a visual aspect only); negative (indicating a hindrance to the site); and, functional (indicating a necessity for the site project, but subject to design modifications). Table VII-1. Figure VII-10 shows a general view of the site.

DISTANT VIEWS. The large area covered within the site boundaries limits view from the site to distant views. The distant views are primarily mountain silhouettes with closer views of surrounding foothills. The mountains on the northeast and west are similar, with grass covered foothills

developing into steeply sloped forests of fir trees. The mountains to the south-southeast are somewhat higher, showing a similar growth pattern, but including more rock outcroppings on a steeper sloped terrain. Figure VII-11 shows views looking from the site toward the surrounding mountains.



VIII AESTHETICS

INDUSTRIAL AESTHETICS

Industry is in a curious position of spending large sums of money to develop huge building complexes which become an equally huge tax on our aesthetic sensibilities. Industry destroys large tracts of land by erasing all natural features with vast areas of asphalt paving, stacks of rusting machinery, and large sterile building forms. Not satisfied at this point, they pollute air, water, and land resources.

What then, should be the role of industry in aesthetics? Their responsibility is simply to fulfill a moral obligation to consider the aesthetic qualities of their industrial plants. This obligation is given importance by the impact of industrial facilities on our landscape. Acceptance of

their obligatory role frees industry from further responsibility; it is the designer's tasks to evaluate the problem and propose a solution. To propose solutions involving industrial aesthetics, it is necessary to understand the unique problems of industrial planning. These problems relate to individual processes.

Limiting a building program to areas within the influence of the industry, and the designer, is the first step in the design analysis. Evaluation of the range and degree of influence of an industry depends on the specific function and physical boundaries of the project. Physical boundaries vary considerably with the building program proposed, and the specific site conditions. Obviously an urban site would impose different restrictions than a large rural acreage. Functional influence on aesthetics is often related to nuisance factors associated with some industries. Pollution, high noise levels, networks of utilities, and large transportation facilities are often the object of local criticism. These areas must be considered in the initial program outline, for they will shape the aesthetic image of the completed project.

200 BEV ACCELERATOR LABORATORY - SITE AESTHETICS

Criteria for development of the Arlee site will depend upon three factors. These are: the visual impact of the laboratory buildings on the site; functional requirements of the complex that affect areas outside of specific buildings; and, the natural features of the site and surrounding area.

Of these three factors, not one can take a secondary role. The immense size of the accelerator buildings and the number of utilities and functions throughout the site, and the strength of the mountainous valley are all competing visual aspects of the site. Since function dictates the size and number of elements necessary for the accelerator complex, aesthetics judgements must combine these elements in harmony with the site.

Limitation of program to areas within the designer's influence, as discussed in industrial aesthetics, is very important to site development. The site occupies an area of 8,000 acres situated in a valley of small farms and open grassland surrounded by mountains of dense evergreen forests. The view of these mountains and natural conditions of the valley (both outside of the influence of the designer) suggest the method of developing the site.

Removal of natural tree cover within the site should be allowed only where necessary to fulfill functional

requirements, and areas disturbed in construction should be landscaped in a manner blending with the native growth common to the valley. There should be very little recreational development on the site. There is little need for this type of site improvement and design efforts could be used more effectively elsewhere.

One of the areas of site aesthetics that should be considered in some detail is the locating and method of introducing various utilities onto the site. These utilities include power and water lines, railroad spurs, and roadways. With the exception of water sources, all of the mentioned utilities involve connections with facilities outside of the site boundaries. Here again, there is a limitation on the designer's control.

Location of power lines can be handled quite simply by placing underground lines through the site. There is a trend toward such placement of these utilities and future improvement of existing power lines (adjacent to site) would be hoped for.

Railroad spurs and roads are not so easily handled. The easiest method of designing 'surface utilities' (aesthetics do not seem to demand nor economic logic allow a solution of underground or enclosed facilities here) is to allow them to flow with the site, taking advantage of

topographical changes for view or enclosure. This road and railway flow should also have a good visual relationship to buildings approached or passed by.

The suggested methods of handling utilities are in line with the intent of keeping a natural and clean feeling to the site. By keeping landscaping to a minimum and using sublety in placement of utilities, I feel that this atmosphere can be achieved.

200 BEV ACCELERATOR LABORATORY - BUILDING AESTHETICS - EXTERIOR

The exterior of the accelerator laboratory, by its very size, will present a formidable silhouette. The design of the building exterior should relate to the overall site development. In addition, the building must be honest to itself. That is, its appearance should relate to its function.

The combination of the building forms with the site, or more accurately, the entire valley is an aesthetic problem not easily solved. With the guidelines proposed in the site development and the desire to keep an industrial character to the buildings, we have the conditions on which to make aesthetic judgements. These are judgements of form, material, color, and texture.

MATERIAL. Exterior materials will have an important effect on the visual appearance or character of the buildings. Since the choice of materials is based on many variables other than aesthetic considerations, it is impossible to make sweeping generalities of material choice in this area. Aesthetically successful solutions are possible using various materials. Often a material chosen for its functional value can effectively induce the desired character to a building. To keep an industrial character it follows that materials that function well for the industrial requirements would be natural choices. It is the manipulation of these materials that will form the aesthetic character desired.

FORM. The form of the accelerator complex is highly dependent upon the function of the interior spaces. Form and aesthetics are related here in a more subtle manner. With the restrictions function places on the accelerator form, it is necessary to evaluate the form of the entire complex as it relates to the site. The form of the exterior can be modified to extremes by the placement of buildings in relation to existing topography or revised site contours. The manner in which this is done will have a strong effect on the harmony between the buildings and the site.

COLOR & TEXTURE. Color and texture are closely related to material. In some cases the material choice is based on its color or texture, but more often color or texture is added to complement the material. I intend to use both color and texture as secondary criteria to influence the desired character of the complex. Secondary importance to these variables means more emphasis on the natural appearance of materials.

200 BEV ACCELERATOR LABORATORY - BUILDING AESTHETICS - INTERIOR

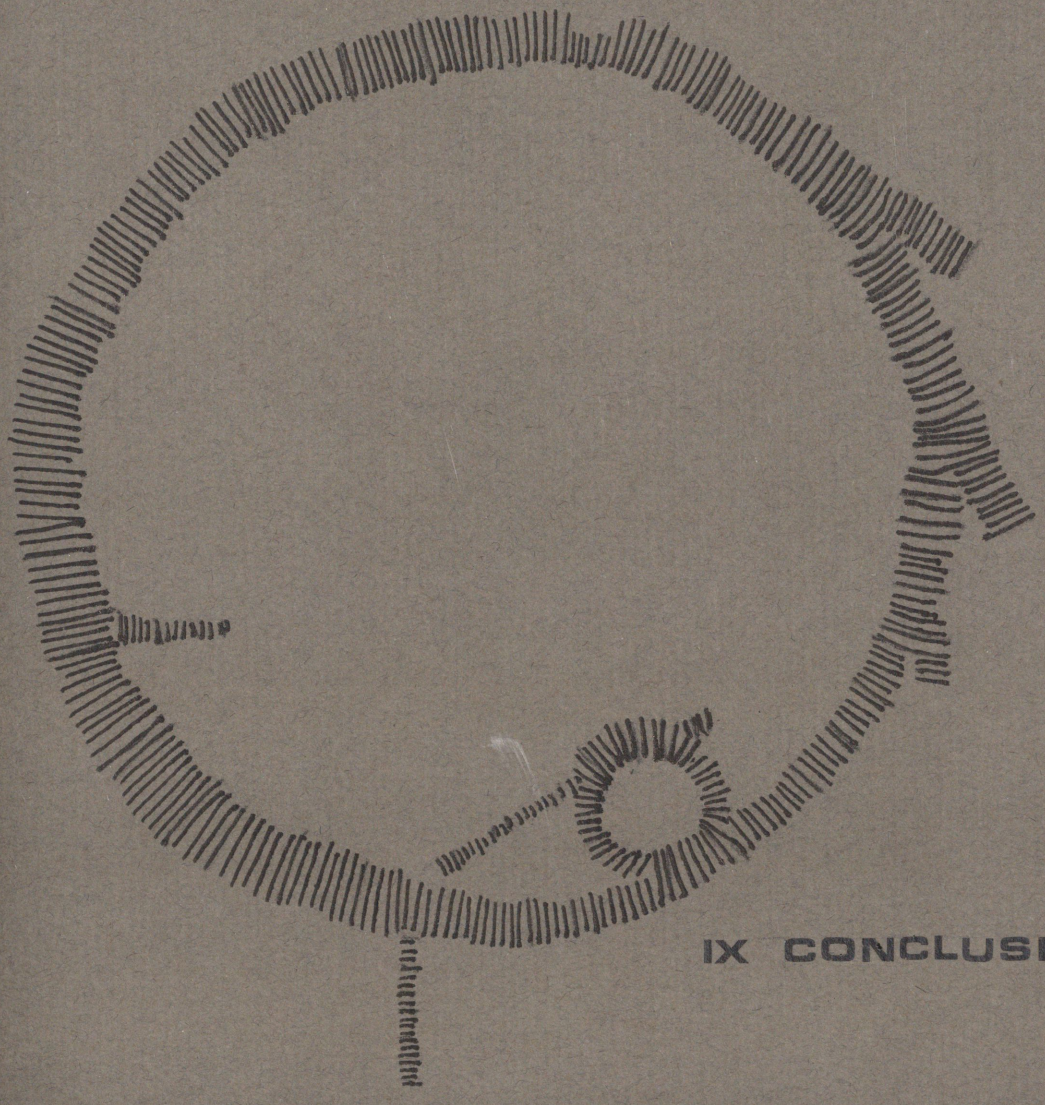
The relationship between function and aesthetics is probably more important in the design of interior spaces than anywhere else. Here there are problems of fulfilling functional relationship and designing aesthetically pleasing spaces. The first concern is with the design of various spaces, relating to specific functions, secondly the design of functional and aesthetically pleasing relationship of one space to another. From the exterior these two areas become problems of form, on the interior they are problems of the visual aspects of negative spaces (i.e. rooms, corridors, courts, etc.).

The design of individual spaces must consider the function of the space and compare this functional character

with the entire complex, including the site. Here I refer to the program requirements which discuss the function and size of the various interior spaces of the accelerator laboratory. Design of space volumes, color combinations, lighting levels, and application of accoustical materials combine to give a distinct visual appearance. Here again aesthetics is based on the manipulation of material, form, color and texture.

Designing of functional and aesthetically pleasing relationships between spaces is less dependent upon choices of material, form, color and texture. Granted, they will have an effect on the aesthetic appearance. However, the desired effects will depend primarily on the configuration of open spaces.

Manipulation of interior spaces will depend upon the function of the space and the visual effect desired. Obviously areas of vehicular movement would be handled differently than areas of pedestrian traffic. The combination of functional requirements and desired psychological effects will shape the aesthetics of interior design.



IX CONCLUSIONS

The design solution of the accelerator complex is a result of working from the large scale problems of an industrial site to the evaluation of smaller areas within the site. The obvious connections of the parts to the whole have necessitated an interplay of many design decisions. The guiding factor in the planning of all parts of the complex has been to enhance the aesthetic image of an industrial project while retaining an honest working posture of the processes involved.

It has been this designer's intent to reveal, through physical forms and their positioning, an expression of the accelerator function. The excitement of the architecture will be the excitement of the accelerator's unique activity.

I believe this approach will enable the preliminary configuration of the site to remain intact even as the intricacies of the parts are investigated and detailed. Minor changes will be made in physical forms, but the spirit of the design will remain unchanged. Location of all parts (buildings, utilities, roads, etc.) have been guided in a direction that will enable the site to expand without losing this spirit.

I have tried to work with the site wherever possible, taking advantage of topography to fit the large earth forms of the accelerator ring and to position other activities of accelerator personnel.

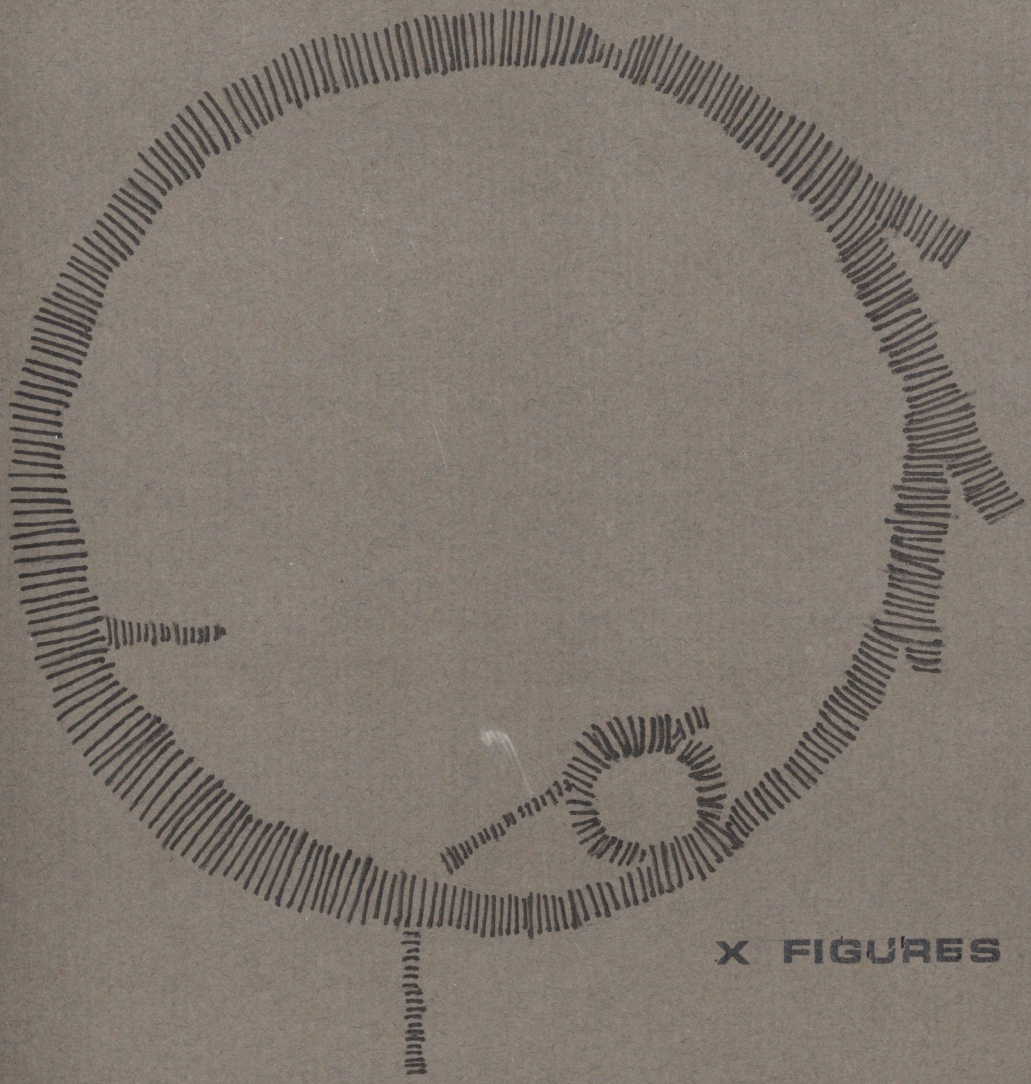
The main ring has been positioned as shown, for two reasons. First, to expedite the problems of future expansion of its function. Secondly, through the balance of cut and fill, to work a smooth flowing arc into the plane of the valley floor.

The support facilities have also been positioned in a manner that is determined by the topography of this site.

The existence of the river drainage cutting through the site has enabled this designer to locate these facilities on the brow of this drainage while retaining a proximity of all spaces to the area of concentrated accelerator activity.

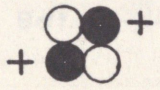
The complexity of accelerator activity has been reflected in the building forms and their positioning. The future expansion

of the accelerator's functions should be able to work easily with the existing buildings. The addition of more forms will simply increase the complexity of the working area, the spirit of the spaces will remain the same. As I have previously said, the excitement of the architecture will be found in the excitement of the accelerator's activity.



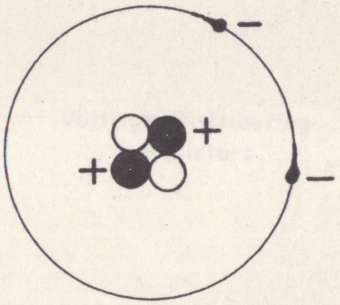
X FIGURES

1-1



ALPHA PARTICLE

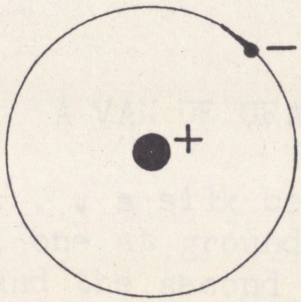
	CHARGE
2 PROTONS	+2
2 NEUTRONS	0
TOTAL CHARGE	+2



HELIUM ATOM

	CHARGE
2 ELECTRONS	−2
2 PROTONS	+2
2 NEUTRONS	0
TOTAL CHARGE	0

1-2



HYDROGEN ATOM

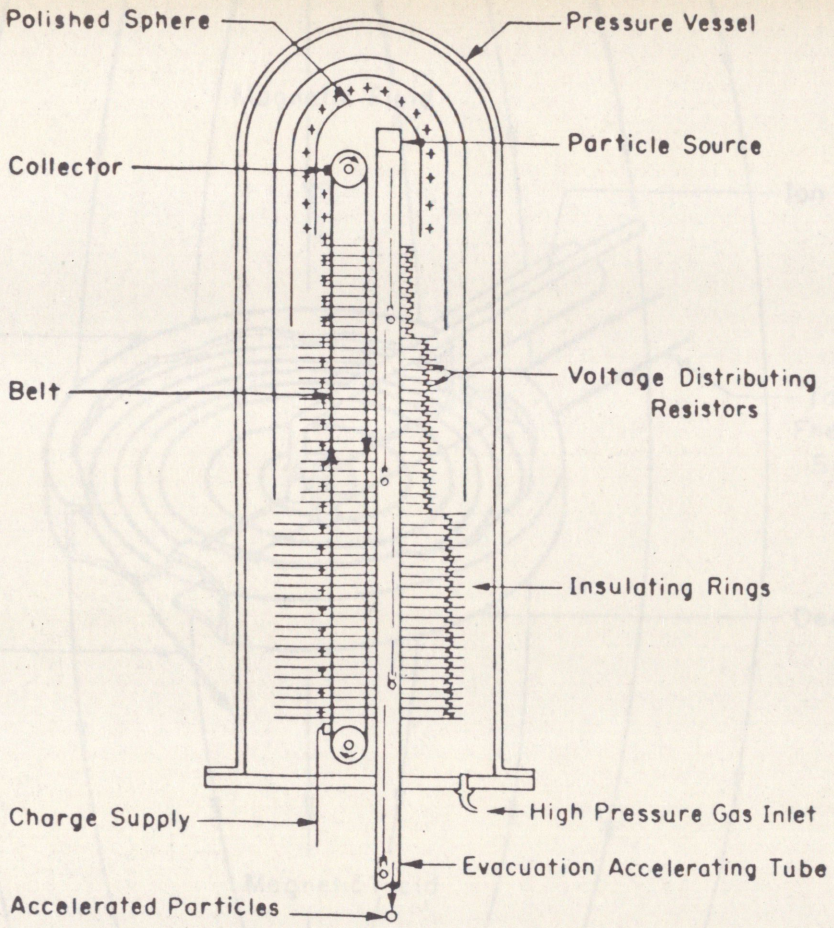
	CHARGE
1 ELECTRON	−1
1 PROTON	+1
TOTAL CHARGE	0



HYDROGEN NUCLEUS

	CHARGE
1 PROTON	+1
TOTAL CHARGE	+1

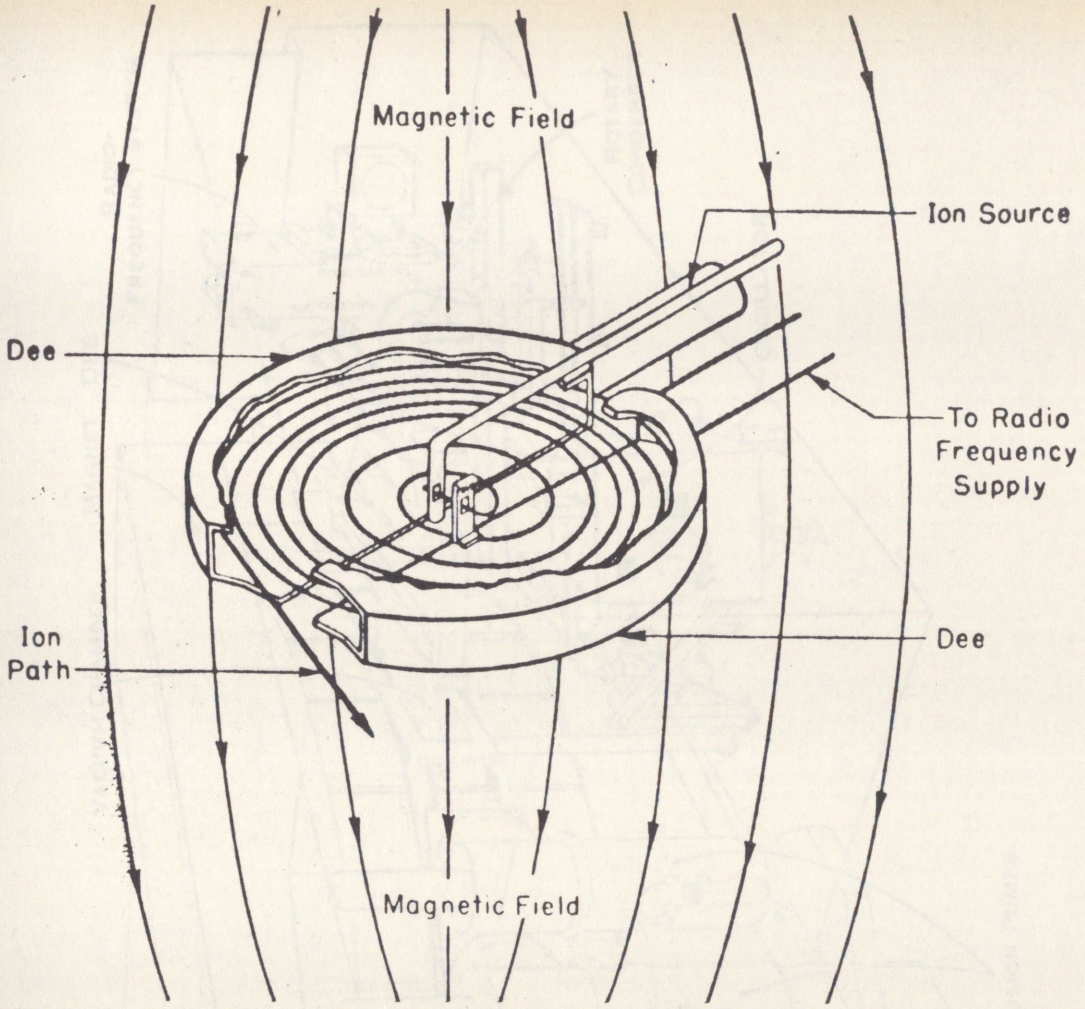
FIG. 1-3



A VAN DE GRAAFF EIECTROSTATIC GENERATOR

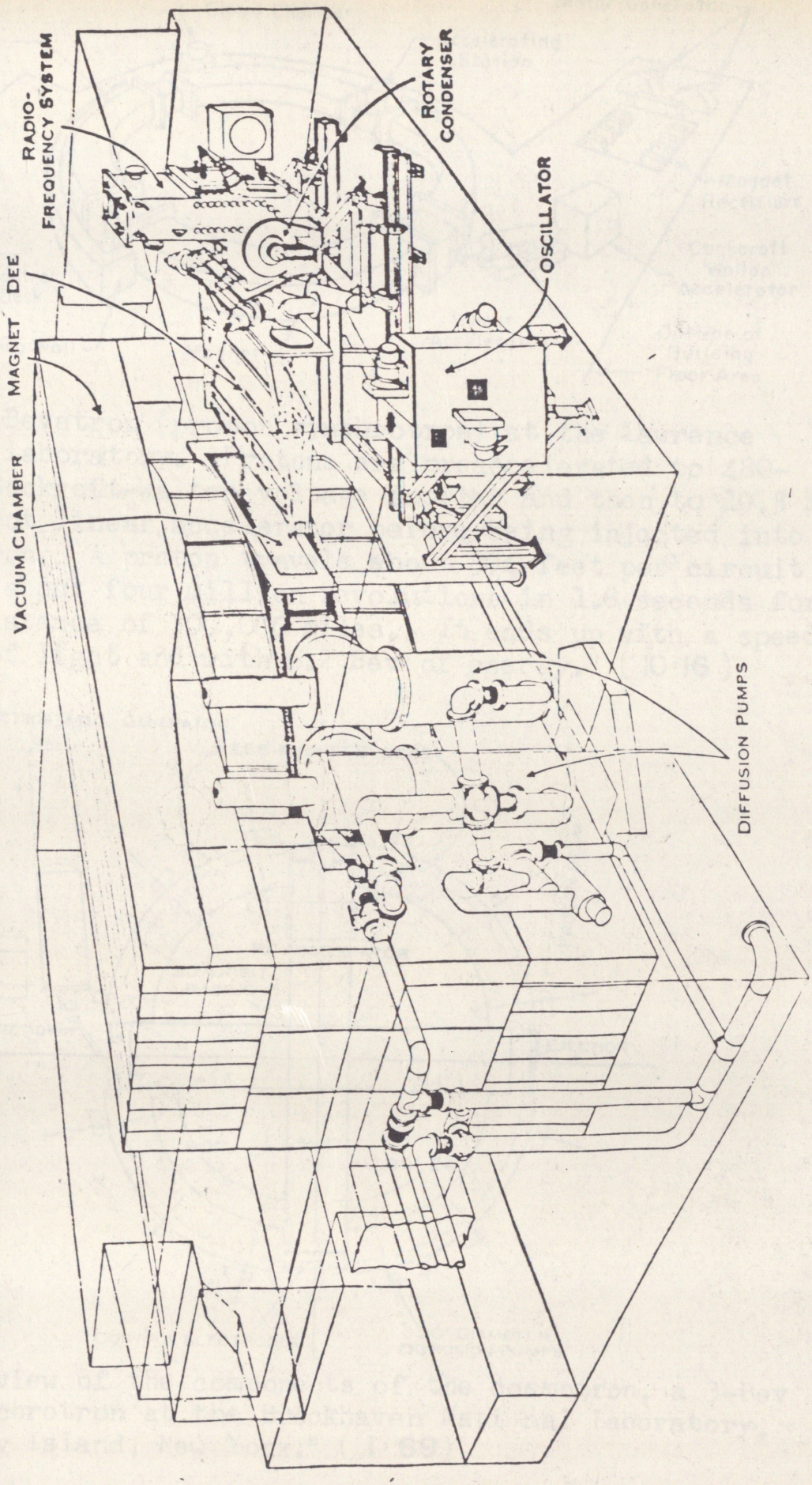
" . . . a silk belt $2\frac{1}{2}$ inches wide was carried by two pulleys, one at ground potential and powered by an electric motor, and the second inside a polished metal sphere 24 inches in diameter. The sphere was supported by glass insulating rods. Electric charge from a row of needle points held at a positive potential of about 10 kv was sprayed as corona current (an electrical discharge in air) onto the belt surface just after it left the grounded pulley. Before the belt reached the second pulley another row of needle points picked up the charge and conducted it to the metal sphere. This process could be continued until a very high potential was developed in the sphere.

