**LAWRENCE LIVERMORE NATIONAL LABORATORY,**
**100 MEV LINEAR ACCELERATOR BUILDING**
**(Building 194)** **HAER No. CA-2354**
7000 East Avenue
Livermore
Alameda County
California

WRITTEN HISTORICAL AND
DESCRIPTIVE DATA PHOTOGRAPHS

HISTORIC AMERICAN ENGINEERING RECORD
Pacific West Region
National Park Service
U.S. Department of the Interior
1111 Jackson Street, Suite 700
Oakland, CA 94607

**HISTORIC AMERICAN ENGINEERING RECORD**

**LAWRENCE LIVERMORE NATIONAL LABORATORY, 100 MEV LINEAR ACCELERATOR BUILDING**
**(Building 194)**

**HAER No. CA-2354**

**Location:** Northwest corner of intersection of Eighth Street and Avenue B, Lawrence Livermore National Laboratory (LLNL), 7000 East Avenue, Livermore, Alameda County, California

Building 194 is located at Latitude 37*41'31.39" N, Longitude 121*42'43.34" W. This point was obtained on May 1, 2019, using Google Earth (WGS84). There is no restriction on its release to the public.

**Historian:** R.A. Ullrich, Sandia National Laboratories, November 2012

**Present Owner:** U.S. Government, Department of Energy, National Nuclear Security Administration

**Present Use:** LLNL 100 million electron volt (MeV) accelerator and control room, with related laboratories and offices

**Significance:** The 100 MeV Linear Accelerator Building (Building 194) is historically significant for its contributions to accelerator research and LLNL weapons design work within the context of the Cold War arms race. The development of the use of annihilation photons for research, and the design of the 100 MeV Electron-Positron Accelerator, represent a significant contribution to accelerator research and development, and to the history of neutron physics in the 1960–1969 period.

Building 194 is also significant for the neutron cross-measurement studies done for the LLNL nuclear weapons program from 1969 to 1984. These experiments were directly linked to specific nuclear weapons designs during this time period.

Building 194 is also historically significant for the design of both the 100 MeV Electron-Positron Accelerator and the underground cave complex. The building thoroughly reflects its purpose as housing for and enabler of operations on the accelerator.

The building possesses historic integrity for the 1967–1984 period.

**Project Information:** In 2005, LLNL and DOE/NNSA completed consultation with the California State Historic Preservation Officer (SHPO) regarding the historic significance and eligibility of Building 194 to the National Register of Historic Places. Building 194 was found eligible. This report is part of the proposed mitigation of potential negative effects of undertakings in and around Building 194.

Large-format photographs were taken by LLNL photographer Don Gonzalez in 2006 during the first building tour. A second building tour took place in 2007.

Aaron Tremaine supplied detailed information about the 100 MeV accelerator and its research uses past and present, as well as access to Building 194 and its files. Gerry Anderson provided information on accelerator control and processes. Rudy Bauer offered insight into historic accelerator research and its importance. Ed Magee gave details on EBIT and its uses.

Maxine Trost and Xiaorong Zhang of the LLNL Archives and Research Center provided research advice, access to relevant collections, and copies of historical photographs. Carol Kielusiak oversaw the project during photography; Kelly Heidecker took over project management during document preparation. Both offered extensive research support and guidance.

## Part I. HISTORICAL INFORMATION

### A. Physical History[1]

1. **Date of erection:**

   Building 194 High Flux Building (Increment I)
   Designed: 1957
   Construction begun: 1957
   Building completed: 1957

   Building 194 High Flux Building (Increment II)
   Designed: 1959
   Construction begun: 1959
   Building completed: 1960

   Building 194 100 MeV Electron-Positron Accelerator Building (Increment III)
   Designed: 1966
   Construction begun: 1967
   Building completed: 1969

2. **Architect:**

   Leland S. Rosener, Jr., Engineers, of San Francisco, designed Increment I of Building 194 (known at the time as the High Flux Building).

   Rosener's firm also designed the majority of the Rover complex (buildings 171, 173, 174, and 176) at LLNL's main site in the 1950s.

   Corlett and Spackman, Architects, of San Francisco, designed Increment II of Building 194. Increment II housed a new counting and control room for the linear accelerator (Linac), as well as offices, a darkroom, a set-up room, and restrooms.