Once the sphere of a Van de Graaff machine is charged to its maximum voltage, the protons or other particles to be accelerated are ejected from an ion source in the high-voltage terminal into the accelerating tube. They are accelerated by the potential difference between the sphere and the grounded end of the tube." (10:4)

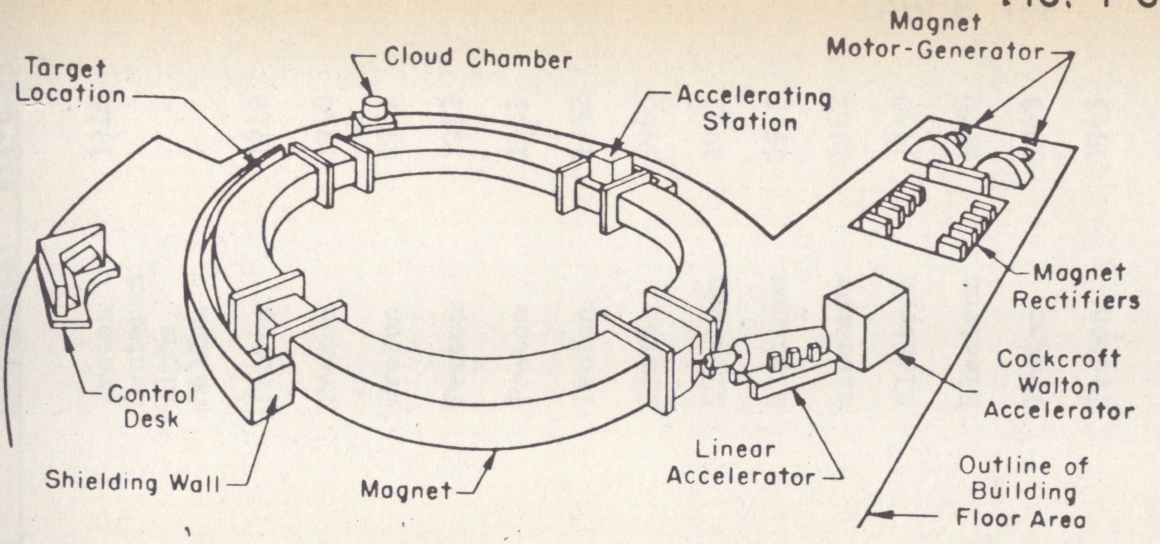


A CYCLOTRON

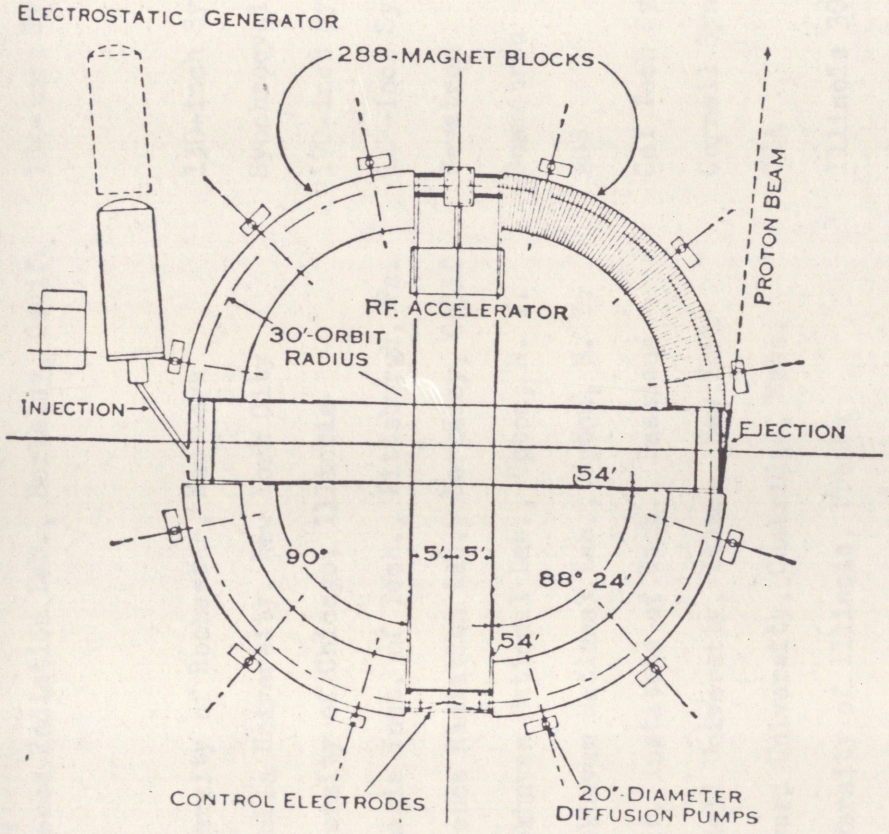
"Particles injected at the center are bent into circular paths by traveling in a vertical magnetic field. A rapidly alternating horizontal electric field applied between hollow electrodes (dees) accelerates the particles each time they complete a half circle. The particles are extracted by deflecting electrodes and aimed at an external target. The dees are enclosed in a vacuum so that air molecules will not obstruct the motion of the particles." (10:8)



THE 170-IN. SYNCHROCYCLOTRON AT THE UNIVERSITY OF CHICAGO



"The Bevatron (proton synchrotron) at the Lawrence Radiation Laboratory. Protons are preaccelerated to 480-kev in a Cockroft-Walton voltage doubler and then to 19.3 Mev in a 40-foot linear accelerator before being injected into the Bevatron. A proton travels about 394 feet per circuit and makes about four million revolutions in 1.8 seconds for a total distance of 300,000 miles. It ends up with a speed 99% that of light and with 6.2 Bev of energy." (10:16)

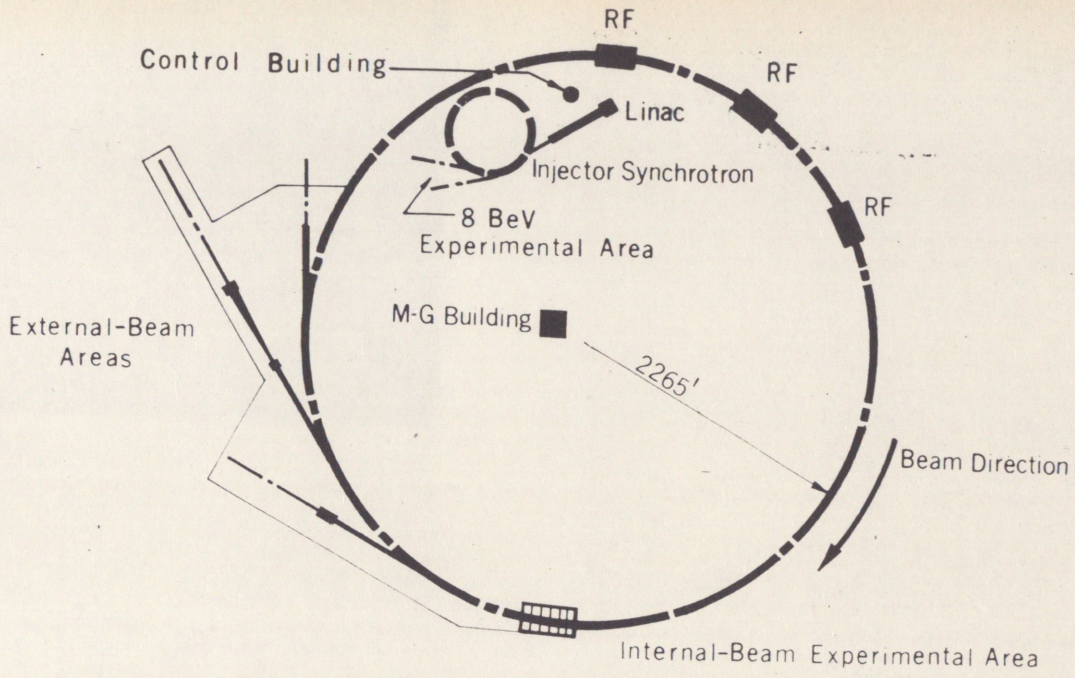


"Plan view of the components of the cosmotron, a 3-Bev proton synchrotron at the Brookhaven National Laboratory, Upton, Long Island, New York." (1:69)

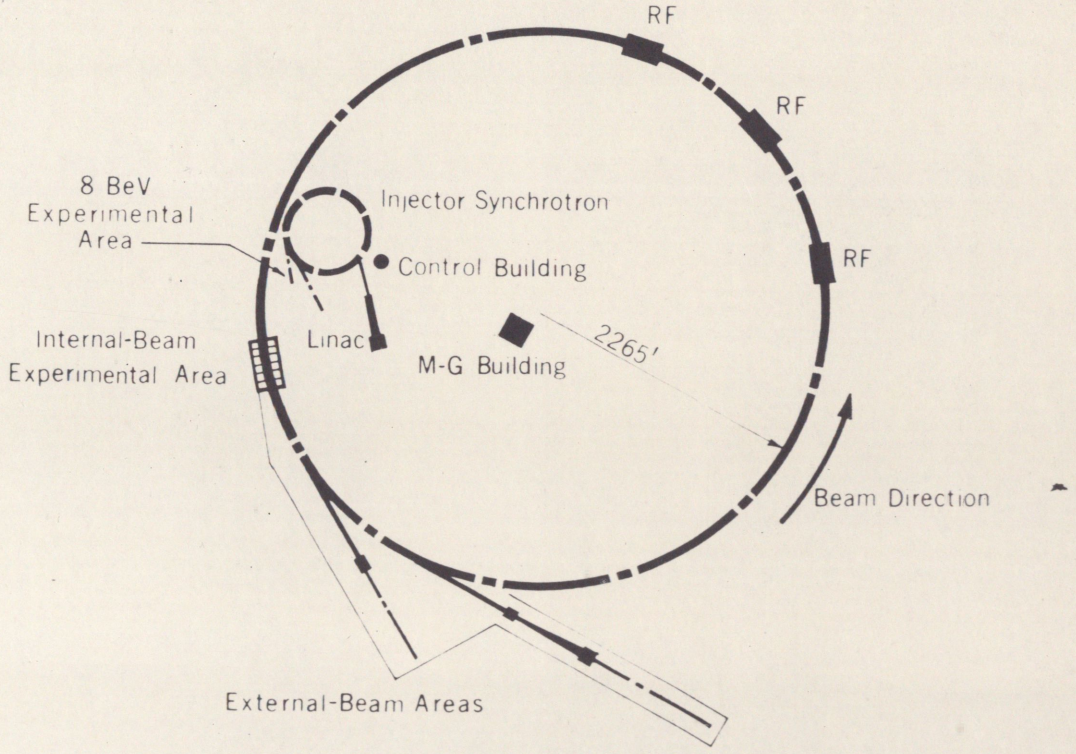
U.S. ACCELERATORS WITH ENERGY GREATER THAN 200 MEV (AUGUST 1, 1964)

Location	Common name	Energy (Mev)	Particle accelerated	Year of start-up
Operating:				
Lawrence Radiation Lab., Berkeley, Calif.	184-inch Synchrocyclotron	740 460 910 1140	Proton Deuteron Alpha Helium 3	1946
University of Rochester, New York	130-inch Synchrocyclotron	240	Proton	1948
Columbia University, New York City	Synchrocyclotron	400	Proton	1950
University of Chicago, Illinois	170-inch Synchrocyclotron	450	Proton	1951
Carnegie Inst. of Tech., Pittsburgh, Pa.	142-inch Synchrocyclotron	440	Proton	1952
Lawrence Radiation Lab., Berkeley, Calif.	Bevatron	6200	Proton	1953
Brookhaven National Lab., Upton, N. Y.	Cosmotron	3000	Proton	1952
Brookhaven National Lab., Upton, N. Y.	AGS	33,000	Proton	1960
Calif. Institute of Tech., Pasadena	Cal Tech Synchrotron	1500	Electron	1953
Cornell University, Ithaca, New York	Cornell Synchrotron	2200	Electron	1953
Harvard University, Cambridge, Mass.	CEA	6000	Electron	1962
University of Illinois, Urbana	Illinois 300-Mev Betatron	300	Electron	1950
Stanford University, Palo Alto, Calif.	Mark III Electron Linac	1100	Electron	1950
Princeton University, New Jersey	PPA	3000	Proton	1963
Argonne National Laboratory, Argonne, Ill.	ZGS	12,700	Proton	1963
Under Construction:				
Stanford University, Palo Alto, Calif.	SLAC	20,000	Electron	1966
Space Radiation Lab., Newport News, Va.	Proton	600	Proton	1965

TABLE I-1

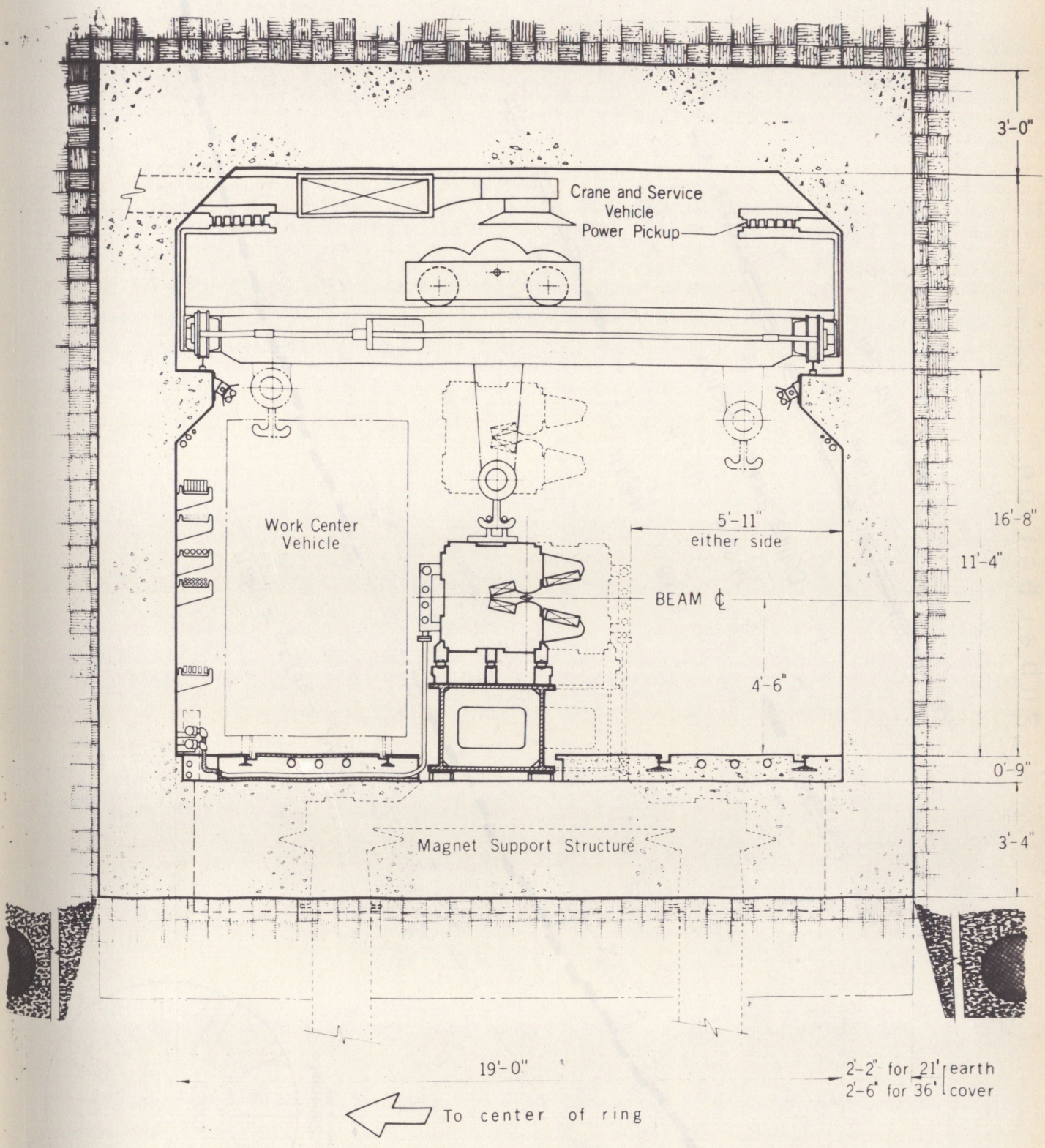


Site Example A

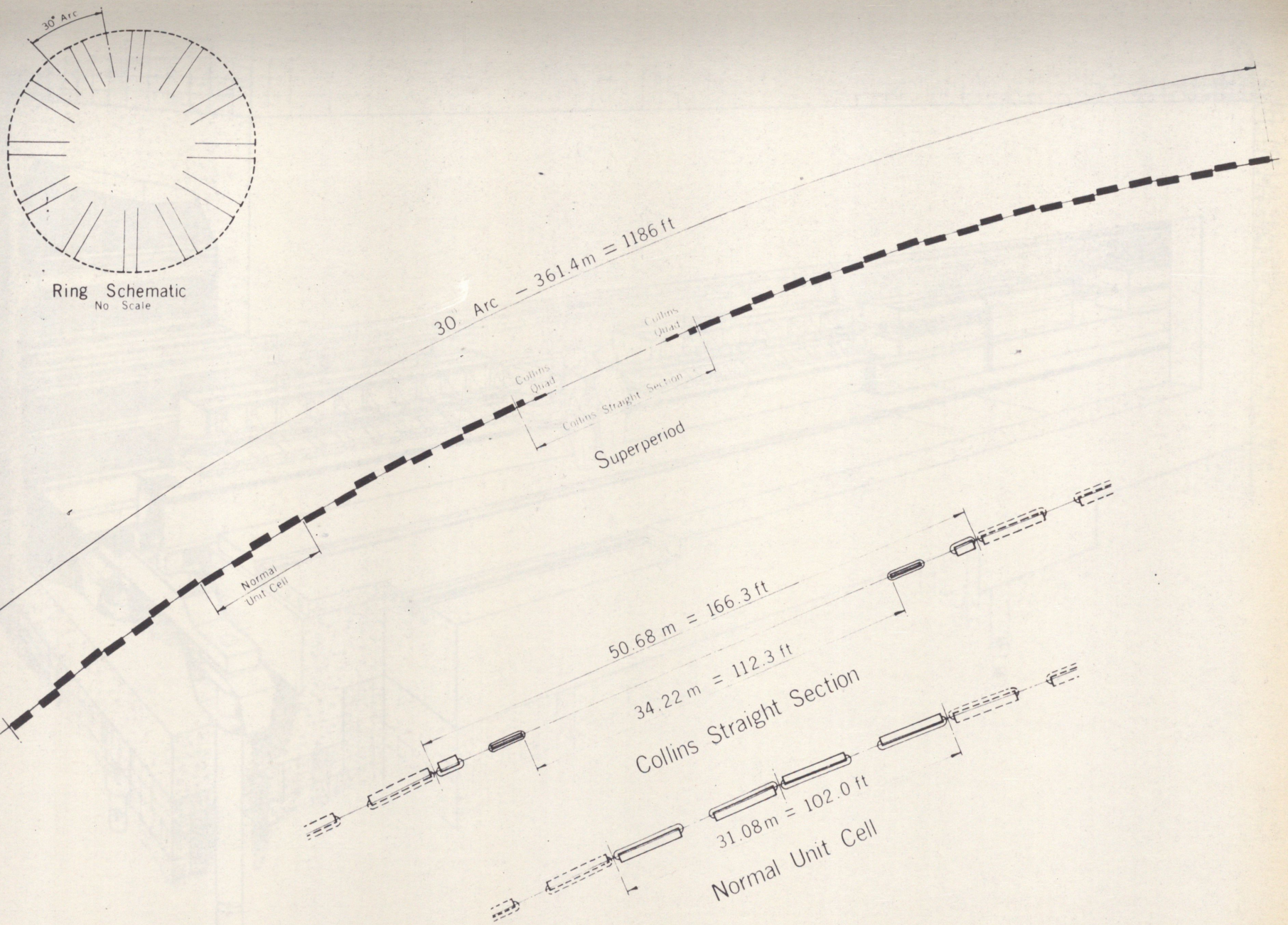


Site Example B

Schematic Layout of Accelerator Facility

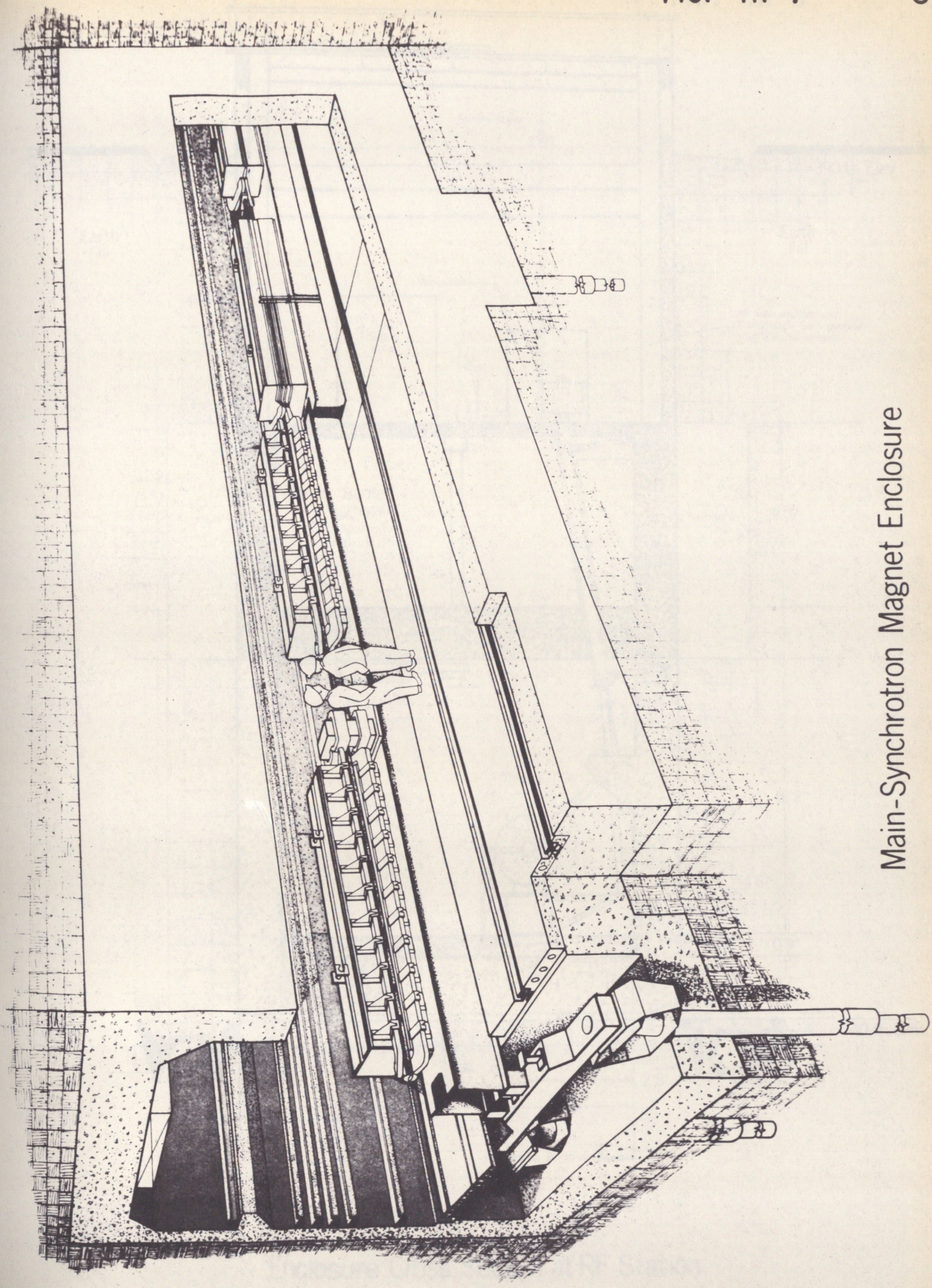


Main-Synchrotron Enclosure Cross Section

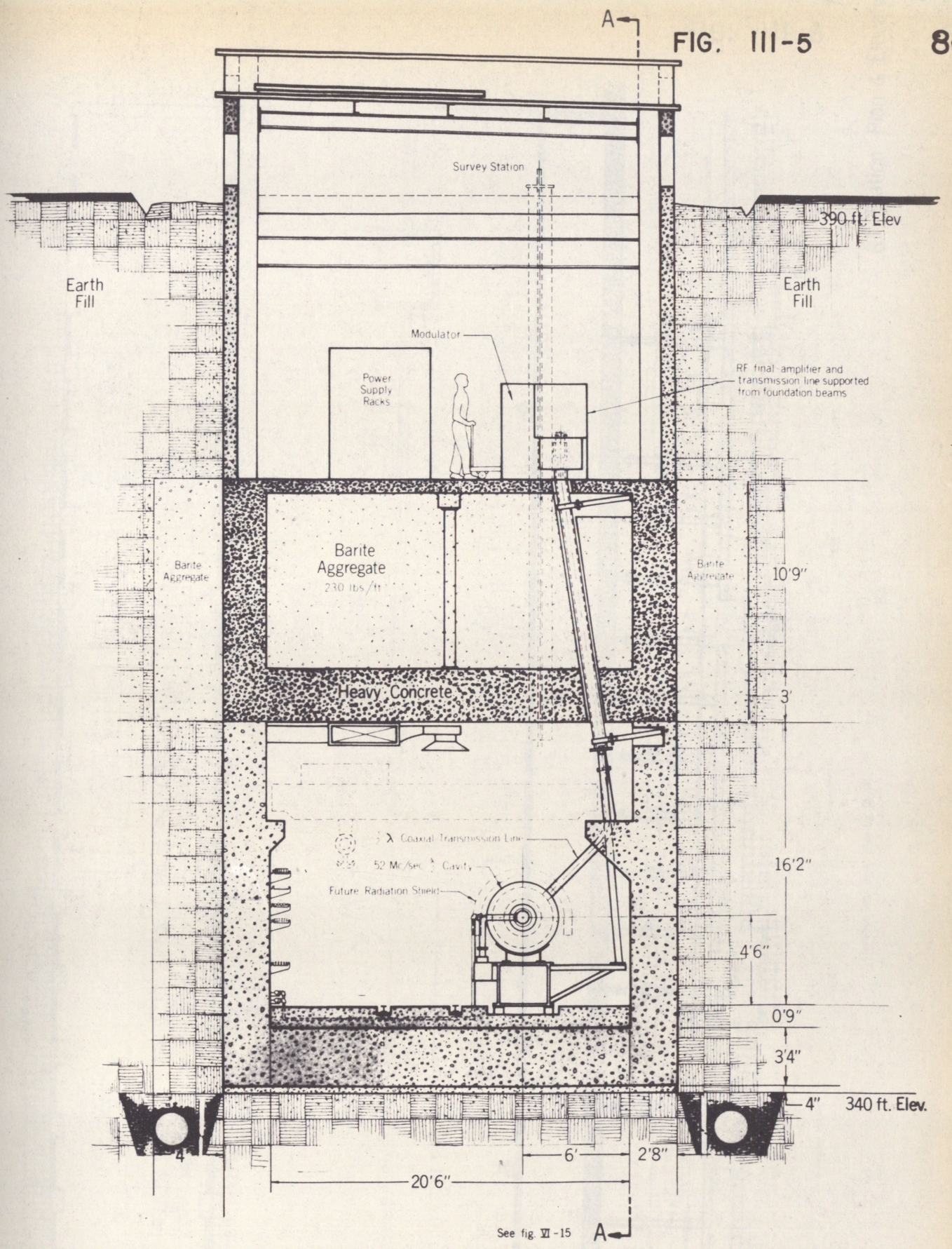


Superperiod

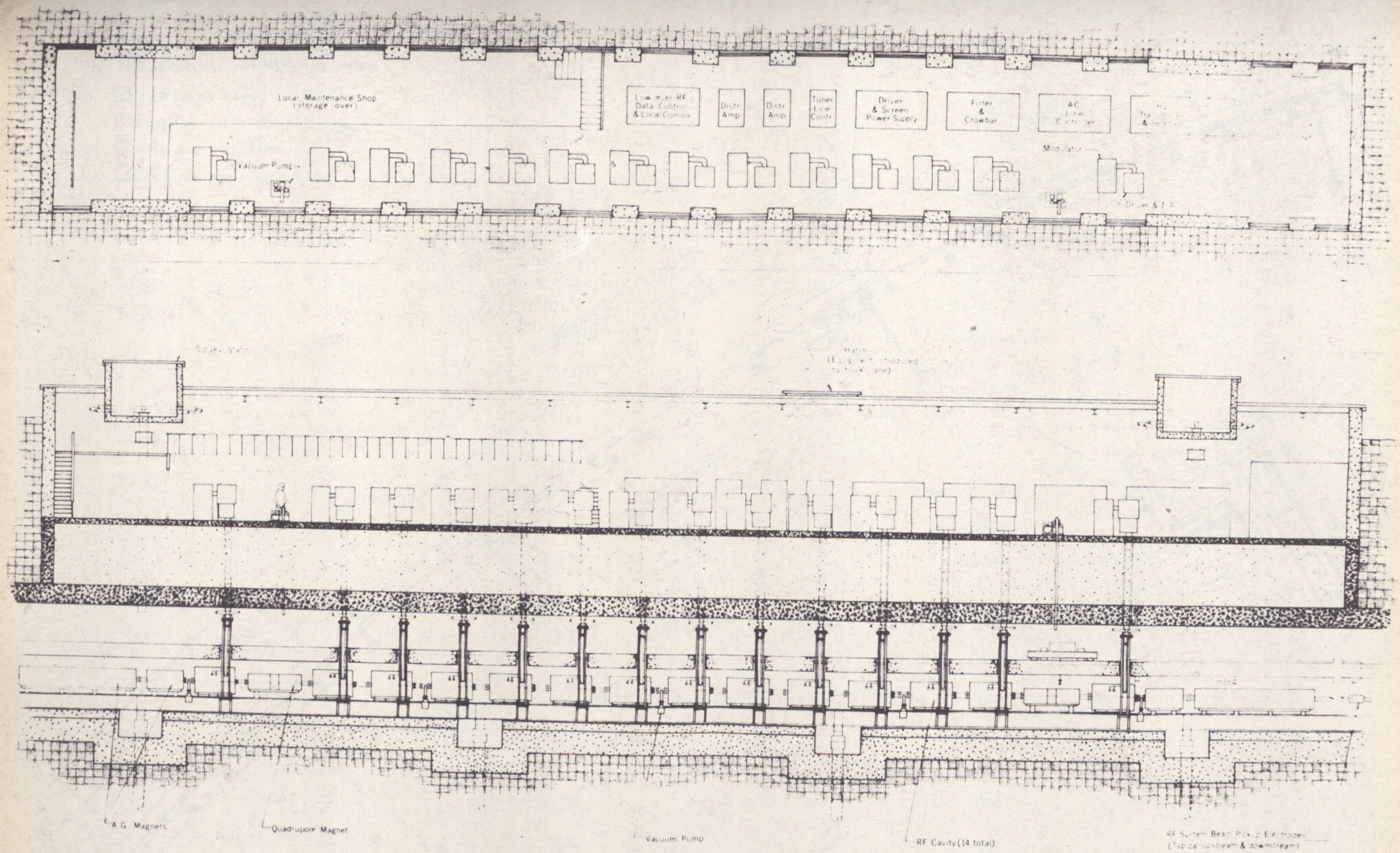
FIG. III-3



Main-Synchrotron Magnet Enclosure



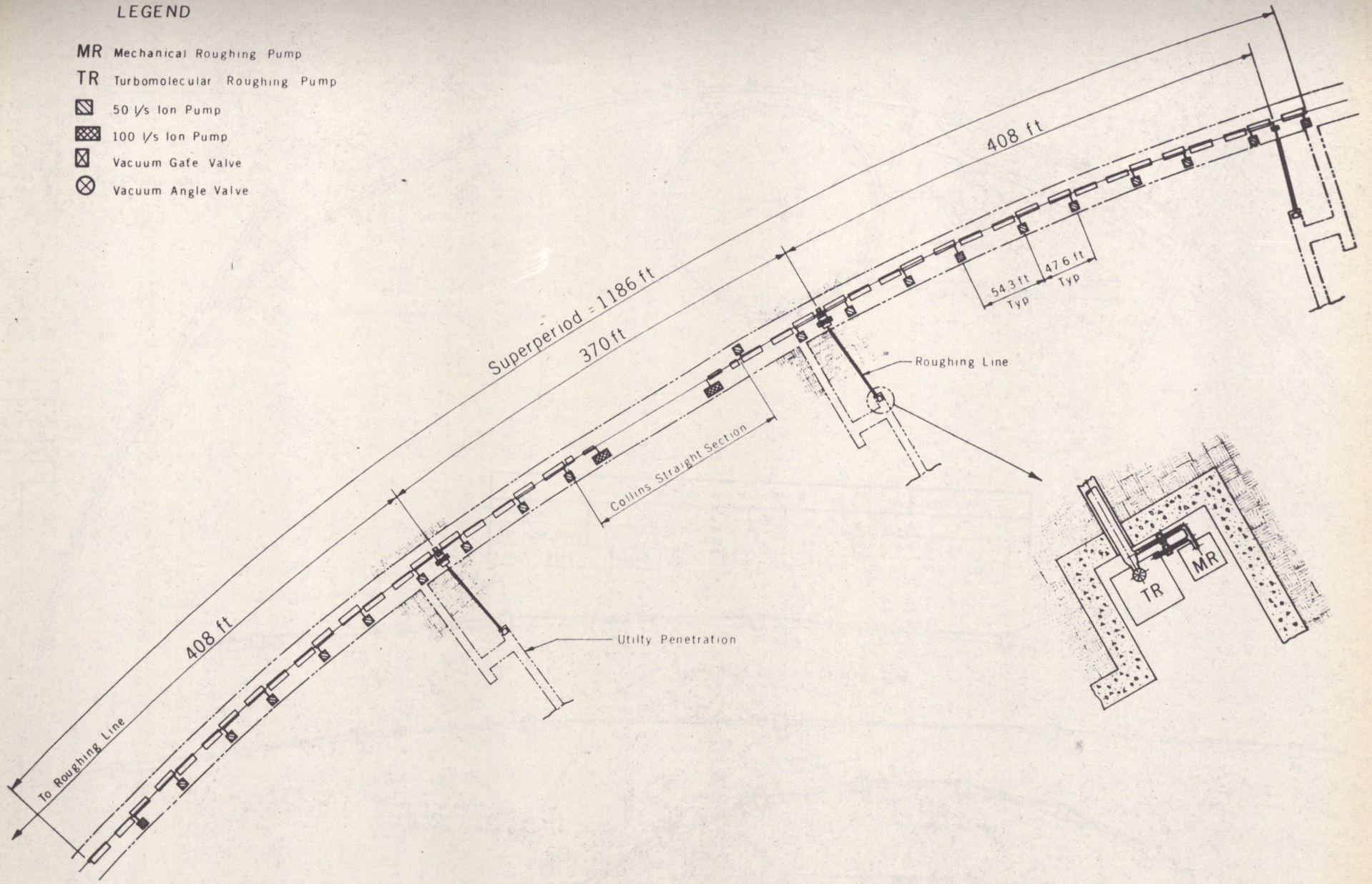
Enclosure Cross Section at RF Station



Elevation Sect. A–A (See fig. VI–14)

FIG. III-6

RF Station Plan & Elevation



Vacuum Pumping System Schematic

FIG. III-7

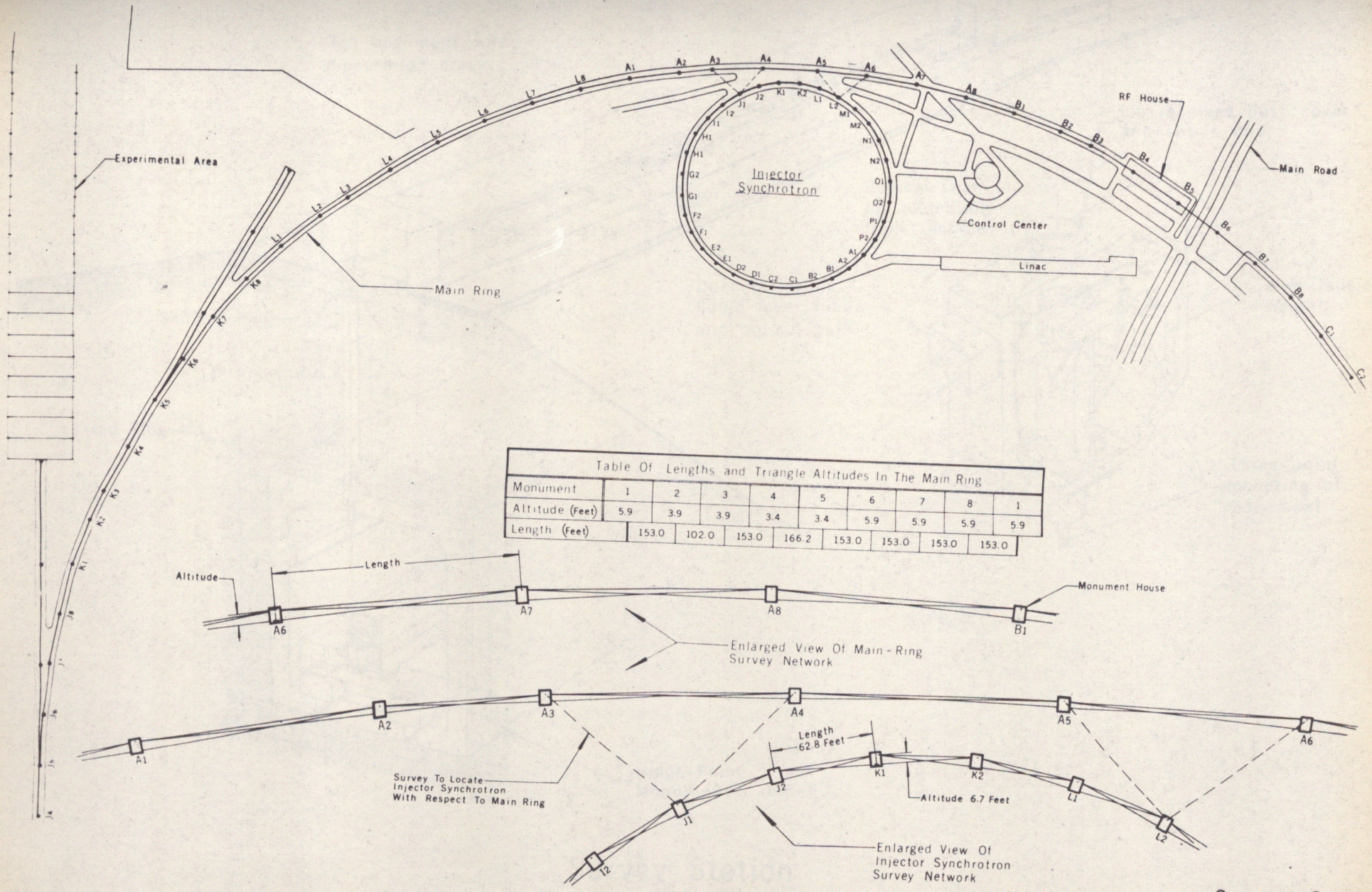
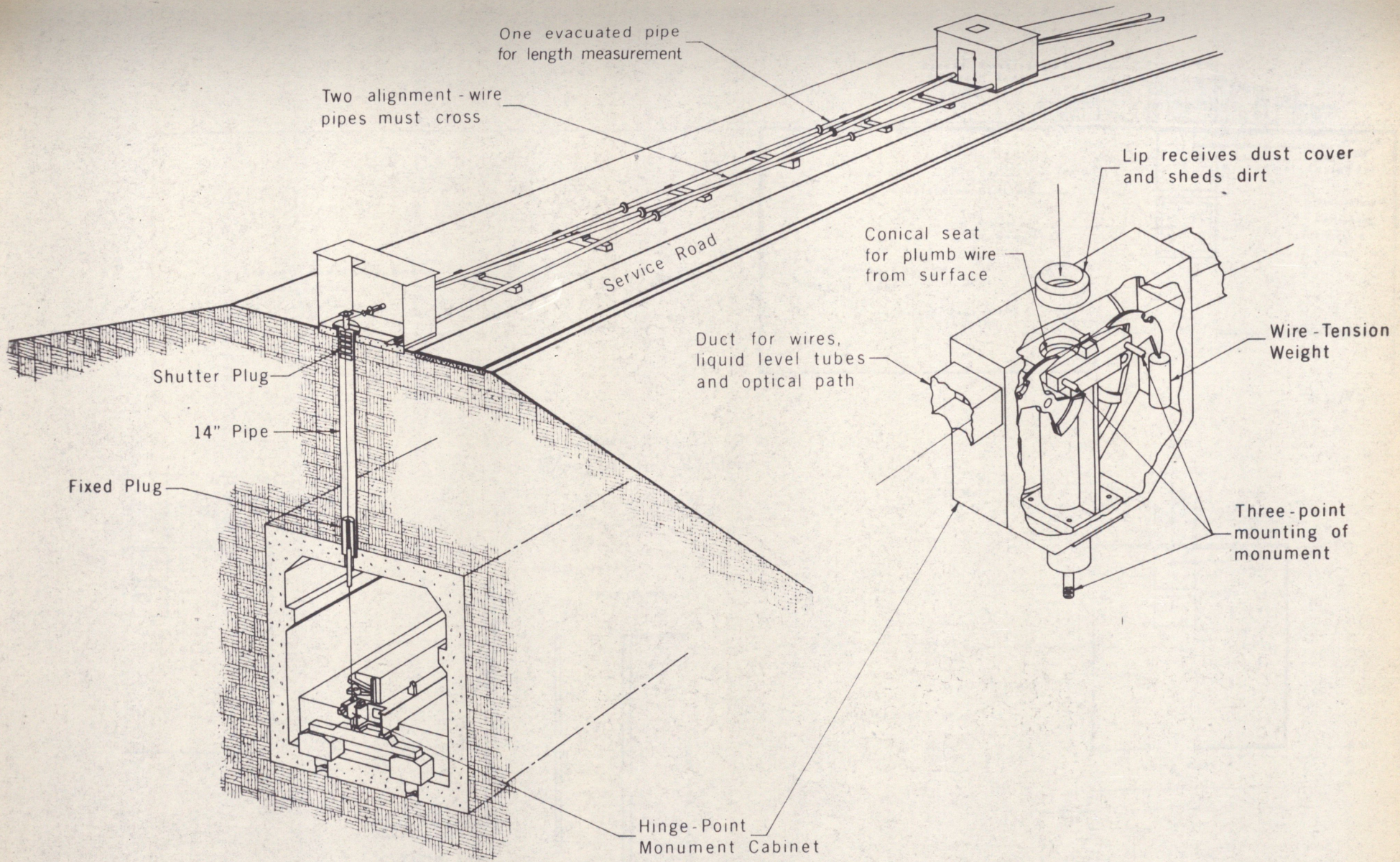


FIG. III-8

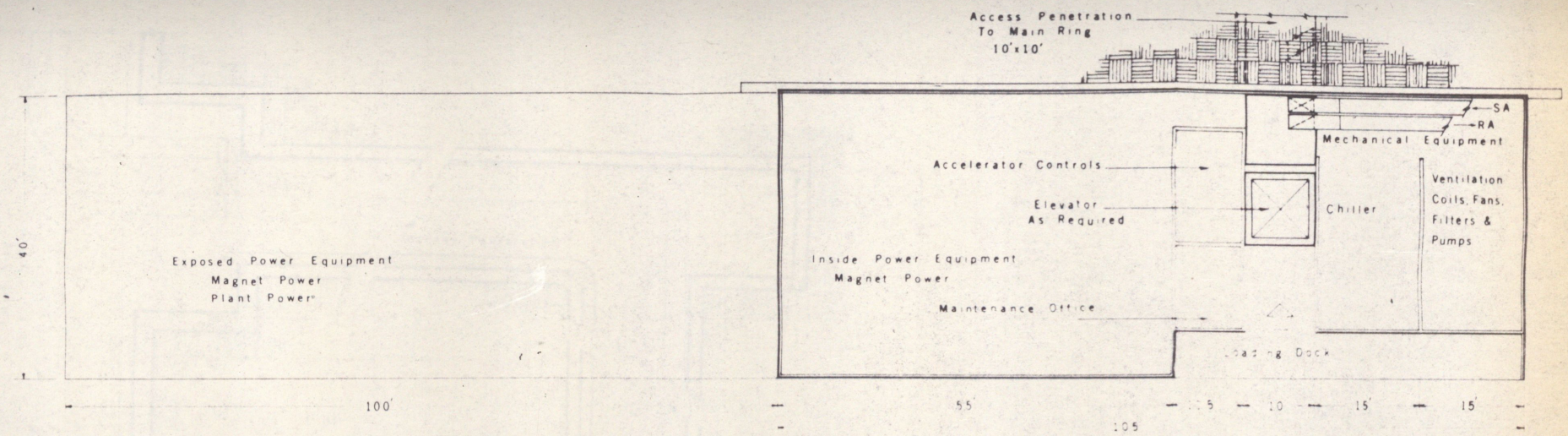
Survey System
Primary Monument Network



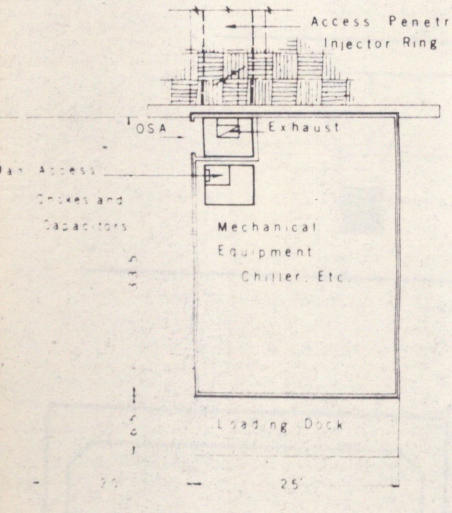
Survey Station

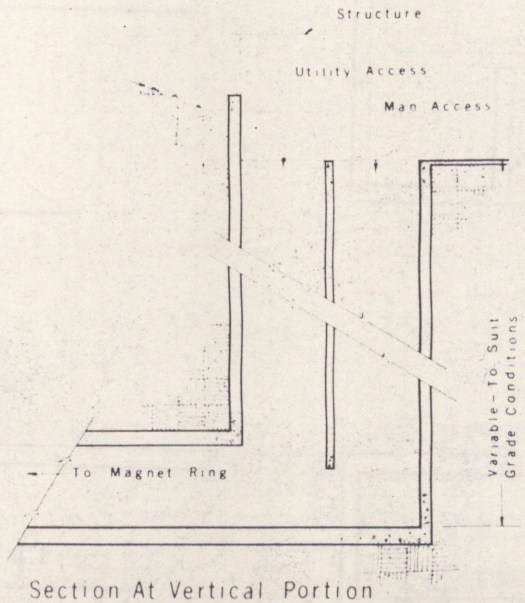
Primary Monument, Penetration & Hinge Point Monument

FIG. III-9

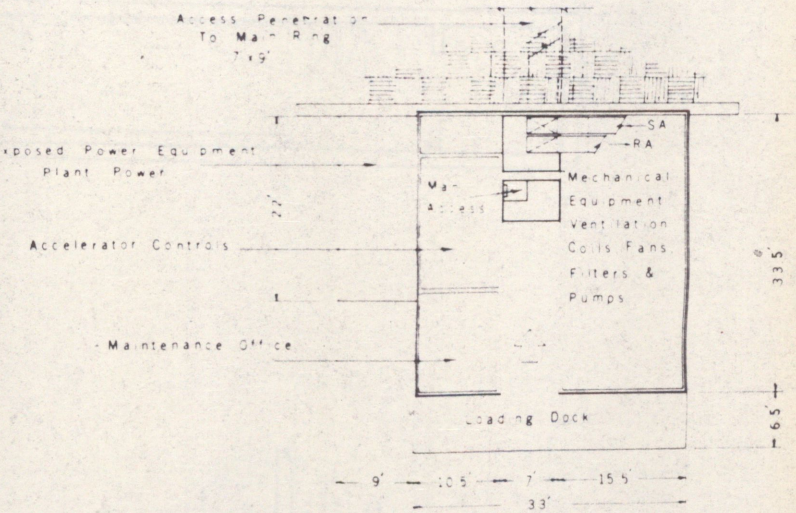


Main-Ring
Major Utilities Building





Section At Vertical Portion
Of Access Penetration



Main-Ring
Minor Utilities Building

FIG. III-10

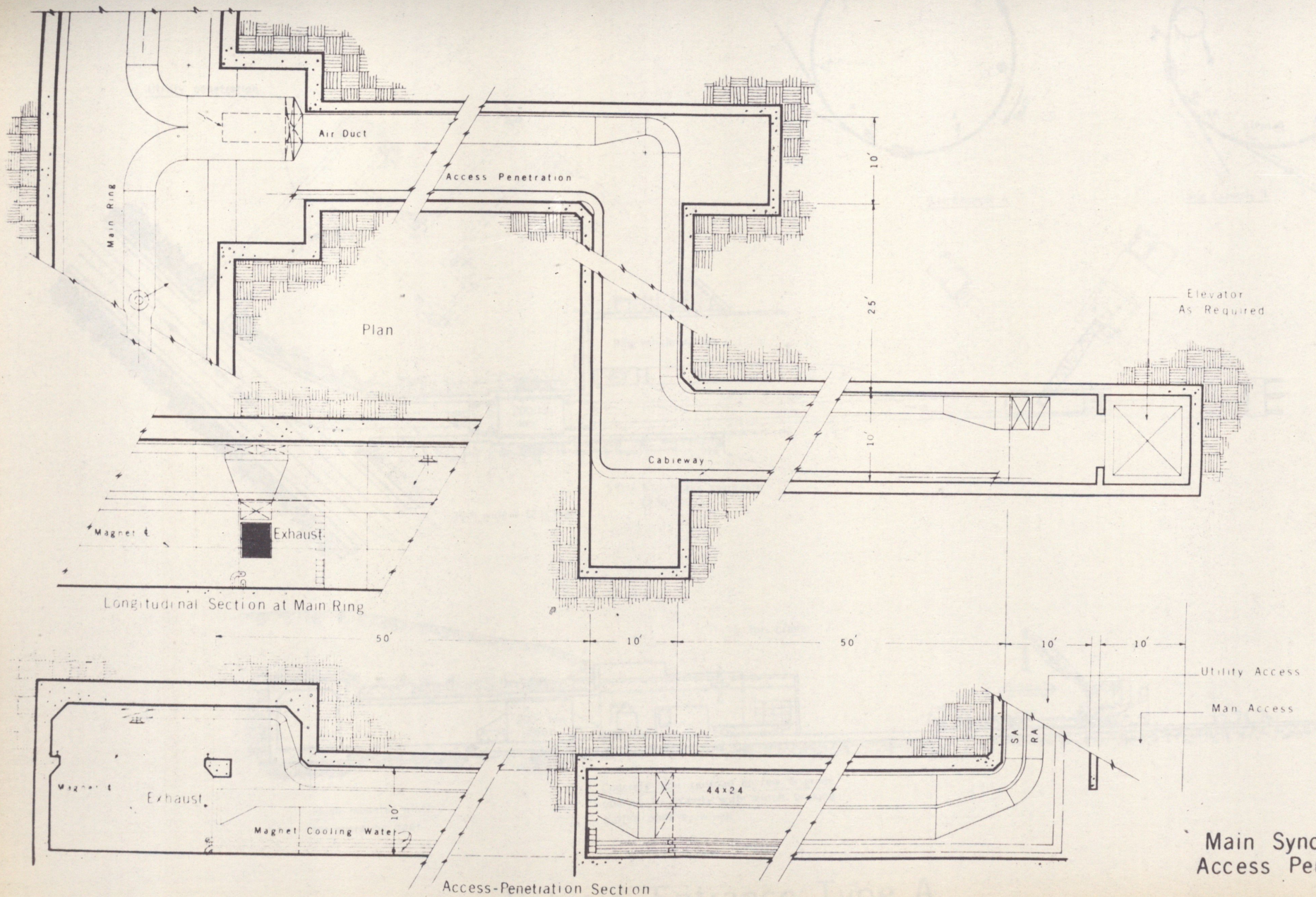
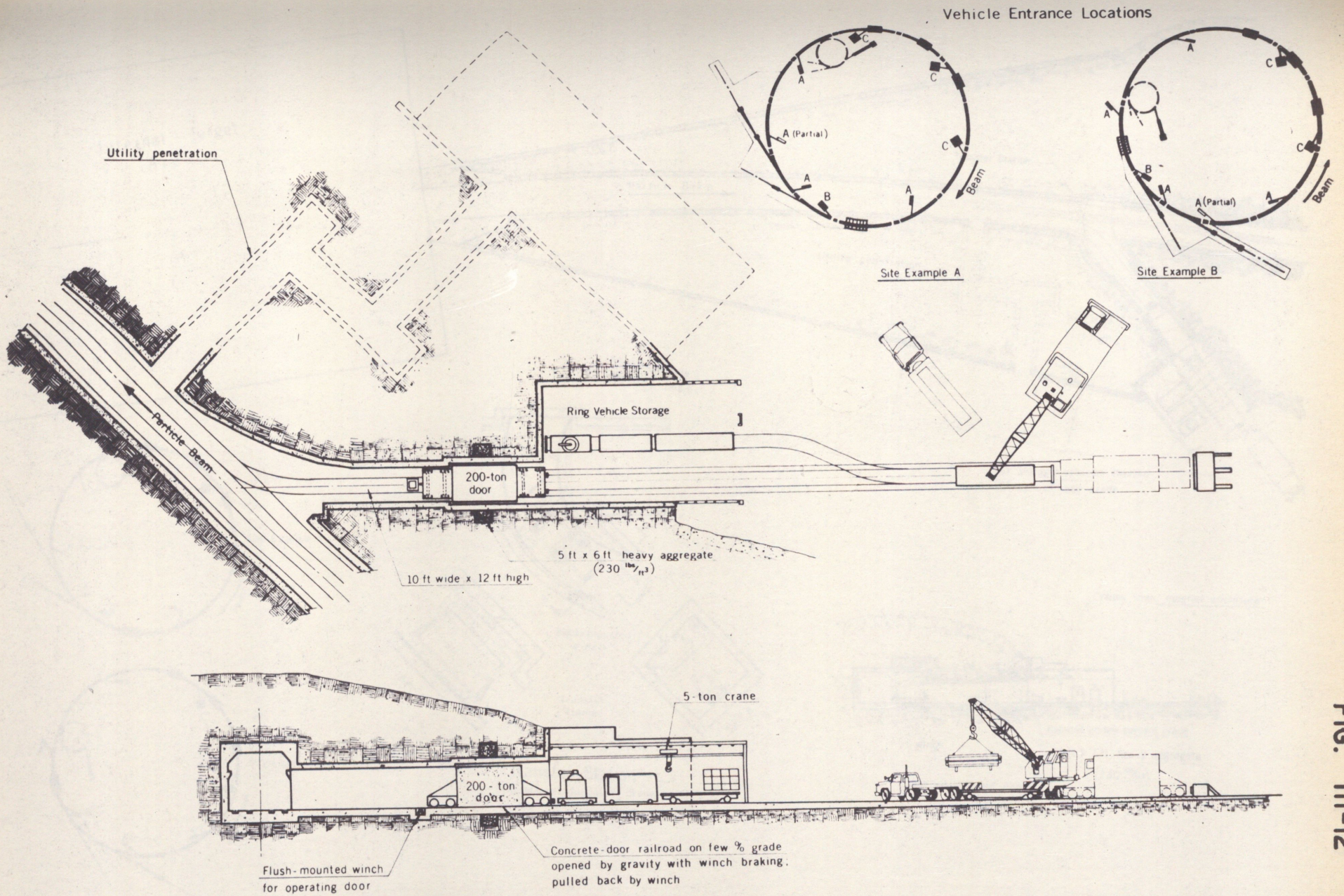