   Corlett and Spackman were involved in a variety of building designs at LLNL's main site through the 1950s and 1960s. They were also involved in the design of the Heavy Ion Accelerator Building (Building 71) at

---

[1]The following drawings and documents were used in determining the dates of the physical history of Building 194: "High Flux Building—194, Site & Plot Plans, Grading, Paving & Drainage Details," 1957, PLZ57-194-001JA, LLNL Plant Engineering Library (hereafter PEL); "High Flux Building—194, Sections, Elevations & Details," 1957, PLZ57-194-002JA, PEL; "High Flux Building 194—Increment 2, Floor Plan, Exterior Elevations, Finish Schedule, Door Schedule," 1959, PLZ59-194-002J, PEL; "Construction Completion Report: Electron-Positron Accelerator Facility, Building 194—Increment III" (Livermore: University of California Lawrence Radiation Laboratory, 1971), Building 194 Files.

Lawrence Berkeley National Laboratory (LBNL) beginning in 1957 and giving them experience with accelerator building requirements. The Department of Energy (DOE) has determined that LBNL's Building 71 is historic. Outside of LLNL, they are best known for their prize-winning design of the 1960 Olympic Winter Games main arena in Squaw Valley, California.

B. D. Bohna & Co., Engineers, designed Increment III of Building 194. Increment III included a new office/control room building, a new modulator/power supply building, the underground complex of caves and tunnels to house the new, larger accelerator, and the aboveground neutron cell silo and time-of-flight tubes.

B. D. Bohna designed other buildings at LLNL, including the Disassembly Building (Building 855) at Site 300 in the 1960s and Increment II (the Microprobe Laboratory) of Building 332 at the main site. Like Corlett and Spackman, Bohna was also involved in building design elsewhere in the Atomic Energy Commission's (AEC) laboratory system.

3. **Original and subsequent owners, occupants, uses:** The building has always been owned by the U.S. Government, by the AEC and its successor agencies (currently the DOE's National Nuclear Security Administration NNSA). Building 194 was built to house the 16 MeV electron linear accelerator. Although the accelerator was expanded, replaced, and modified (with related modifications and significant additions to the building itself) over time, the building's central mission of deploying a linear accelerator in basic physics research associated with nuclear weapons design remained consistent throughout its history.

4. **Builder, contractor, suppliers:**
   Leland S. Rosener, Jr., Engineers was both the architect/engineer and the construction manager for Increment I.

   Corlett and Spackman, Architects was the architect for Increment II.

   Ralph Larsen & Sons, Inc. served as construction manager for Increment III.

   The 16 MeV accelerator for Increment I was purchased from Varian Associates.

   The 100 MeV accelerator for Increment III was purchased from Applied Radiation Corporation (ARCO).

Alpha Scientific Laboratories, Incorporated, built the Beam Transport System for the 100 MeV accelerator.

5. **Original plans and constructions:** Leland S. Rosener, Jr., Engineers, of San Francisco, completed the design for Increment I of Building 194, referred to as the High Flux Building, in May 1957. Construction was complete in December 1957. It was a standard Butler-type 5020 rigid-frame building, modified to accommodate specific needs such as a large crane and large rolling door.

   The Increment I building was a high-bay structure of approximately 5,000 square feet (sq. ft.) on a 6" poured concrete slab foundation. It was steel framed, with a metal exterior (Figures 1 and 19). The exterior walls were corrugated galvanized iron with 12'x9' sliding doors on the south and north sides, pedestrian doors on the east and north side, and a 38'6"x15' overhead rolling door on the west end. The pitched roof was corrugated galvanized iron with corrugated plastic skylights. When built, the interior was a large high-bay with a 10-ton crane running the length of the building.[2]

   Varian Associates of Palo Alto, California, designed the 16 MeV linear accelerator for Building 194 based on LLNL specifications. The accelerator was completed in 1958 and underwent acceptance testing.

6. **Alterations and additions:** In 1959, Corlett & Spackman provided designs for Increment II of Building 194. Built directly to the east of Increment I, Increment II was a one-story, steel-framed, concrete building of approximately 3,000 sq. ft. on a poured concrete slab foundation. It had two-leaf hollow metal pedestrian doors with windows on the west and east sides and two-leaf hollow metal pedestrian doors on the south side (Figure 18). Increment II was connected to Increment I by an enclosed passageway of steel-framed windows with cement-asbestos panels on the lower third of the wall. The east, west, and south sides of the building were concrete block, while the north side was metal-framed windows with cement-asbestos panels on the lower portion.

   Increment II was originally designed to hold the control room for the Linac in Increment I, as well as a set-up room, dark room, mechanical

[2]"High Flux Building—194, Sections, Elevation & Details," 1957, PLZ57–194–002JA, PEL; and "High Flux Building—194, Floor & Roof Plans & Details," 1957, PLZ57–194–003JA, PEL.

room, restrooms, and three offices (Figure 1). Construction was completed in January 1960 and the control room move was finalized in May.[3]

The 16 MeV Linac also was modified to increase its power to 25 MeV in 1960; testing and debugging were completed in 1963.