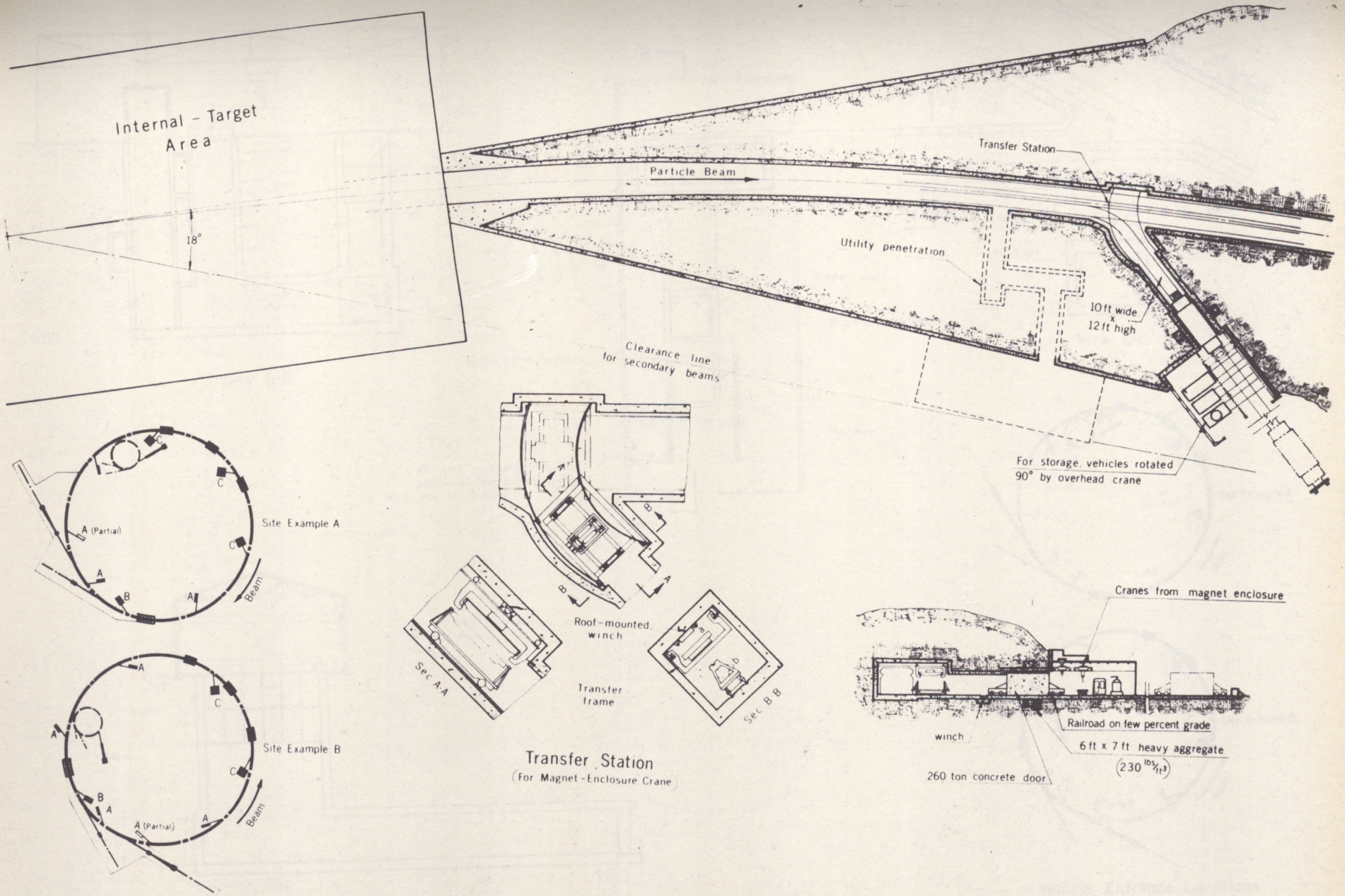
FIG. III-11

Main Synchrotron
Access Penetration



Vehicle Entrance Type A

FIG. III-12

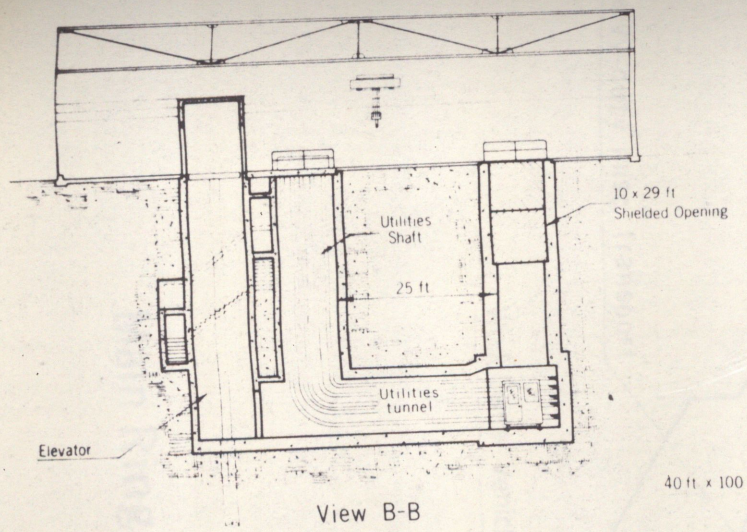


Vehicle Entrance Locations

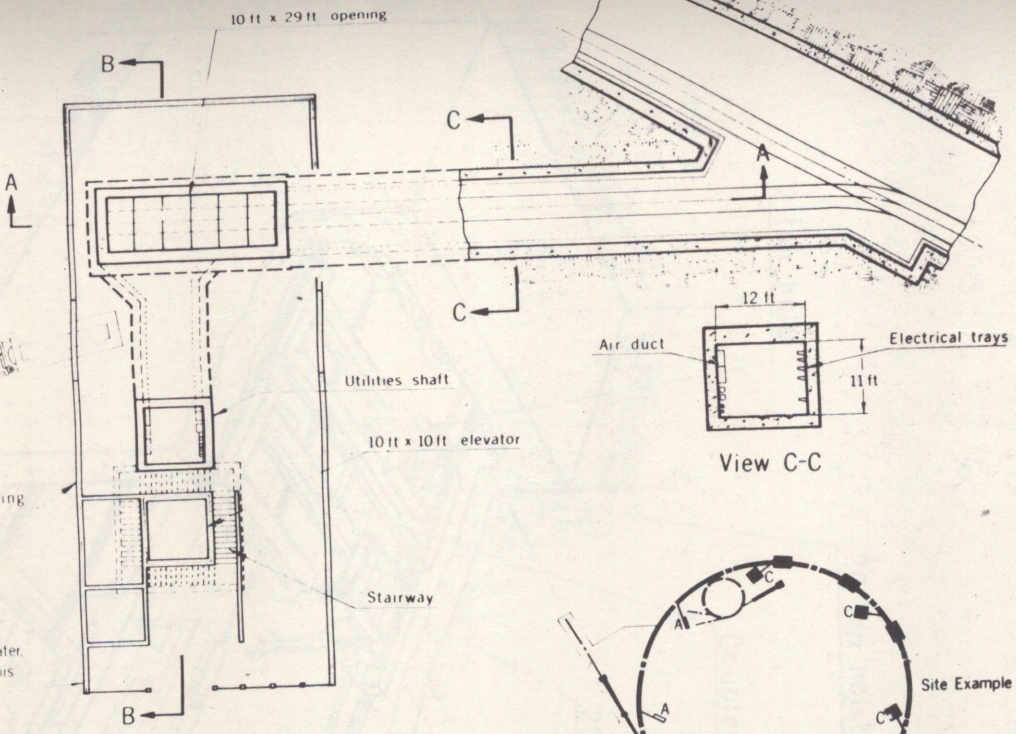
Transfer Station
(For Magnet-Enclosure Crane)

Vehicle Entrance Type B

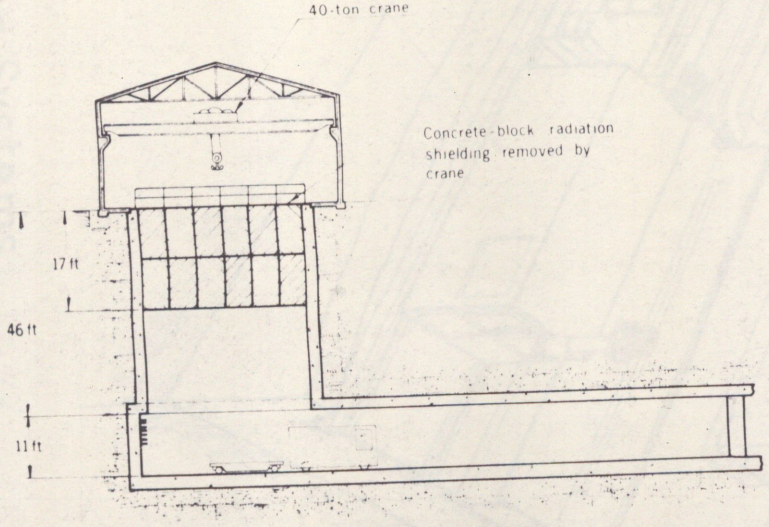
FIG. III-13



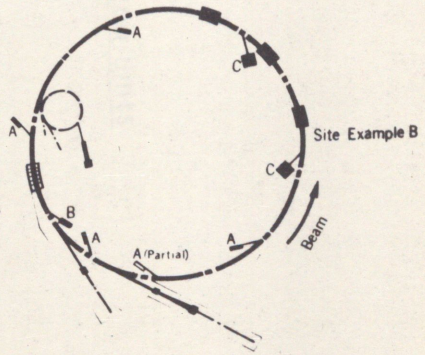
View B-B



View C-C



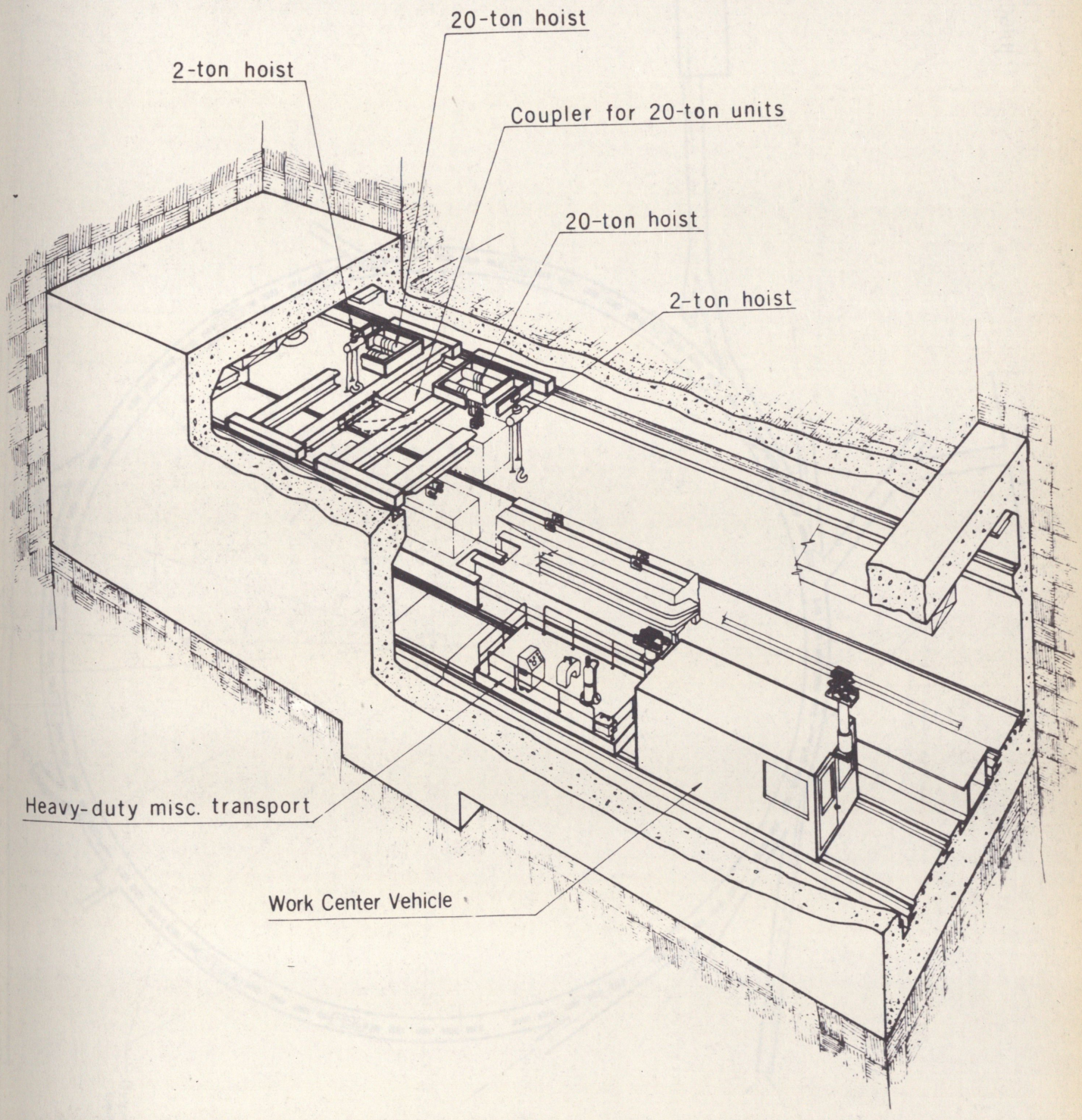
View A-A



Vehicle Entrance Locations

Vehicle Entrance Type C

FIG. III-14



Main Ring Handling Systems

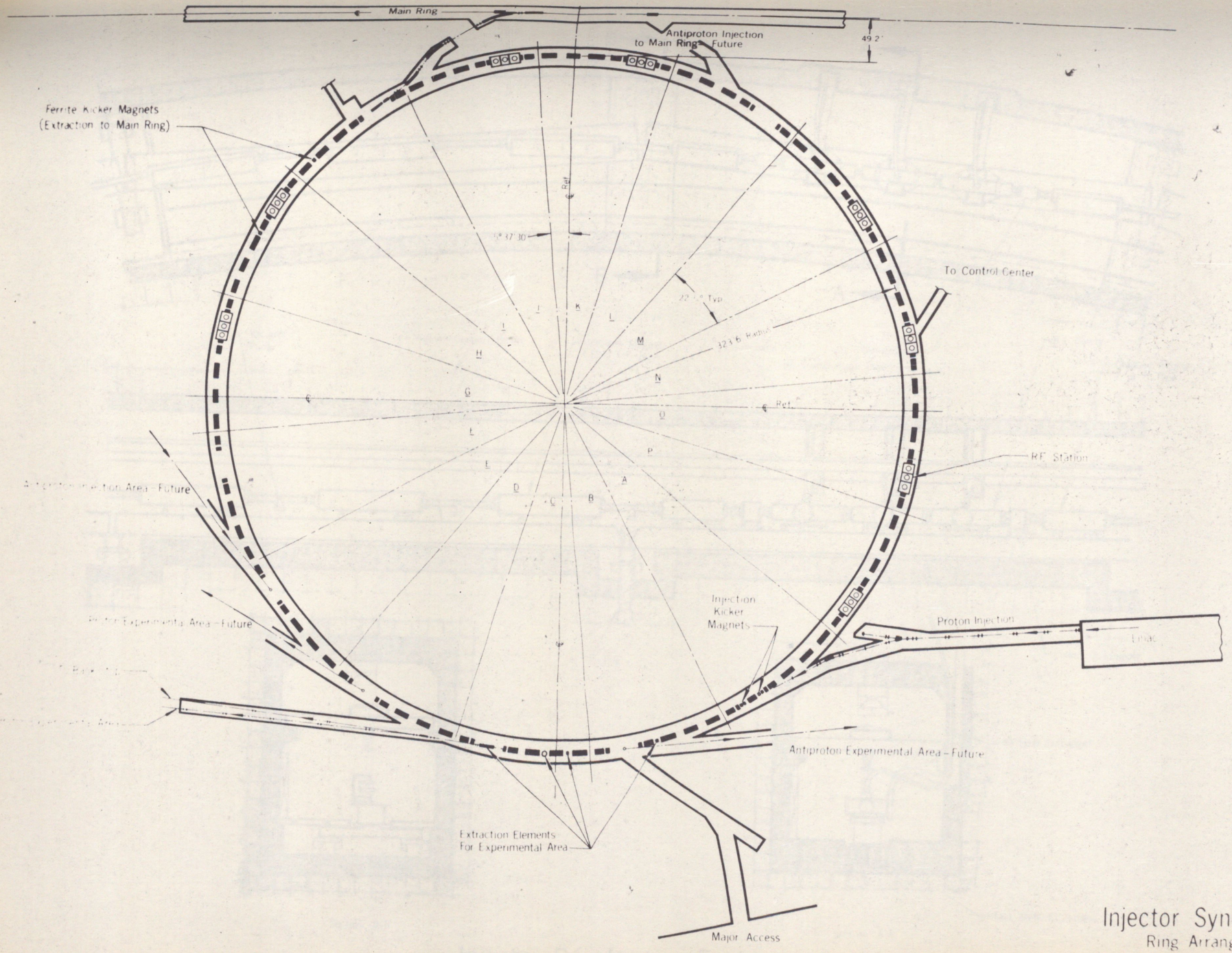
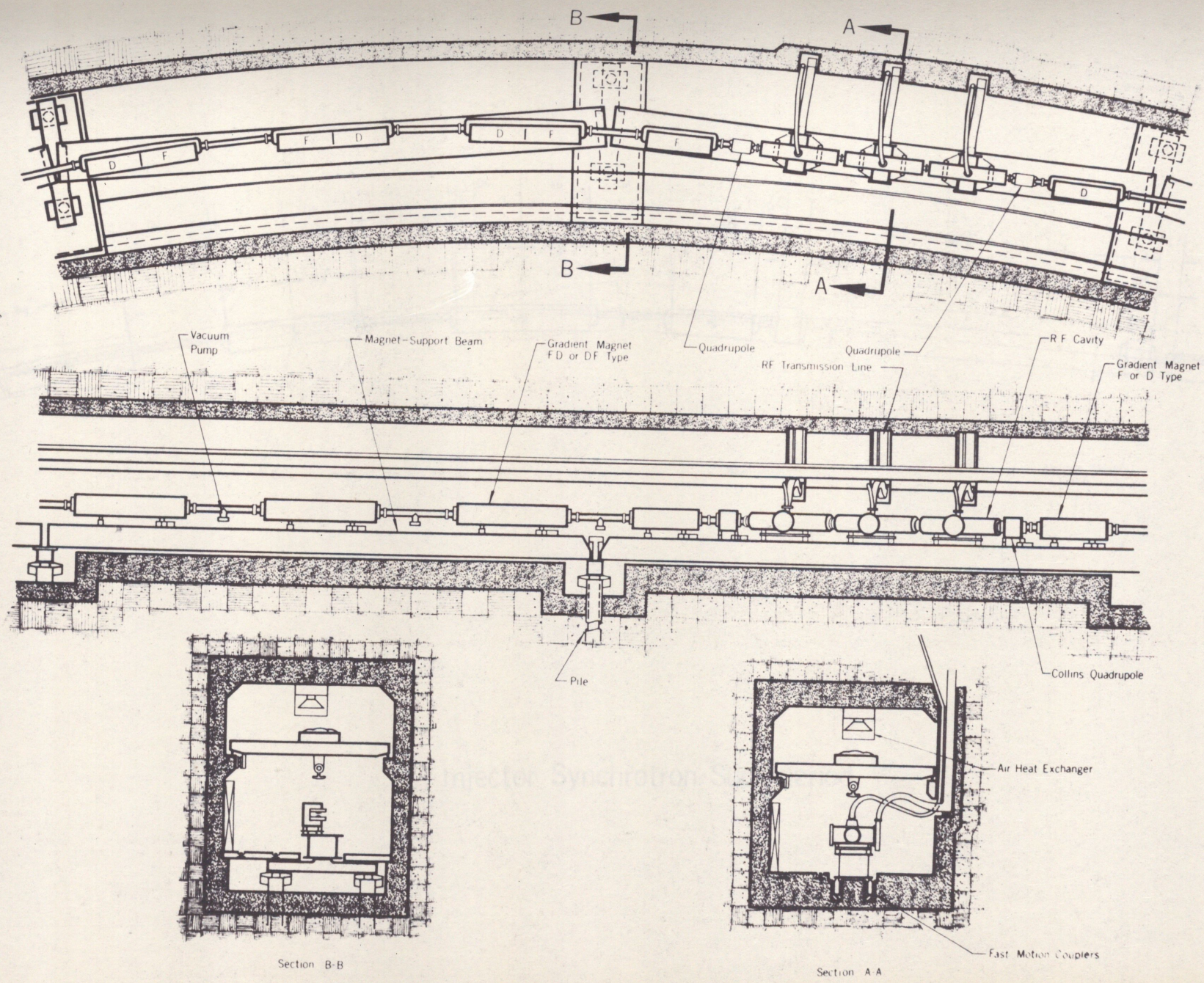


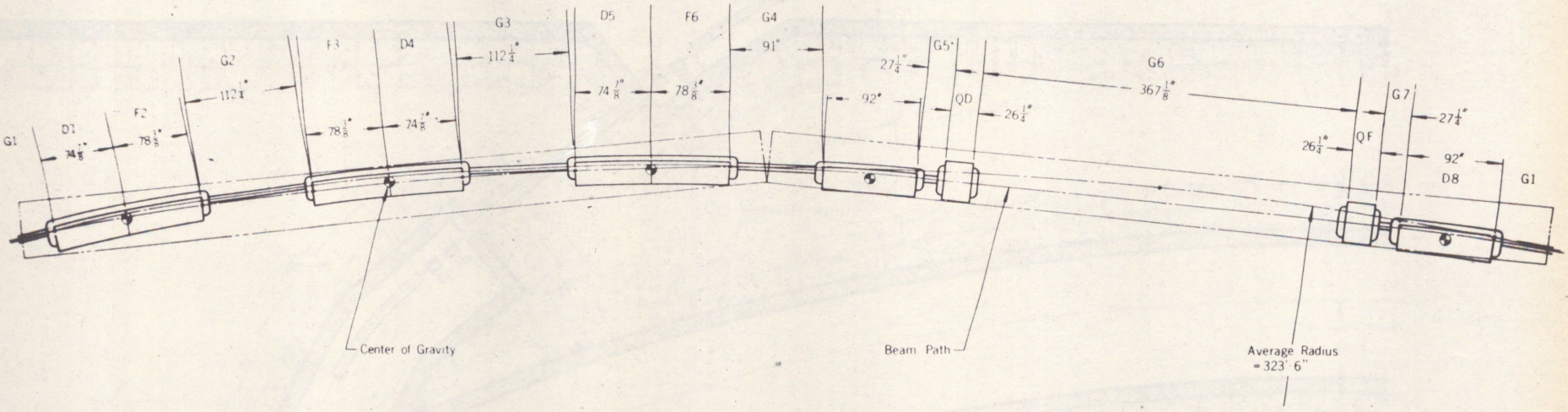
FIG. III-16

Injector Synchrotron
Ring Arrangement



Injector-Synchrotron Enclosure

FIG. III-17



Injector Synchrotron Superperiod

FIG. III-18

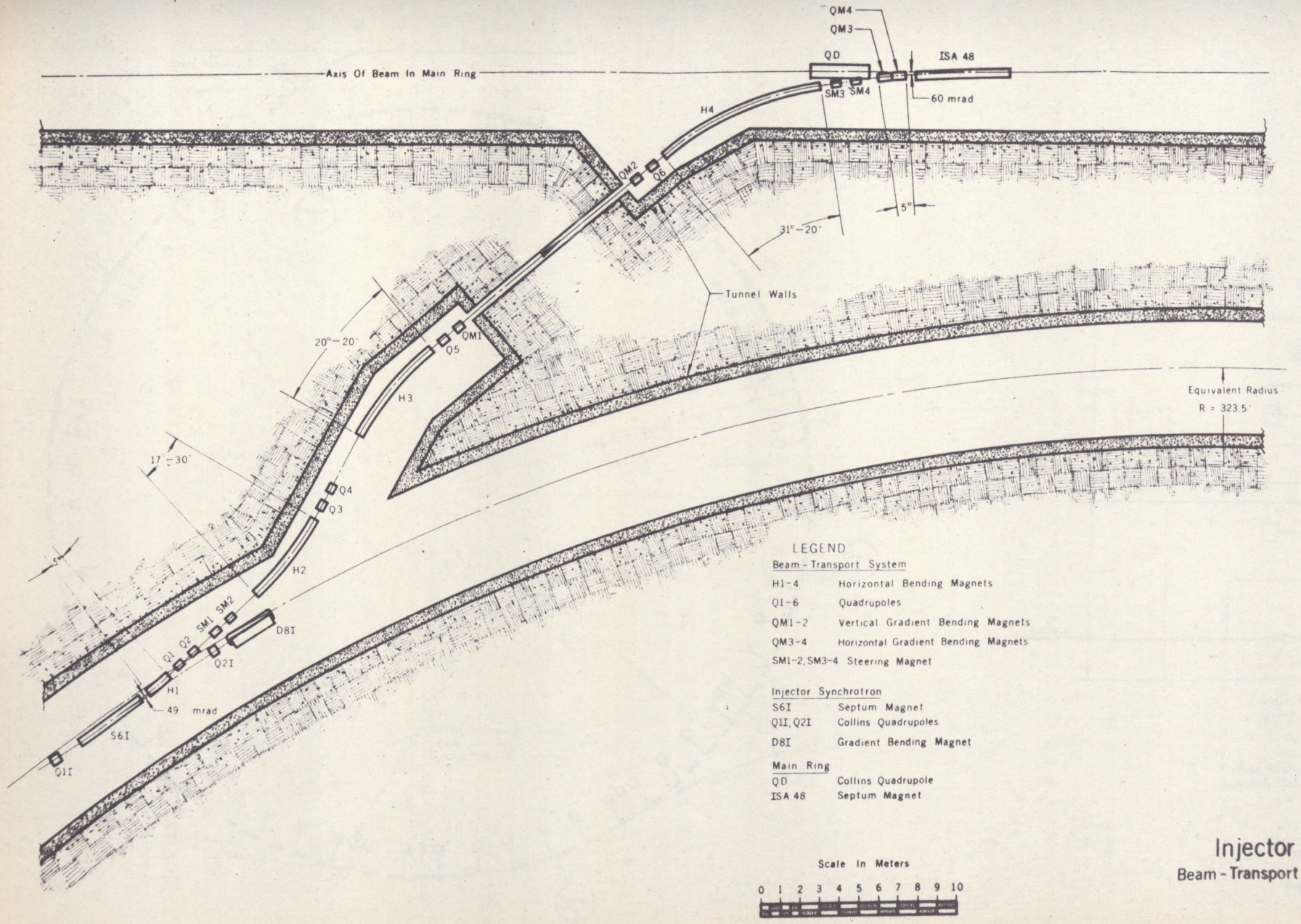
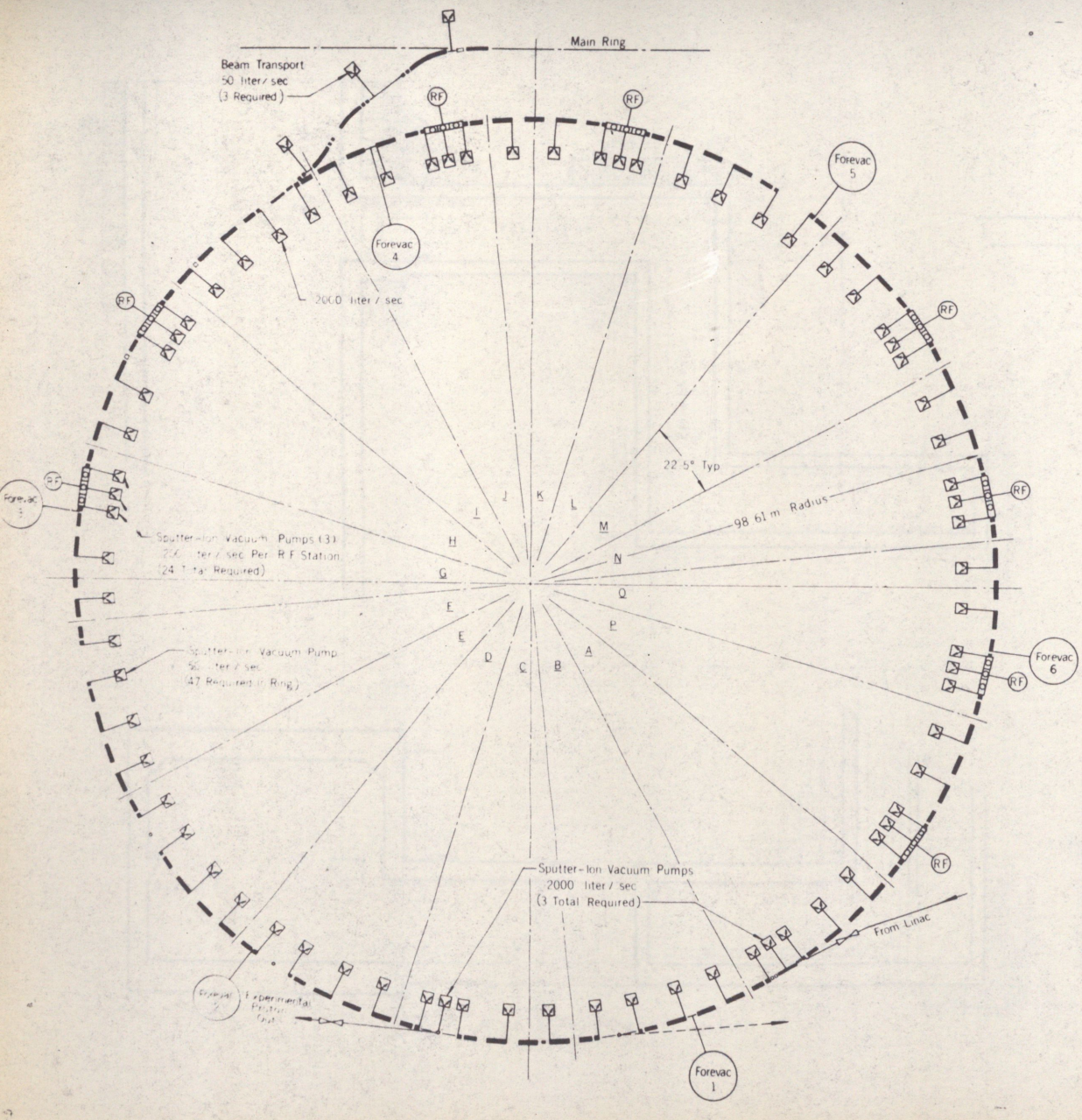
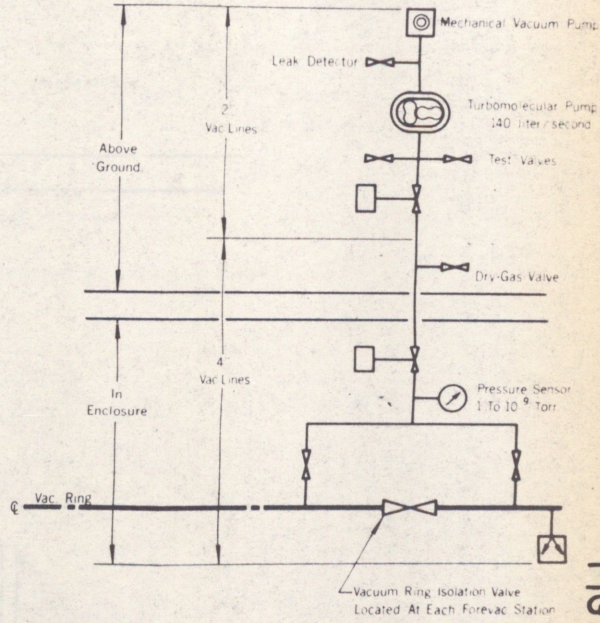


FIG. III-19

Injector Synchrotron
Beam-Transport System

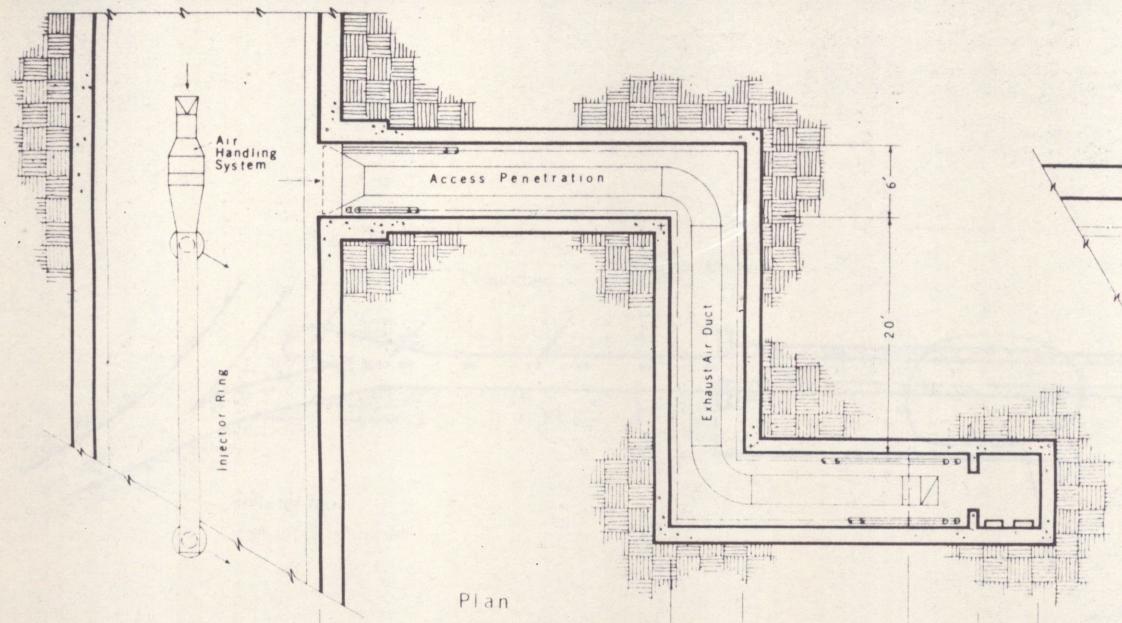




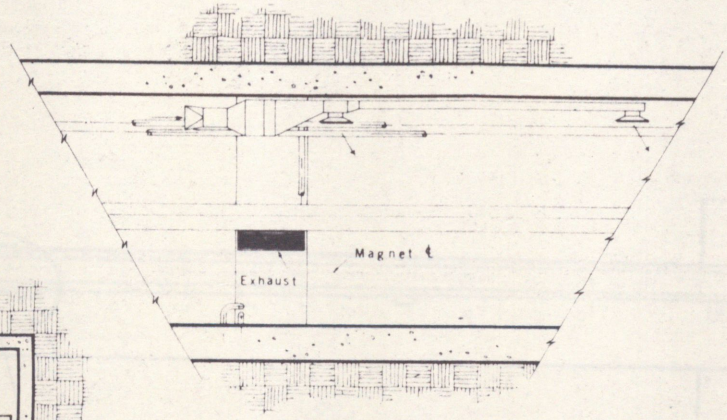
Forevac Station
Typical 6 Places

FIG. III-20

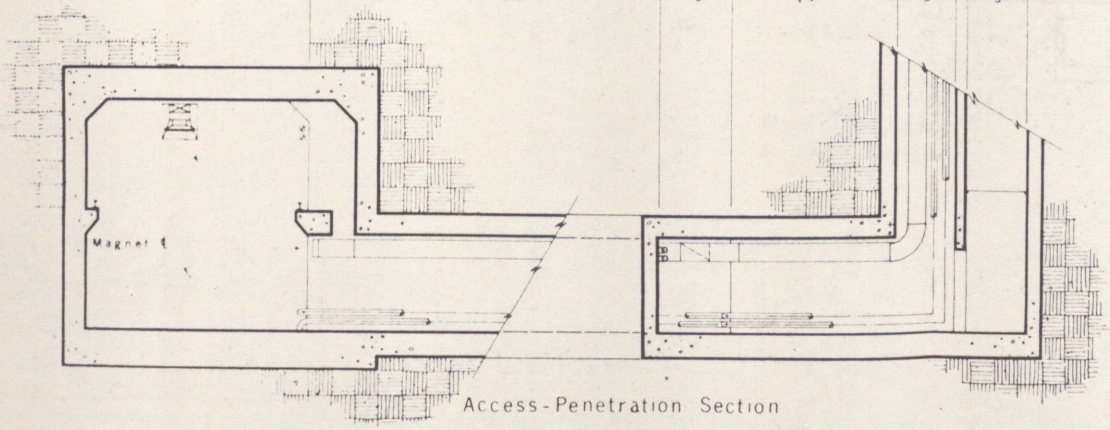
Injector Synchrotron
Vacuum System Schematic



Plan



Longitudinal Section At Injector Ring



Access-Penetration Section

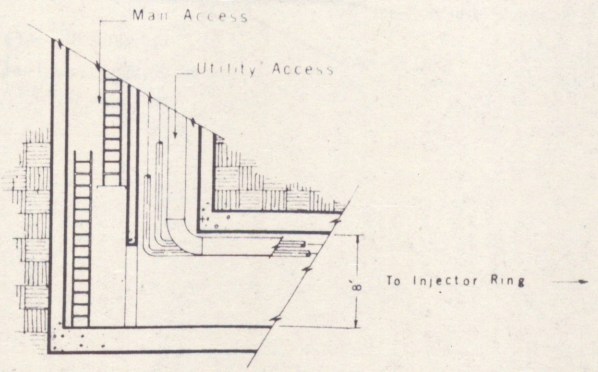


FIG. III-21

Injector Synchrotron
Access Penetration

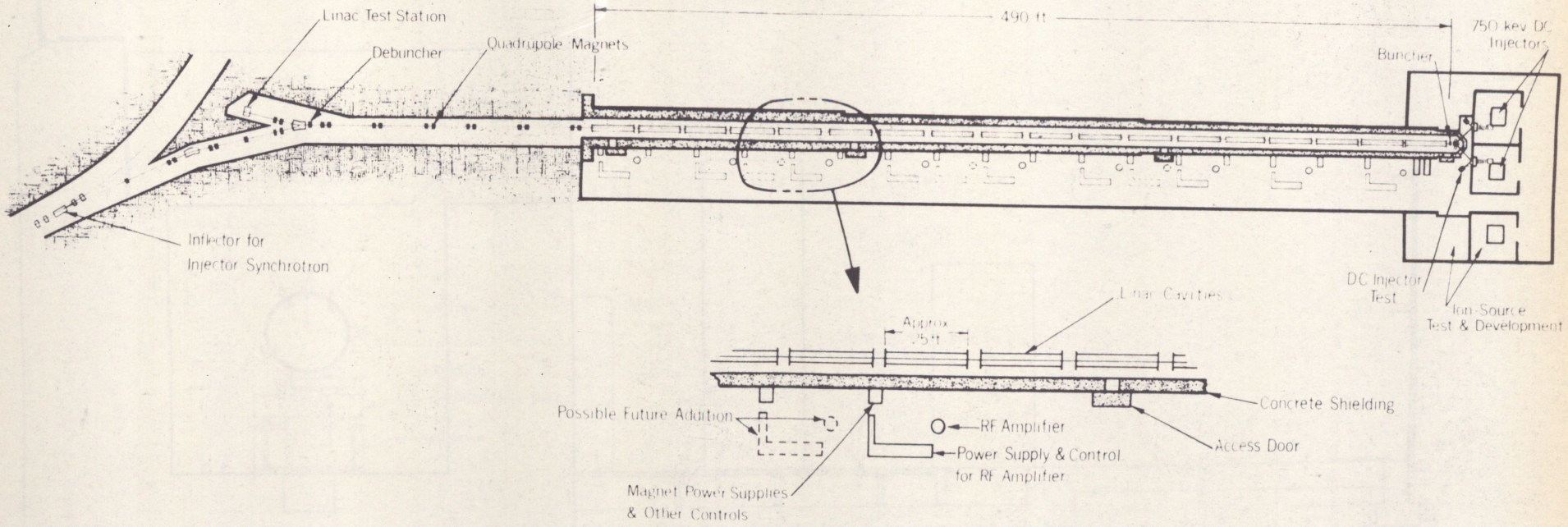
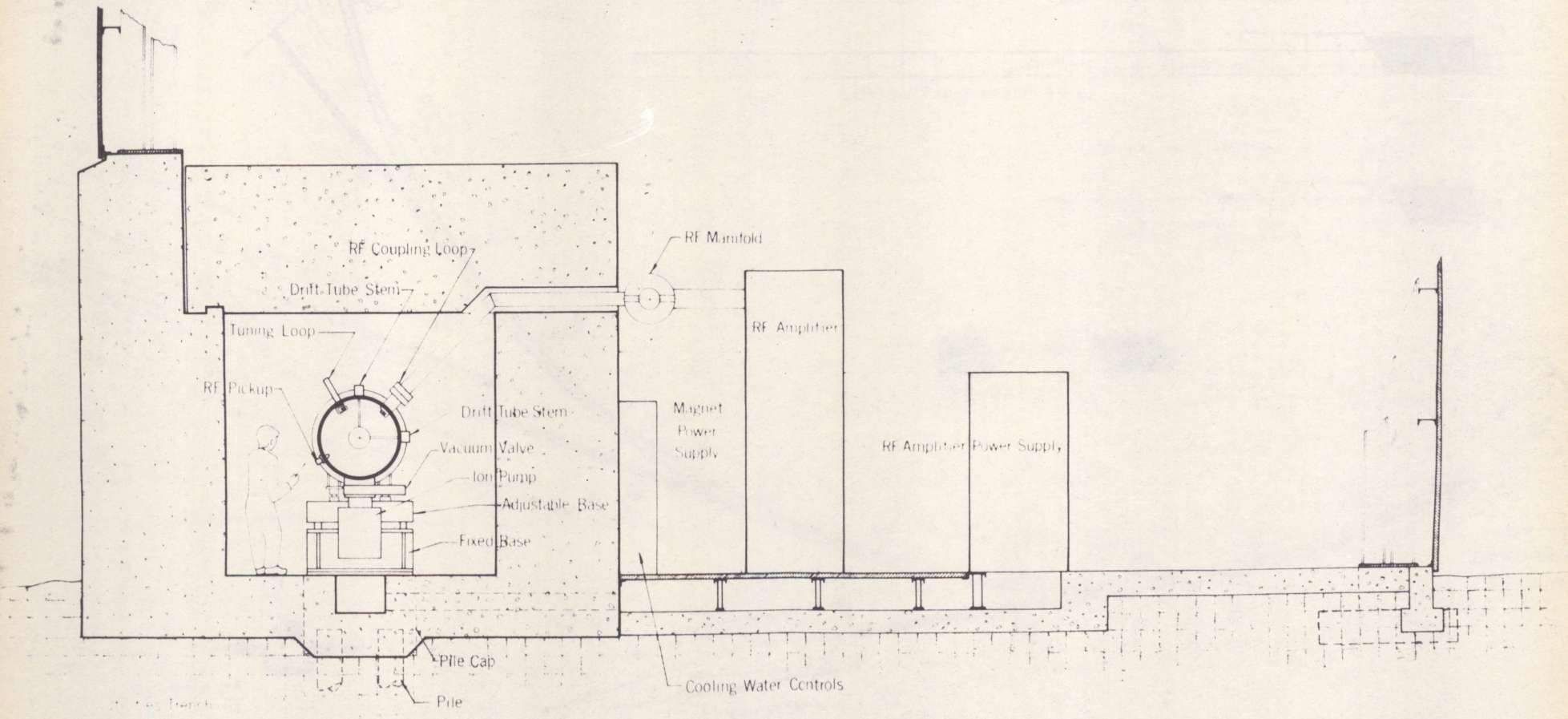


FIG. III-22

Linac Plan View



Linac Cross Section

FIG. III-23

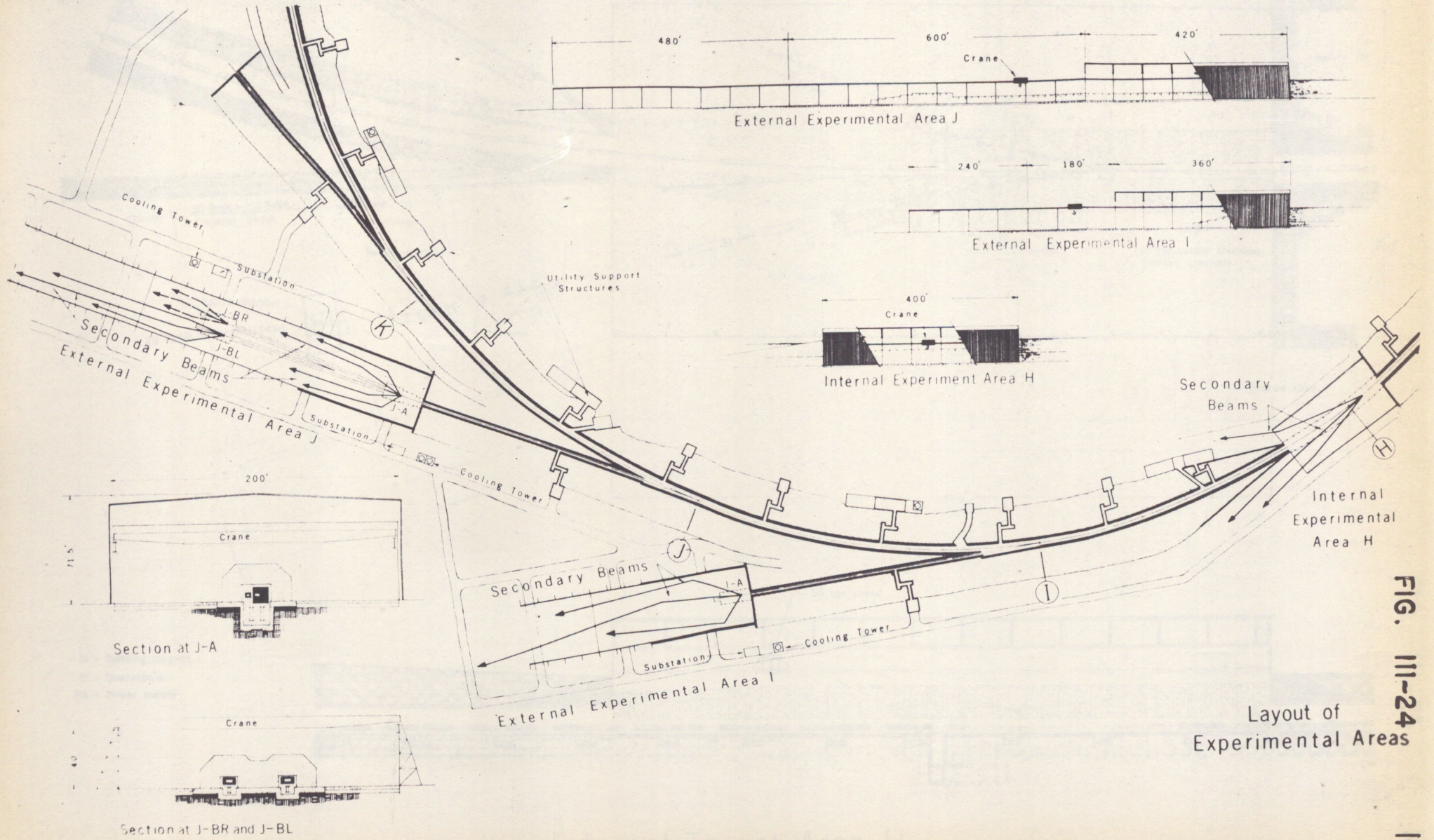
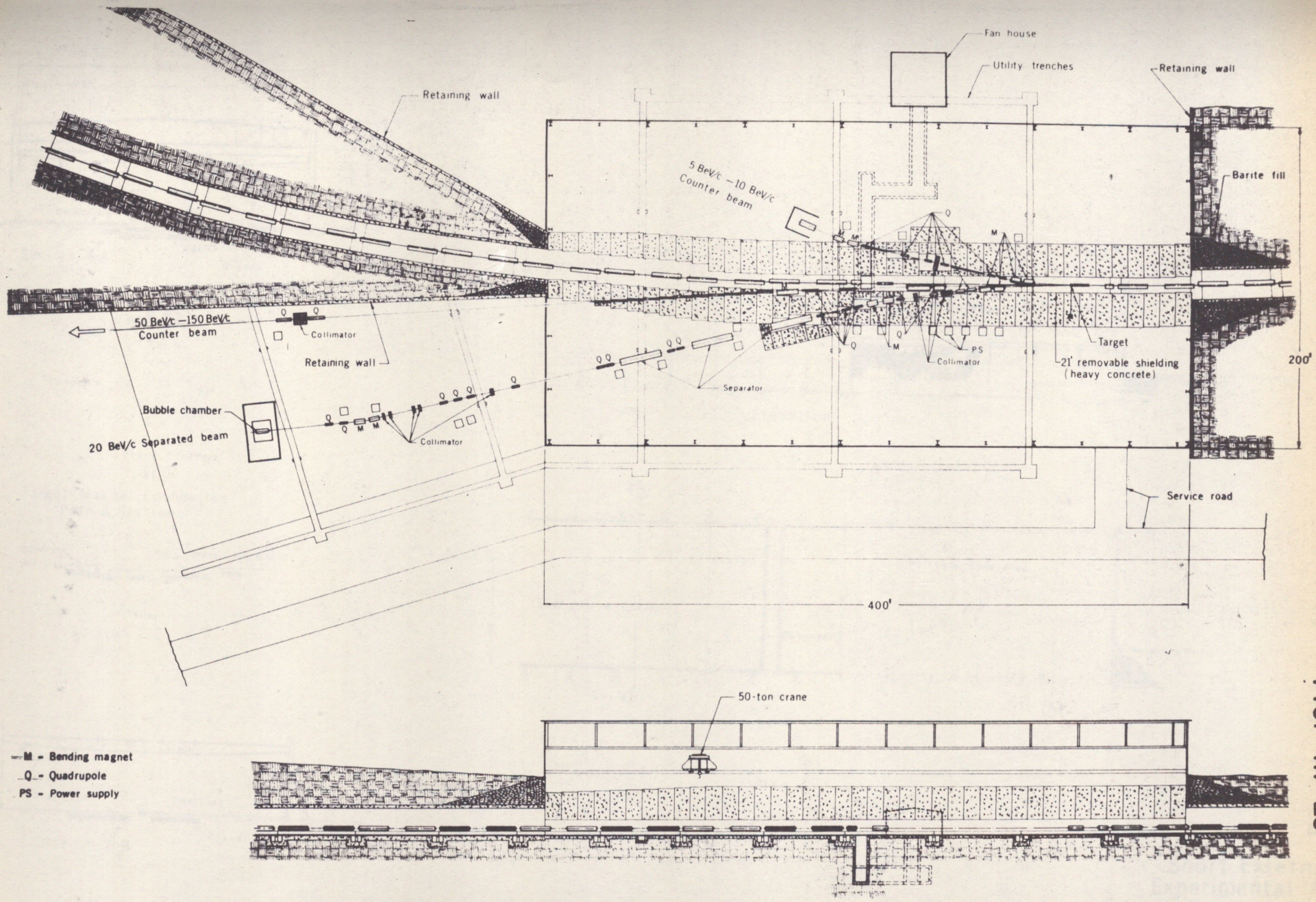


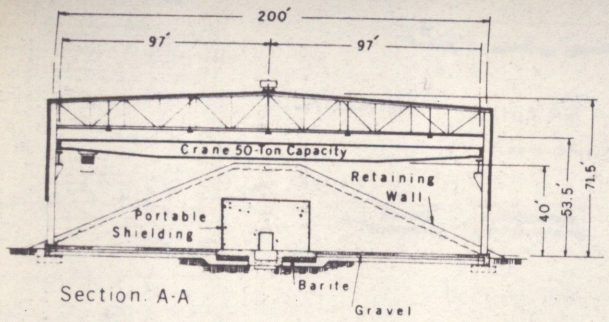
FIG. III-24

Layout of Experimental Areas

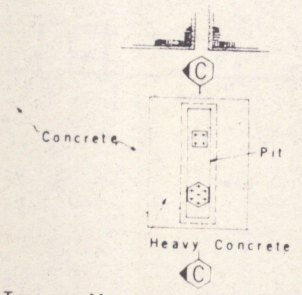


Internal Target Area H

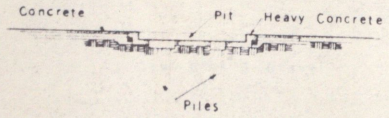
FIG. III-25



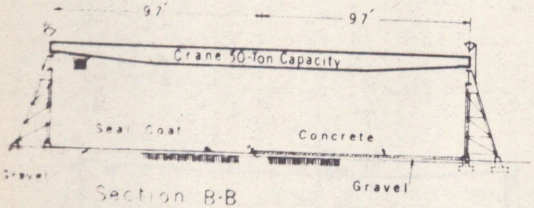
Section A-A



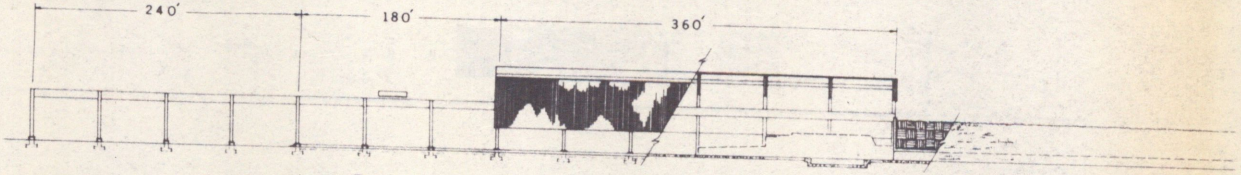
Target-Magnet Foundation
Plan & Sections



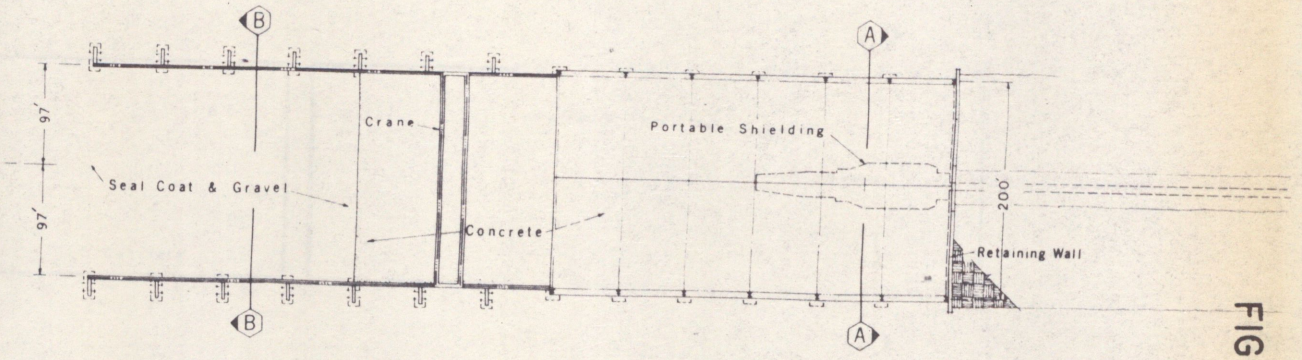
Section C-C



Section B-B



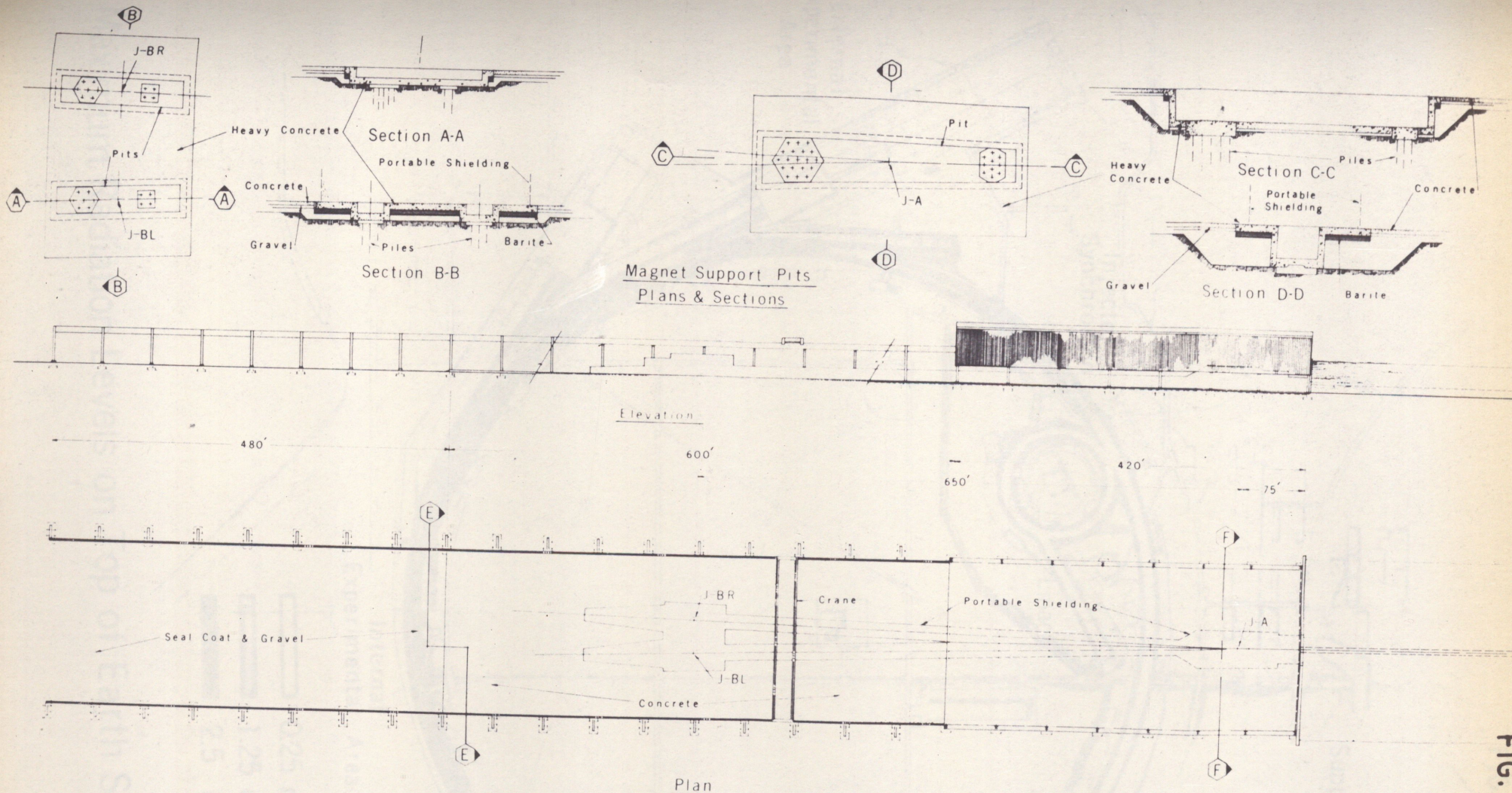
Elevation



Plan

FIG. III-26

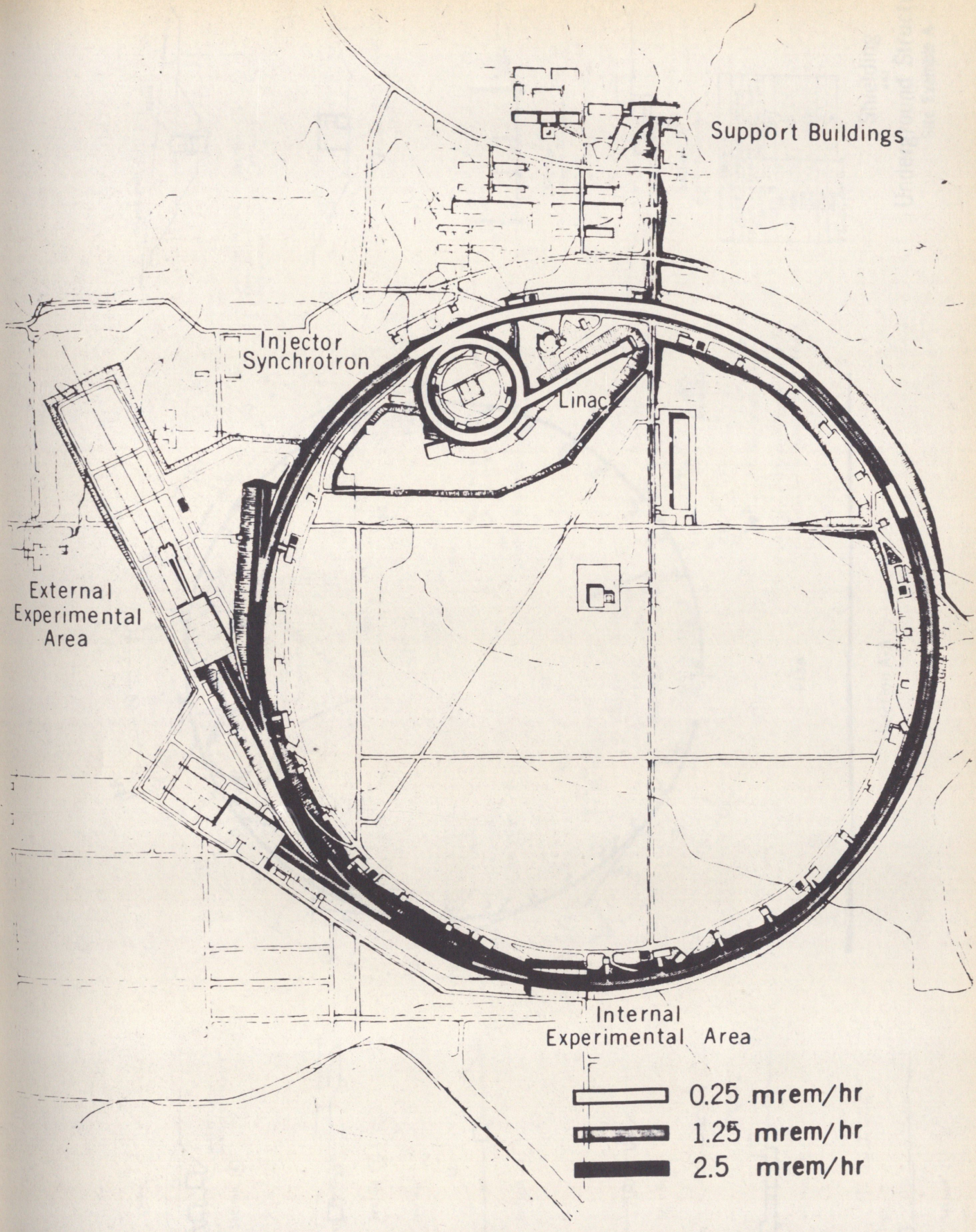
Short External
Experimental Area



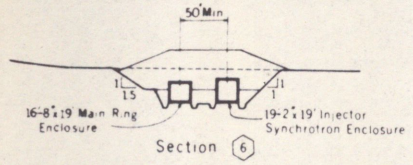
Magnet Support Pits
Plans & Sections

FIG. III-27

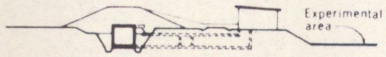
Long External
Experimental Area



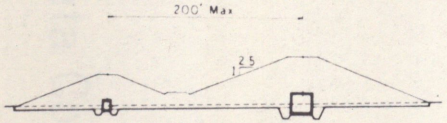
Maximum Radiation Levels on Top of Earth Shielding



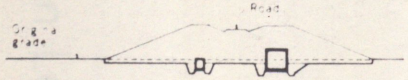
Section (6)



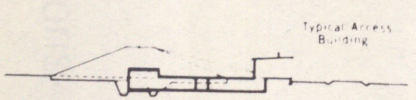
Section (5)



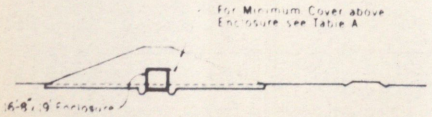
Section (4)



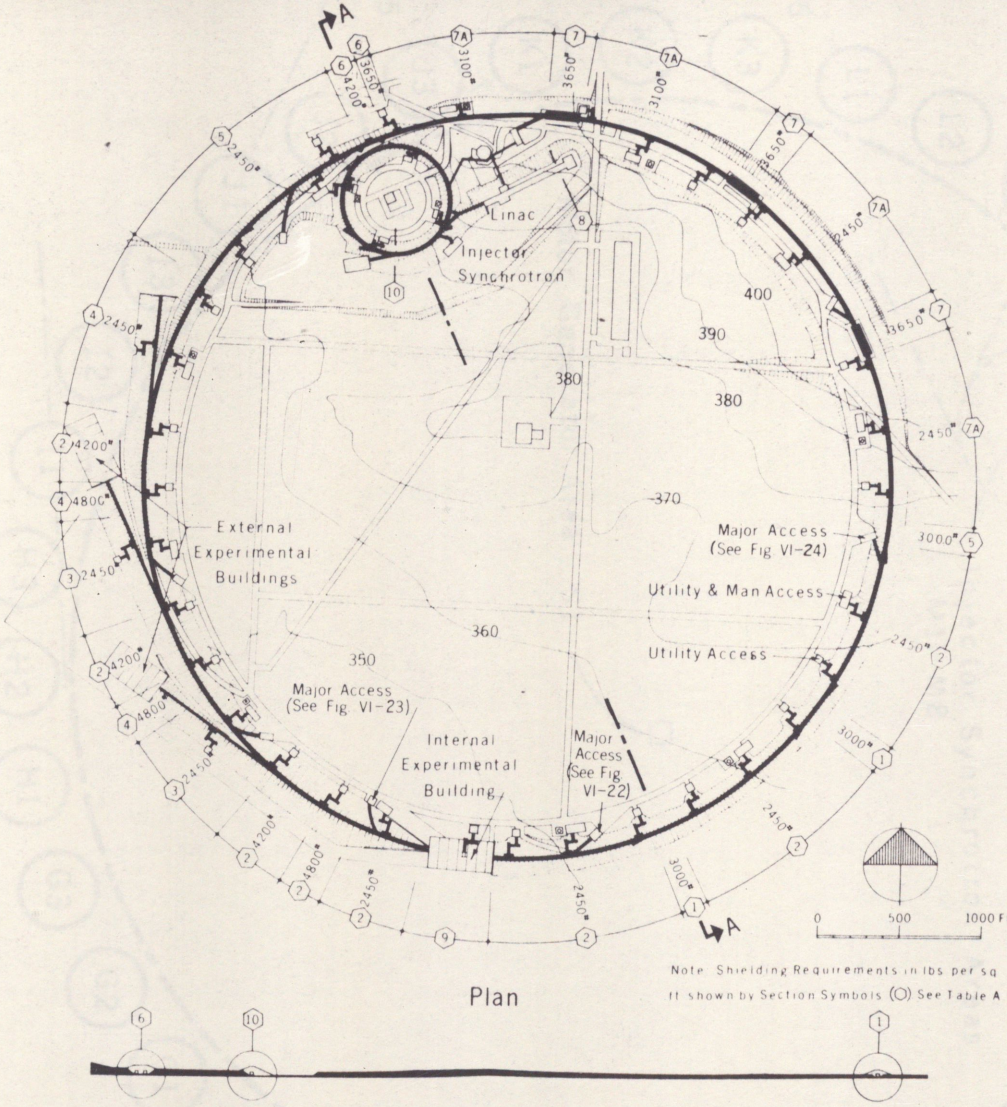
Section (3)



Section (2)



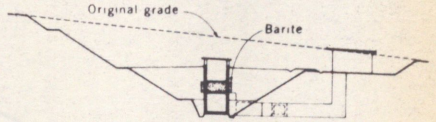
Section (1)



Plan

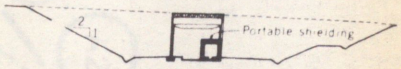
Note: Shielding Requirements in lbs per sq ft shown by Section Symbols (○). See Table A

Section A-A

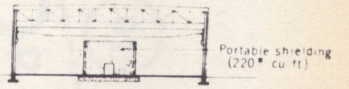


Section (7A) The Same Except Omits RF Building Above Enclosure

Section (7) RF Section



Section (8) Linac



Section (9) Internal-Experimental Building



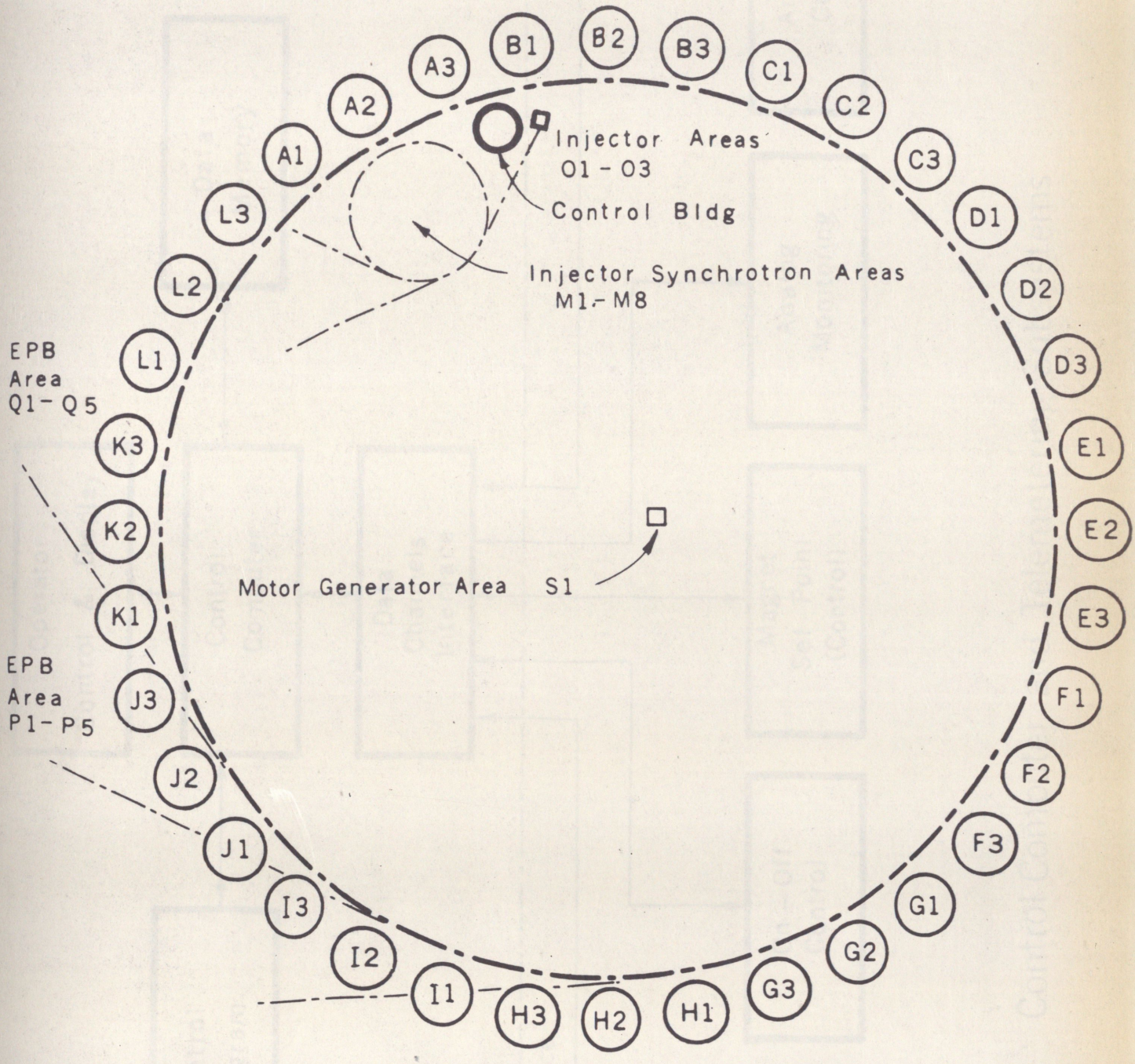
Section (10) Injector Synchrotron

Table A	
Typical Shielding Requirements	
Concrete and Earth Requirement	Minimum Cover above Enclosure*
Lbs per sq ft	Feet
2450	17
3000	21
3100	22
3650	27
4200	31
4800	36

* Density 120* /cu ft

FIG. III-29

Shielding and Underground Structures
Site Example A



Data Collection Locations

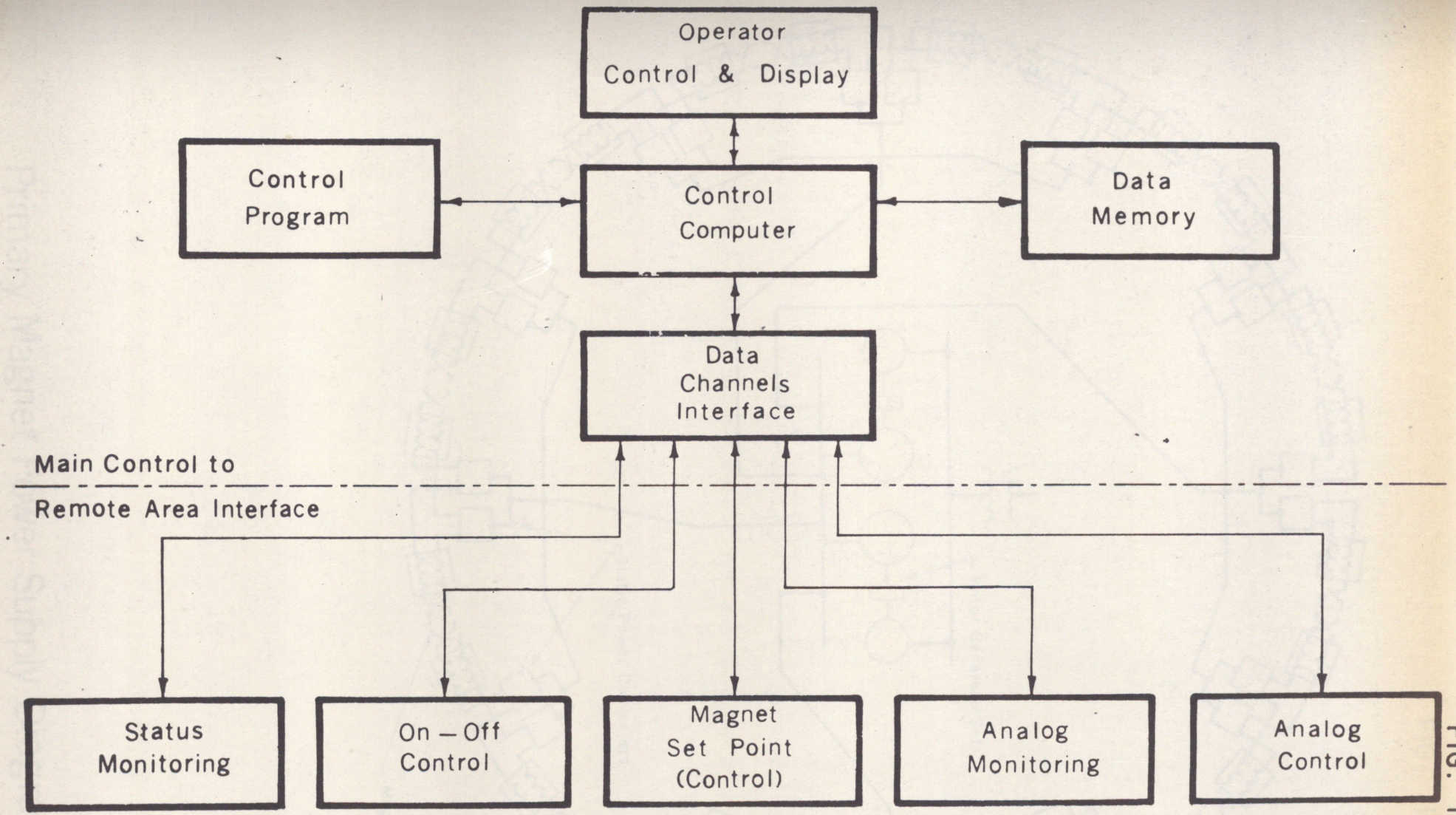
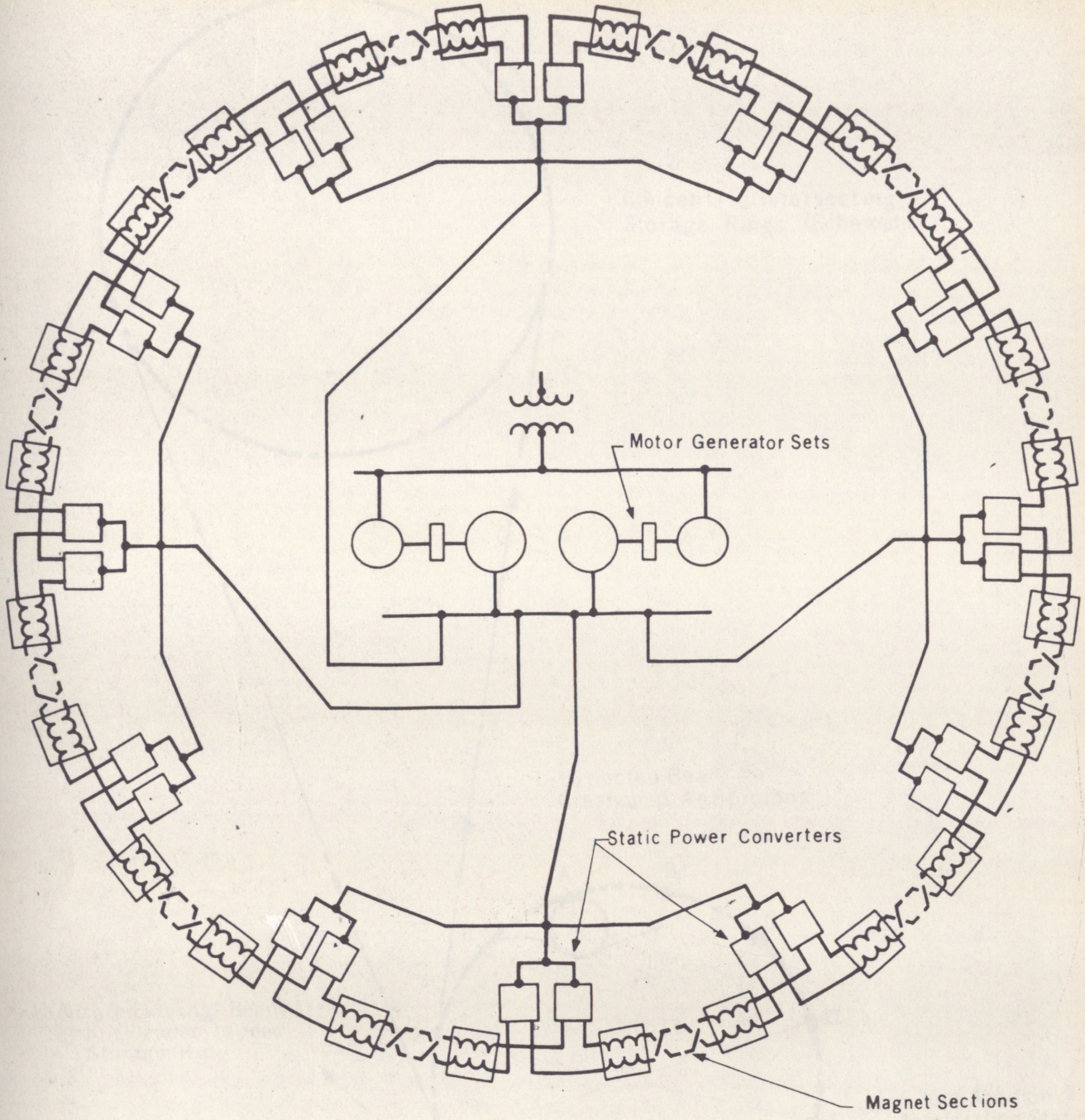
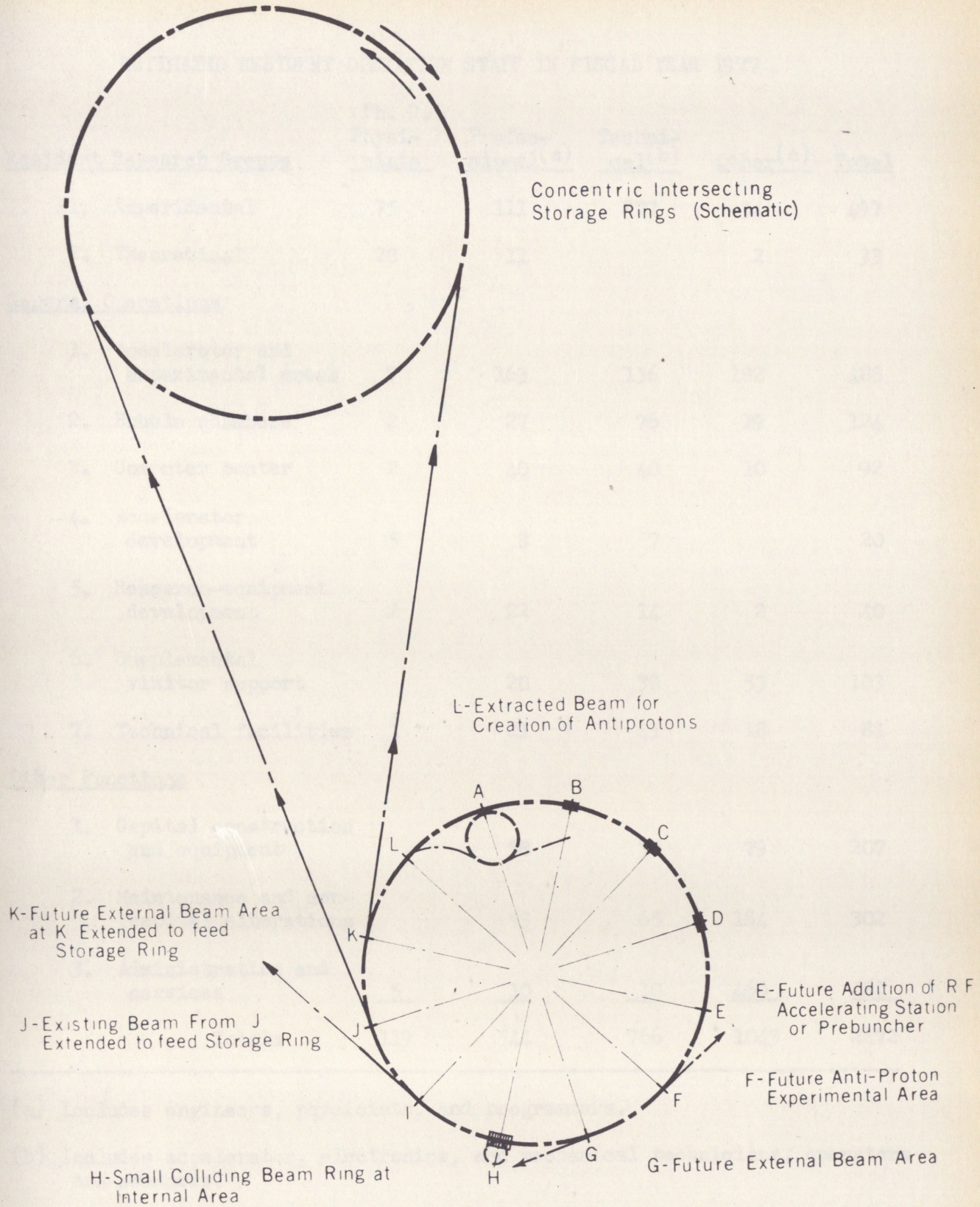


FIG. III-31

Control Computer and Telemetering Subsystems



Primary Magnet Power Supply Diagram



Possible Future Additional Facilities

ESTIMATED RESIDENT OPERATION STAFF IN FISCAL YEAR 1977

Resident Research Groups	Ph. D. Physicists	Professional[a]	Technical[b]	Other[c]	Total
1. Experimental	75	111	277	34	497
2. Theoretical	20	11		2	33
General Operations					
1. Accelerator and experimental areas	7	163	136	182	488
2. Bubble chambers	2	27	76	19	124
3. Computer center	2	40	40	10	92
4. Accelerator development	5	8	7		20
5. Research-equipment development	2	22	14	2	40
6. Supplemental visitor support		20	30	53	103
7. Technical facilities	1	21	41	18	81
Other Functions					
1. Capital construction and equipment		58	70	79	207
2. Maintenance and non-capital alterations		53	65	184	302
3. Administration and services	5	10	10	460	485
Totals	119	544	766	1043	2472

(a) Includes engineers, physicists, and programmers.

(b) Includes accelerator, electronics, and mechanical technicians, operators and scanners.

(c) Includes machinists, building trades and crafts, clerical, custodial and administrative.

ESTIMATED ANNUAL BUDGET IN FISCAL YEAR 1977

Operating Costs		Thousands of Dollars	
Wage expense (1478 full-time equivalents)		16300	
Supplies and expense		5200	
Major procurements:			
Film	3000		
Power(a)	3000		
Computer	1000		
Other	800		
		7800	
Engineering and shop burden (includes department administration, services, clerical and similar costs)		2100	
Total direct costs		31400	
Indirect costs (includes general administration and services)		9750	
Total operating costs			41150
Other Costs			
Equipment		7500	
Accelerator improvements		5000	
General plant construction		5000	
			17500
Total annual budget			58650

(a) Power costs calculated at 5 mills/kwh. Power costs will vary by 600 $K for each 1 mill change in cost.


Eureka
Libby
Kalispell
Whitefish
Columbia Falls
Cut Bank
Browning
Choteau
Thompson Falls
Polson
Ronan
St. Ignatius
Superior
Missoula
Lolo
Hamilton
Stevensville
Corvallis
Darby
Anaconda
Deer Lodge
Philipsburg
Butte
Walkerville
Helena
Lincoln
Augusta
Dupuyer
Valier
Conrad
Shelby
Chinook
Havre
Harlem
Malta
Glasgow
Wolf Point
Scobey
Plentywood
Sidney
Glendive
Miles City
Forsyth
Hardin
Billings
Livingston
Bozeman
Three Forks
Dillon
Wisdom
Jackson
Wise River
Big Hole
Big Hole Battlefield
Big Hole National Battlefield
Big Hole River
Big Hole Valley
Big Hole Basin
Big Hole Mountains
Big Hole Pass
Big Hole Canyon
Big Hole Meadows
Big Hole Ranger Station
Big Hole Lake
Big Hole Creek
Big Hole Forest
Big Hole Divide
Big Hole Range



LOCATIONS OF SOME UNIVERSITIES, COLLEGES, AND RESEARCH ORGANIZATIONS RELATIVE TO MISSOULA, MONTANA

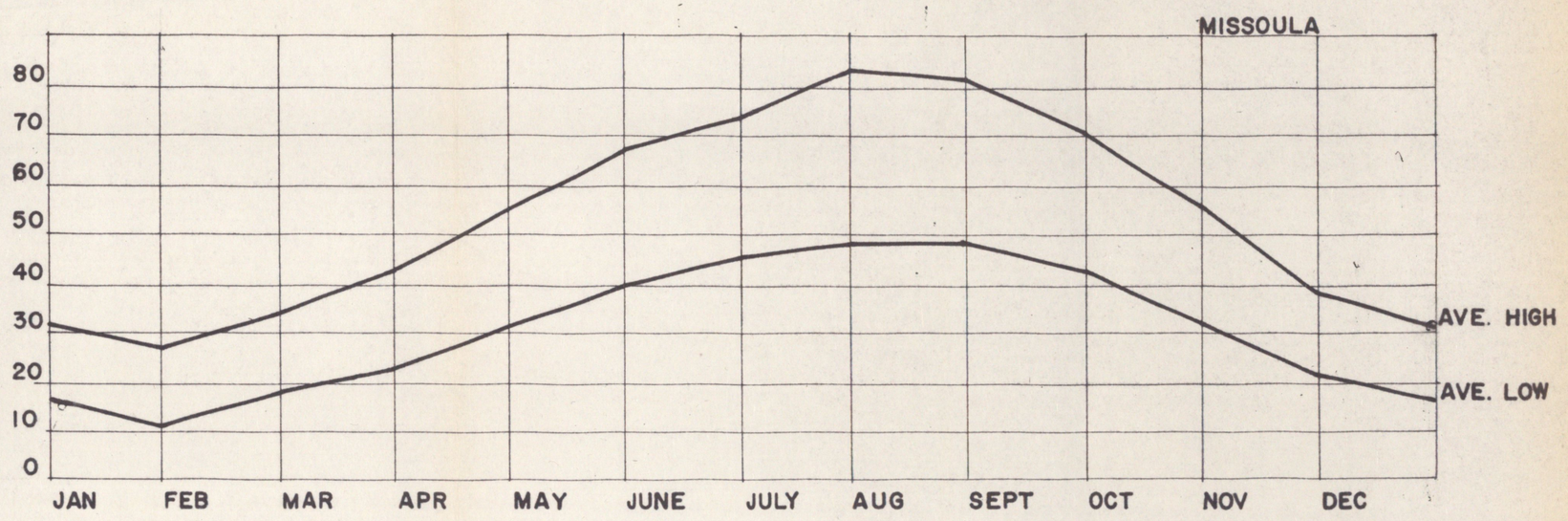
1. University of Montana, Missoula
2. U. S. Forest Service
   Northern Forest Fire Lab., Missoula
3. USPHS Rocky Mountain Lab., Hamilton
4. Montana College of Mineral Science and Technology, Butte
5. Anaconda Co. Laboratories, Butte
6. Montana State University, Bozeman
7. Holter Research Lab., Helena
8. Arco, Idaho, AEC Installation
9. University of Idaho, Moscow
10. Washington State University, Pullman
11. Whitworth College, Spokane
12. Eastern Washington College, Spokane
13. Battelle Memorial Laboratories (formerly Hanford AEC Works), Richland, Washington
14. University of Washington, Seattle
15. Boeing Co. Laboratories, Seattle
16. Oregon State University, Corvallis
17. University of Oregon, Eugene
18. University of Portland
19. Phillips Petroleum Co. Nuclear Research Labs., Idaho Falls
20. Eastern Montana College, Billings
21. Idaho State University, Pocatello
22. Utah State University, Logan
23. University of Utah, Salt Lake City
24. Brigham Young University, Provo
25. University of British Columbia, Vancouver
26. University of Alberta, Calgary campus

FIG. VI-2

Missoula, Montana, airport (17 miles south of Arlee)
Elevation 3190 ft. U. S. Weather Bureau
Station 24-5745-1

Annual Mean Max.	Annual Mean Min.	Annual Mean	Highest Temp. Recorded	Lowest Temp. Recorded
55.8°	31.5°	43.4°	105° Aug. '61	-33° Jan. '57

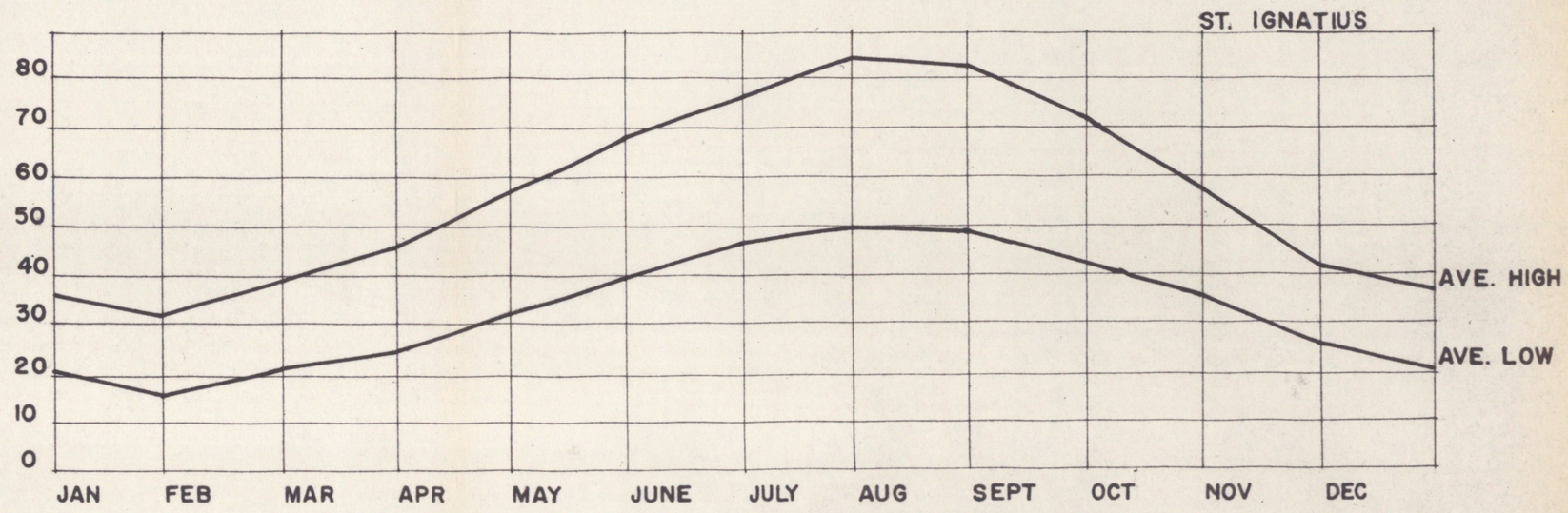
Ave. Days Temp. over 90°F	Ave. Days Temp. under 0°F	Annual Ave. Precip.	Ave. Annual Max. snow Depth
21	13	14.2 in.	10.7 in.



St. Ignatius, Montana (15 miles north of Arlee)
Elevation 2900 ft. U. S. Weather Bureau
Station 24-7286-1

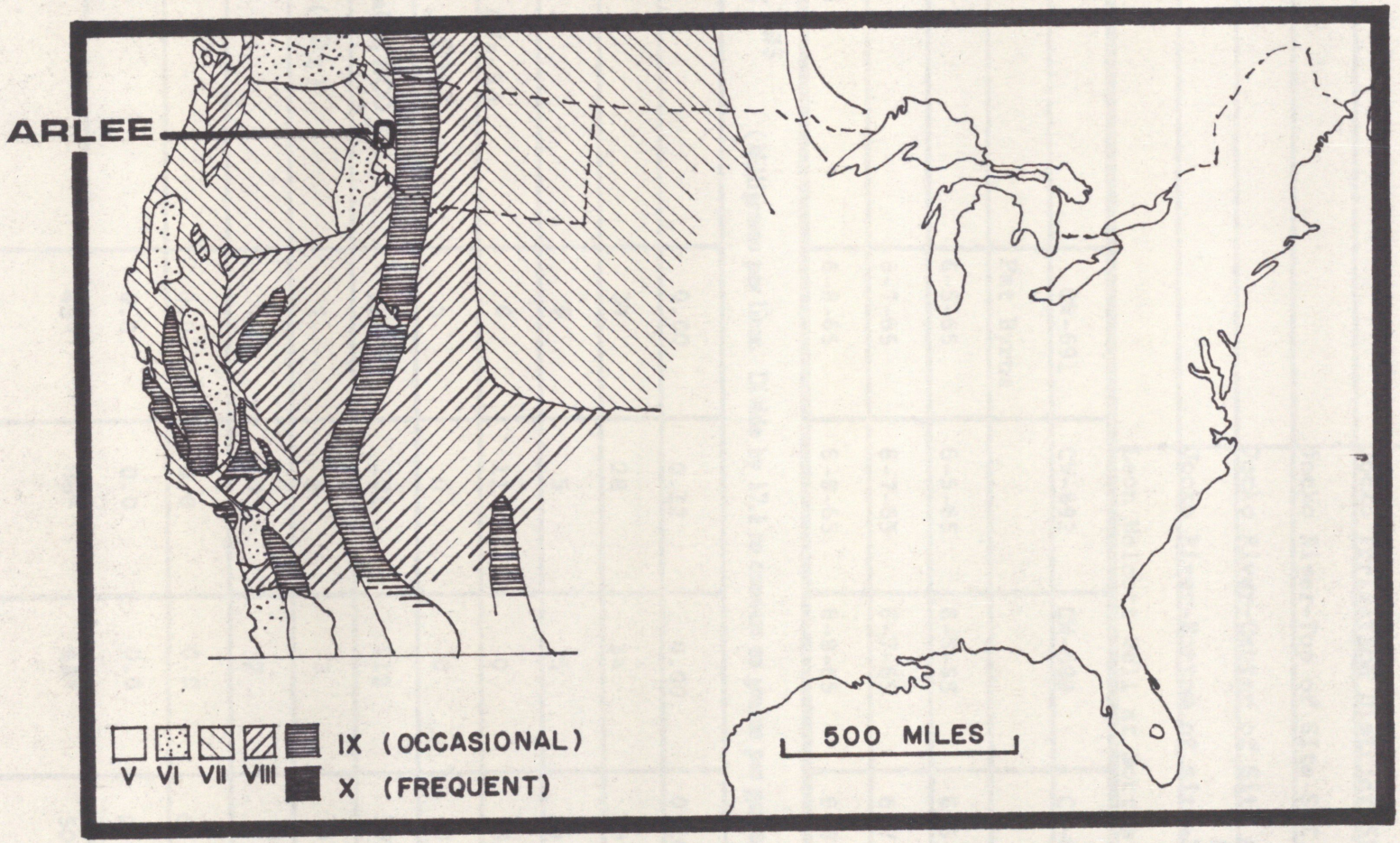
Annual Mean Max.	Annual Mean Min.	Annual Mean	Highest Temp. Recorded	Lowest Temp. Recorded
57.8°	33.4°	45.6°	103° July '56	-27° Feb. '56

Ave. Days Temp. over 90°F	Ave. Days Temp. under 0°F	Annual Ave. Precip.	Ave. Annual Max. snow Depth
22	11	17.1 in.	13.8 in.



VI-3 TEMPERATURE · PRECIPITATION

VI-4 AVERAGE MEAN MONTHLY TEMPERATURES



'SEISMIC REGIONALIZATION' MAP

FIG. VI-5

Form S. E. No. 7

MONTANA STATE BOARD OF HEALTH
REPORT OF CHEMICAL ANALYSIS OF WATER

City of ....Arlee.....

LAB NO.	MAP LOCATION	SPECIFIC LOCATION	SOURCE
CW-691		Jocko Irrigation District Station	Earl Atchley Well - 150'
CW-692		Jocko River-Top of Site-S.E. Section of Site	
CW-693		Jocko River-Center of Site at Highway Bridge	
CW-694		Jocko River-Bottom of site-River After joining of Jocko and Finley Creek	
CW-695		Leon Wolcott Well at Bottom of Site	

Laboratory No.	CW-691	CW-692	CW-693	CW-694	CW-695
Collected by	Pat Byrne				
Date Collected	6-5-65	6-5-65	6-5-65	6-5-65	6-5-65
Date Received	6-7-65	6-7-65	6-7-65	6-7-65	6-7-65
Analysis Reported	6-8-65	6-8-65	6-8-65	6-8-65	6-8-65

CHEMICAL ANALYSIS

(Milligrams per liter. Divide by 17.1 to convert to grains per gallon.)

Iron (Fe)	0.00	0.12	0.00	0.10	0.00
Calcium (Ca)	34	28	34	28	54
Magnesium (Mg)	9	5	5	5	7
Sodium and Potassium Calc. (Na-K)	0	11	0	3	17
Carbonate radical (CO_3)	0	0	0	0	0
Bicarbonate radical (HCO_3)	125	131	113	107	195
Sulphate radical (SO_4)	2	3	3	4	16
Chloride (Cl)	4	3	2	2	15
Fluorine (F)	0.0	0.0	0.0	0.0	0.4
Nitrates (NO_3)	0.0	0.0	0.0	0.0	1.1
Temperature	48°	46°	48°	50°	54°
Total Hardness (as $CaCO_3$)	120	90	105	90	165
Total Dissolved Solids	130	94	102	100	240

June 8, 1965

CHEMICAL ANALYSIS

Five samples of water for mineral analysis have been submitted to the State Board of Health Laboratory by Mr. Pat Byrne of the State Planning Board. These samples were taken in the vicinity of Arlee, Montana - two from wells and three from the Jocko River.

The results of our analysis are recorded on the reverse side of this sheet, the figures representing milligrams per liter, which are equivalent to parts per million (parts of materials per million parts of water). Parts per million may be converted to grains per gallon by dividing by 17.1.

The total mineral contents of these waters as determined by the total dissolved solids varies from 94 to 240 milligrams per liter. These contents are low and classify the waters as good (between 0 and 500 milligrams per liter) from the standpoint of drinking.

These waters have a total hardness, calculated as calcium carbonate, varying between 90 and 165 milligrams per liter. This classifies the water as moderately hard (between 90 and 200 milligrams per liter).

The waters vary between 0 and 0.12 milligrams per liter of iron. These contents do not exceed the limits usually set for this material (0.3 milligrams per liter).

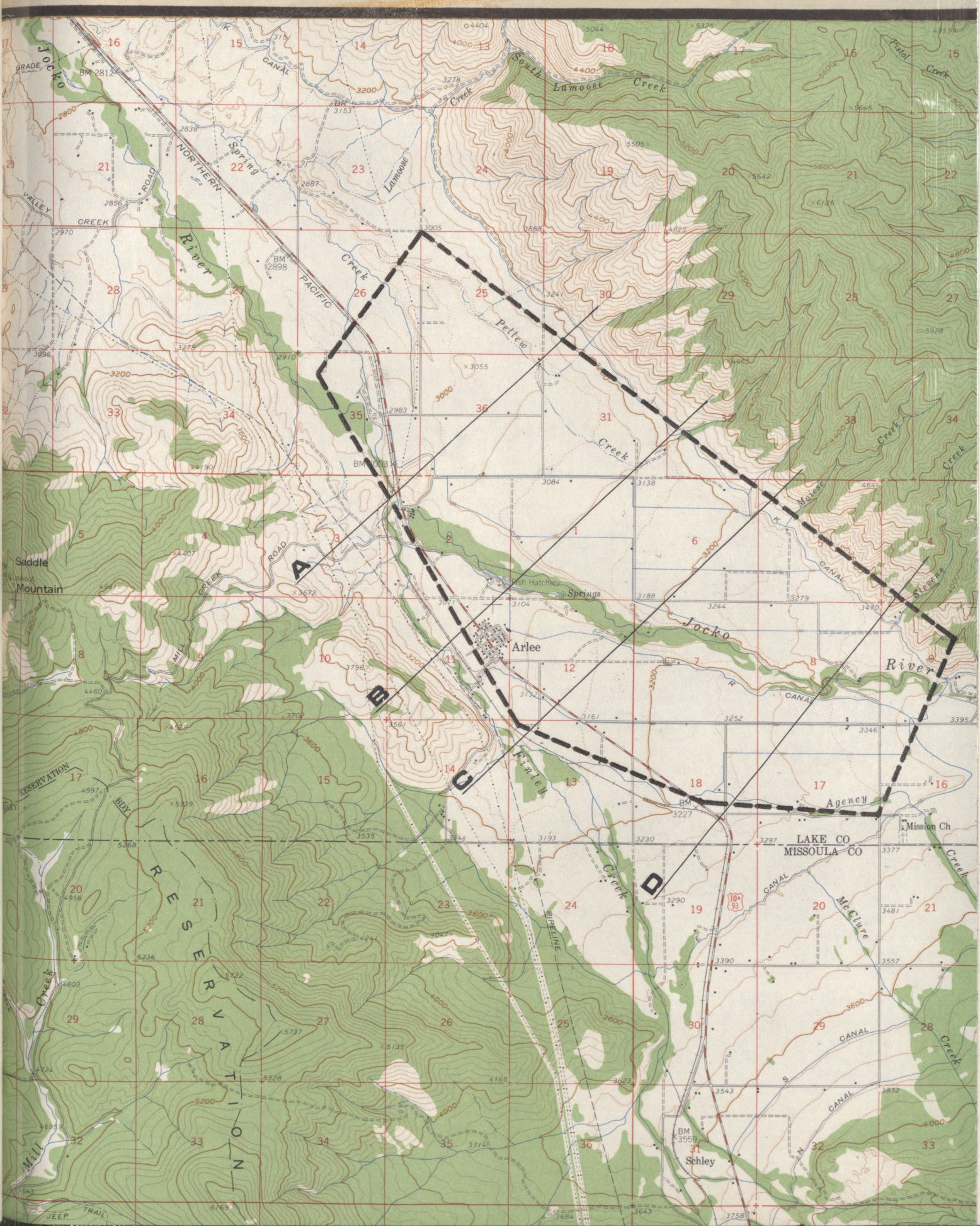
This analysis gives information relative to the chemical quality of the water and has no significance so far as the sanitary features are concerned.

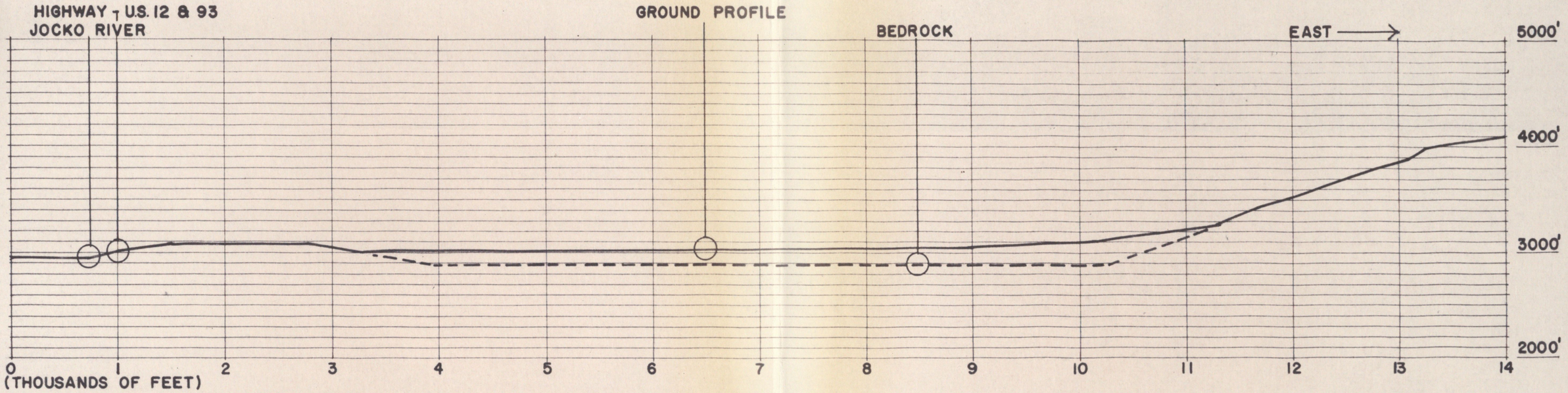
Respectfully submitted,

Claiborne W. Brinck, Director
Div. of Environmental Sanitation

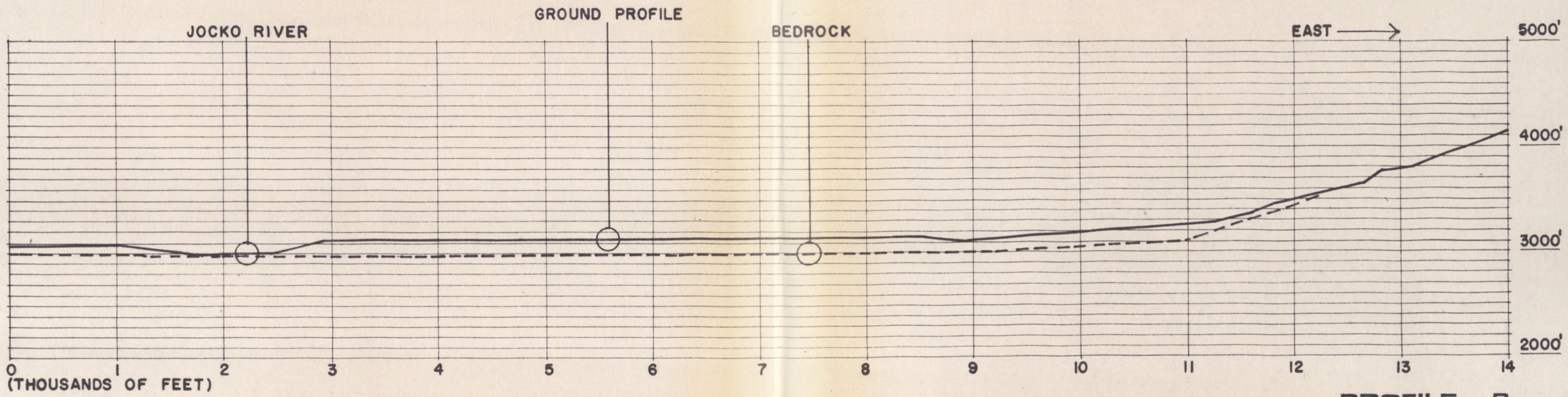
CWB:mg

Reports to: State Planning Board, Helena

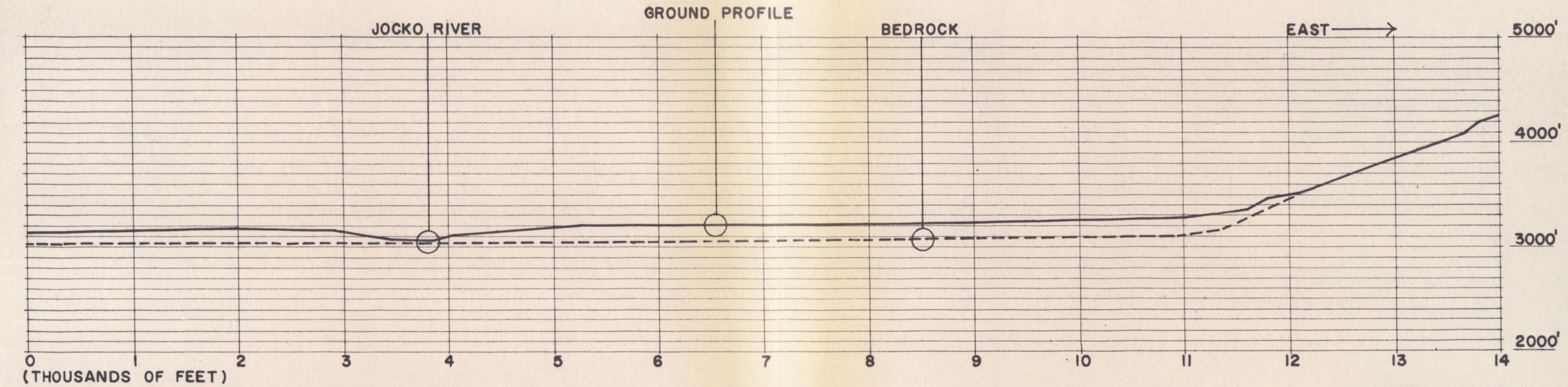

Jocko
GRADE
BM 2812
CANAL
NORTHERN
PACIFIC
ROAD
WALLEY
CREEK
Spring
Lamoose
Creek
South
Pistol
River
BM 2898
Peltew
Saddle
Mountain
Lookout
Fish Hatchery
Springs
Arlee
Jocko
River
Finley
Creek
Agency
Mission Ch
LAKE CO
MISSOULA CO
McClure
PIPELINE
RESERVATION
BDY
Schley
JEEP TRAIL
A
B
C
D



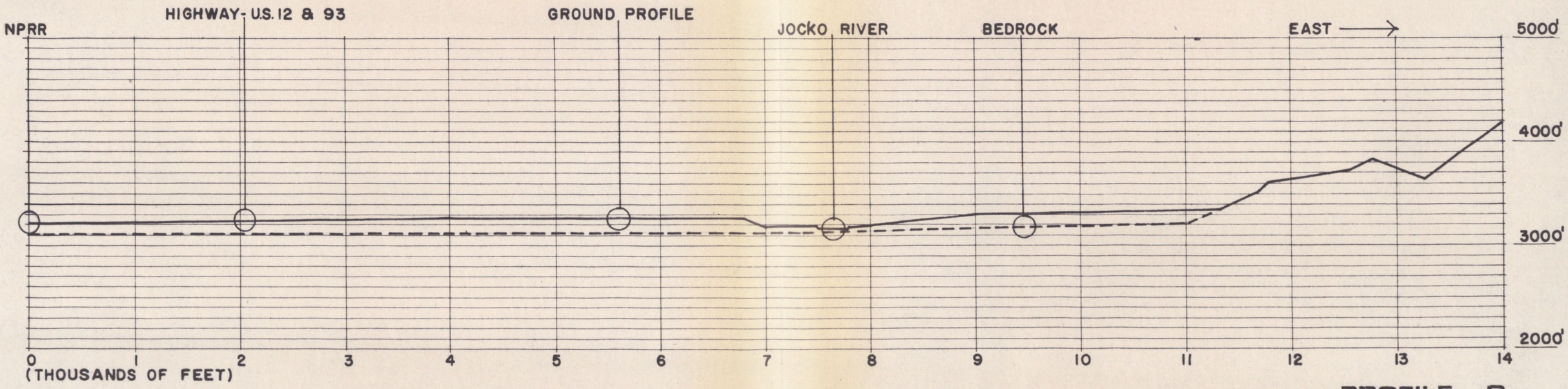
PROFILE A



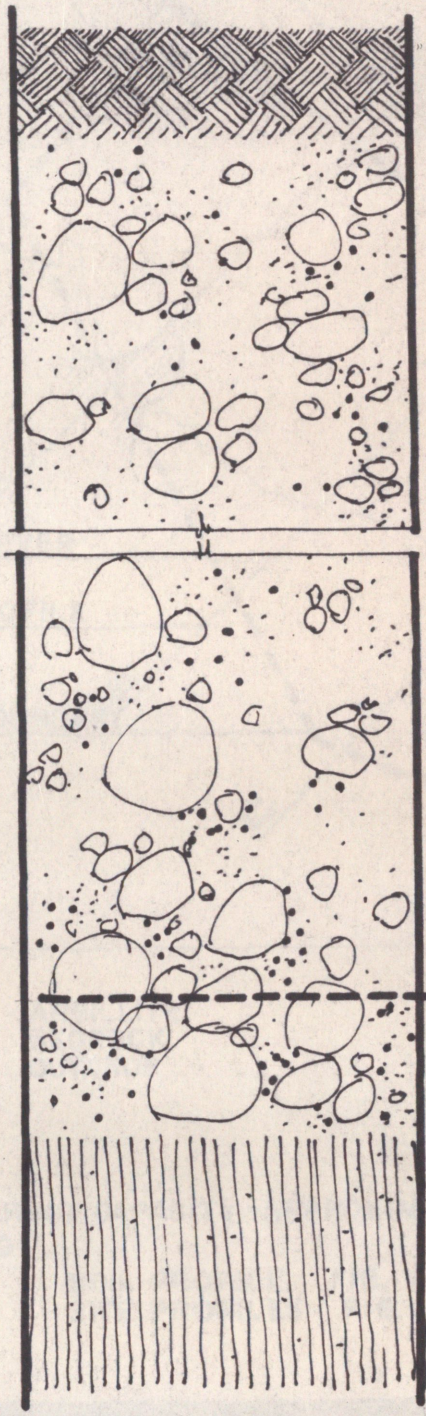
PROFILE B



PROFILE C



PROFILE D



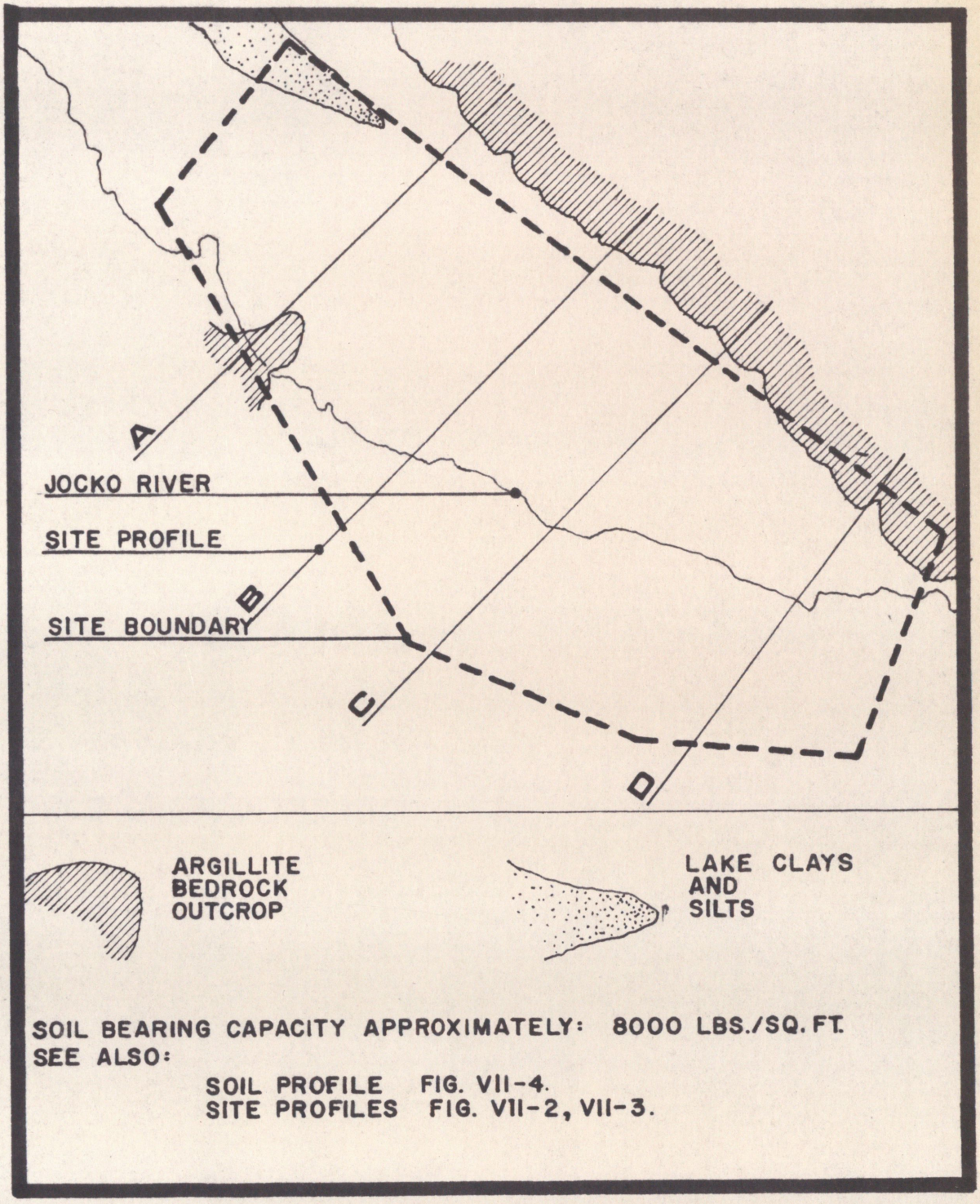
1 TOPSOIL
APPROXIMATELY 18" OF TOPSOIL.

2 SUBSURFACE SOILS
"WELL CONSOLIDATED GRANULAR MATERIAL RANGING FROM BOULDER SIZE TO SAND-SILT SIZES WITH A PREDOMINANCE IN THE GRAVEL SIZE RANGE." (2:7)

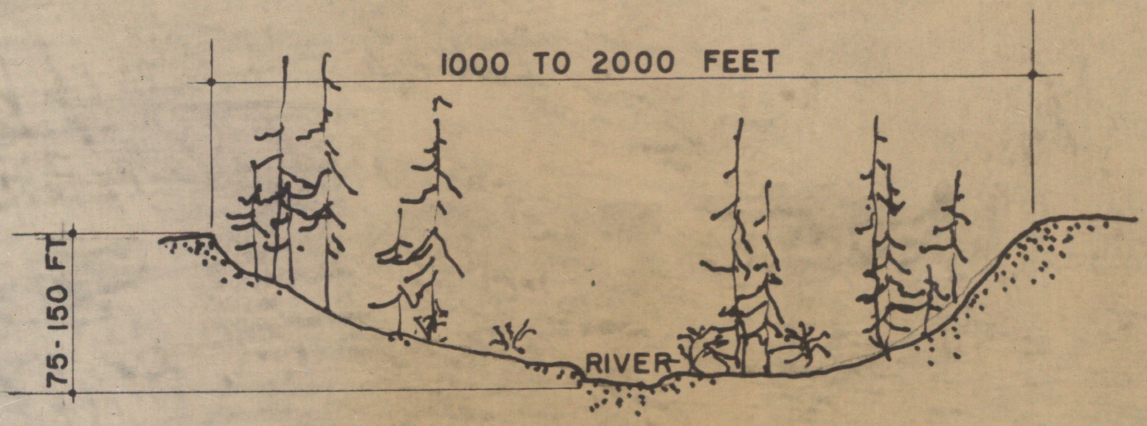
3 WATER TABLE
GROUND WATER LEVEL IS 65 TO 145 FEET BELOW GRADE.(8)

4 BEDROCK
BEDROCK LOCATION 10 TO 20 FEET BELOW RIVER BOTTOM, OR APPROXIMATELY 120 FEET BELOW SITE SURFACE. SEE FIG. VII-2, VII-3.

SOIL PROFILE



SURFACE FEATURES OF SITE



SEE FIG. VII-7, P. 126 B





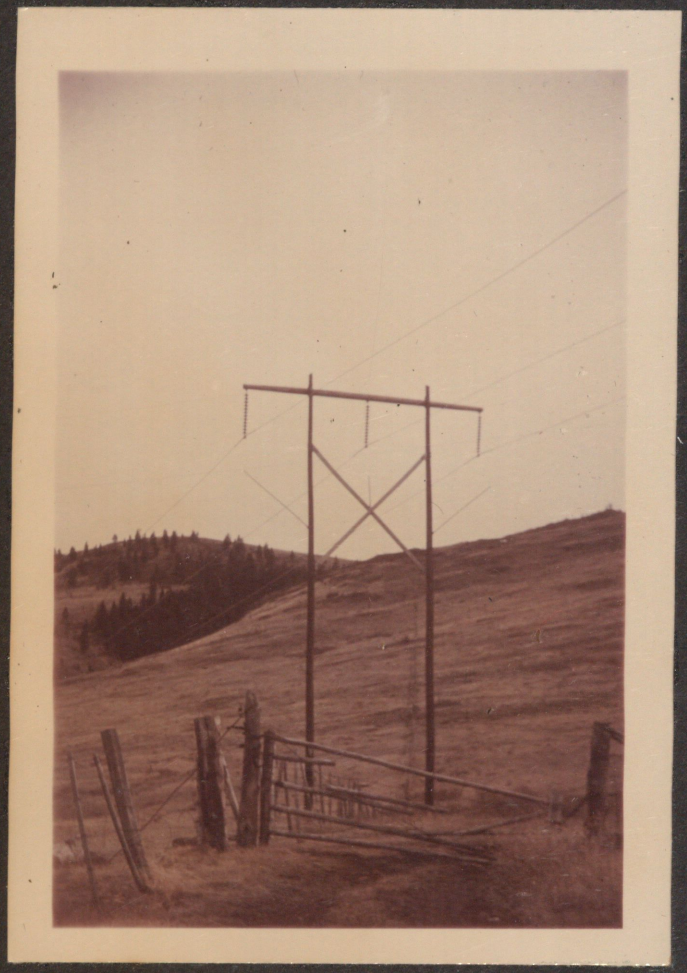





-Nick's
GROCERY-
PEPSI


PEDESTRIAN CROSSING







CONSIDERATION OF SITE VIEWS

	POSITIVE	NEGATIVE	FUNCTIONAL	NOTES
Jocko River	●		●	possible water source
Tree Cover	●			
Small Streams		●		dry in summer
Natural Springs			●	possible water source
Arlee		●		
Highways & Roads			●	
N. P. Railroad			●	
Power Lines			●	relocate underground
Fish Hatchery		●		relocate facilities
Canals			●	water rights for surrounding farms
Farm Buildings		●		

TABLE VII-1

PANORAMA VIEW OF SITE SITE BOUNDARY ———— FIG. VII-10 129A

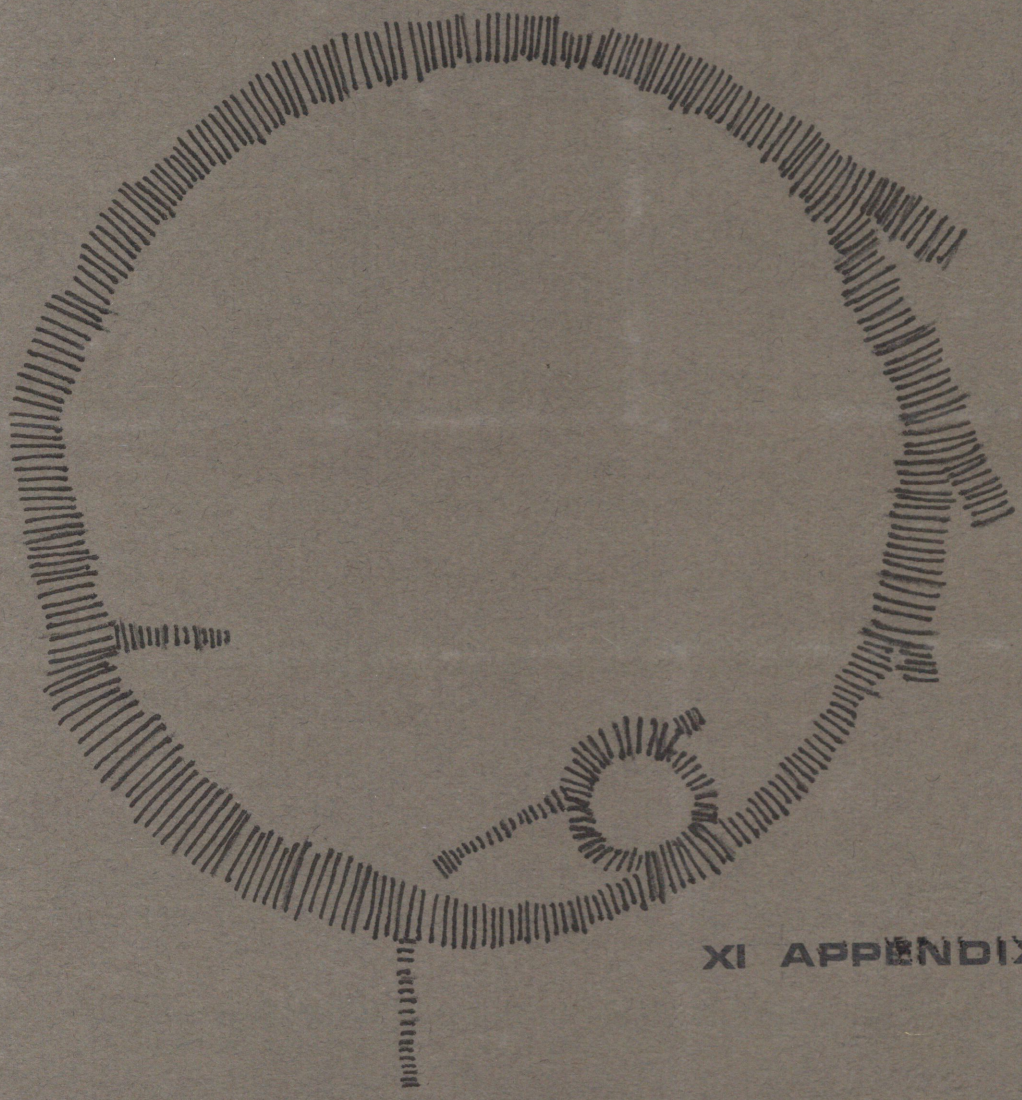




VIEW TO SOUTH



VIEW TO NORTH



XI APPENDIX

REFERENCES CONSULTED

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3. "Advantage Of The Missoula-Arlee Area for the Proposed New National Accelerator Laboratory." Montana State Planning Board. June, 1965.

4. "Arlee Project-Sections Across Jocko River Valley Looking North-West." Montana State Highway Department. July 2, 1965.

5. "200 Bev Accelerator Design Study." Lawrence Radiation Laboratory, University of California, Berkeley, California. June, 1965. Available from the Clearinghouse for Federal Scientific and Technical Information, National Bureau of Standards, U. S. Department of Commerce, Springfield, Virginia.

6. "BPA 1966 Main Grid Transmission Program." Bonneville Power Administration. Map, February 1, 1965.

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8. Farrel, John. well driller from Arlee, Montana. Discussion of valley soils and water tables. Telephone conversation, February 3, 1967.

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10. Kernan, William J. "Accelerators." U. S. Atomic Energy Commission, Division of Technical Information Extension, Oak Ridge, Tennessee. November, 1964.

11. Northwest Orient Airlines. System Timetable, Effective December 15, 1966, pp. 6-15.

12. "Policy For National Action in the Field of High Energy Physics." Report by Atomic Energy Commission, January, 1965. Included in "200 Bev Accelerator Study" by the Lawrence Radiation Laboratory. See Reference 5.

13. Richter, C. F. "Seismic Regionalization." Bulletin of the Seismological Society of America, Volume 49. April, 1959, pp. 123-162.

14. "Status Report on 200 Bev Accelerator." Lawrence Radiation Laboratory. April 24, 1965.

15. U. S. Department of The Interior, Bonneville Power Administration. Letter to Representative Arnold Olson, June 17, 1965. Taken from files of Dr. Fred S. Honkala, Dean of Graduate School, University of Montana, Missoula, Montana.

16. U. S. Department of the Interior - Geological Survey Map. Arlee, Montana, 1959.

17. U. S. Weather Bureau, Climatological data. Included in "Addendum to State of Montana Proposal for New National Accelerator Laboratory." See reference 2.

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