In 1966, B. D. Bohna & Co., Engineers, completed designs for Increment III, a 24,400 sq. ft. addition to the Building 194 footprint. In May 1967, the construction contract for the new increment was let to Ralph Larsen & Son, Inc., of San Francisco. Construction was completed on the building in 1969. Increment III included a central office section attached to the north side of the building's south section formed by Increments I and II, with a hallway opening into Increment II; a modulator/power supply building to the north of the central section and connected to it by a covered walkway; an underground complex to hold the accelerator and its beamlines; and a neutron cell silo to which part of the beamline is directed from the underground complex and then split to follow different time-of-flight tubes (Figure 16; Photos 5 and 6) out to detector booths at different distances from the silo.

The central section held offices, an electronics shop, labs, and the control room for the accelerator. It was a steel-framed, concrete building on a poured concrete foundation. The west, north, and south sides were concrete block; the east side consisted of metal-framed cement-asbestos paneled window walls, with the main pedestrian entrance (two-leaf glass doors) on the set-back portion at the south end of the central section connecting to Increment II (Figure 17).

The north section, the modulator/power supply building, was a steel-framed structure with metal siding and a concrete foundation. It was connected to the underground complex via both modulator tubes that fed power down to the accelerator, and a stairway. The building was partially open on the northwest side. In addition to the modulators, it held power supplies, electronic racks, wave guides, and heat exchangers.

The underground complex was a series of caves and tunnels of poured concrete. There was a 12-foot layer of compressed soil/gravel between the complex's ceilings and ground level, assisting in radiation protection. It was accessed via stairways from the modulator/power supply building and the central section, as well as an elevator from the central section.

---

[3]"Floor Plan—Exterior, Elevations, Finish Schedule, Door Schedule," 1959, PLZ-59-194-002JA, PEL.

The neutron cell silo was a 35' diameter cylinder with a 10' layer of gravel around and above it. It had a 10' thick concrete shielding door and 10' thick walls. It extended 20' above ground and 10' below ground level, sitting above the output end of the accelerator in the accelerator cave, belowground. Several time-of-flight tubes extended from its center to exterior targets in detector booths located 51', 83', 208', and 830' from the neutron cell (Figure 16).

The 100 MeV electron-positron accelerator was designed and built to LLNL specifications by ARCO. The accelerator was built with five sections with the specification that it be expandable to eight. Construction began in 1967 and was completed in 1969, with the machine operational in November 1970. Further work and validation of capabilities continued, with final acceptance of the positron converter in 1971.

In 1977, a small room was added to the north side of the passageway connecting Increments I and II. Room 1042 has a metal exterior, with a hollow metal door opening into the passageway. It is visible on the key plan for the south section of the building (Figure 1).

Increments I and II underwent slight interior modifications as the programs in them changed, but remain intact architecturally. In 2000, the Electron Beam Ion Trap (EBIT) moved from Building 212 to Increment I of Building 194. A low interior wall was constructed to separate EBIT from the machine shop.

Similarly, the accelerator itself has experienced modifications to its components and injector. Parts have been replaced as they failed or were modified from the beginning. By 1980, ARCO was no longer supplying parts and LLNL purchased replacements from other suppliers.

In the early 1980s, a distributed microprocessor control and data acquisition network was implemented for the 100 MeV accelerator. Allowing for both computer and manual control of the accelerator, the system was designed to improve operational efficiency and increase data acquisition, including display of data at locations other than the control console.[4]

[4]Mark L. Mendonca, "Microprocessor Control and Data Acquisition at the LLNL 100 MEV Accelerator," UCRL-86097 (Livermore: Lawrence Livermore Laboratory, 1981), 1.

Also in the 1980s, a concrete block addition was put on the northwest side of the modulator/power supply building. That side had been partially open and was closed in by the addition.

By the late 1980s, the aboveground time-of-flight capability was no longer in use and has since been partially disassembled.

In 2001, a photo injector was added to the accelerator.

**B. Historical Context:**

Completed in 1957, Building 194 originally housed the 16 MeV Electron Linear Accelerator or Linac. The 16 MeV was purchased from Varian Associates of Palo Alto as a portable machine designed to calibrate nuclear detectors for the weapons program.[5] Consistent with the early mission of LLNL, the Linac was also used for more theoretical work in neutron physics. In the course of both programmatic and theoretical work on the Linac, LLNL scientists developed a new technique to produce monoenergetic photons that could be used to investigate detailed nuclear structures with increasing precision. To maintain a lead in this endeavor, LLNL continually modified the original 16 MeV accelerator to increase its power and performance capabilities.

By 1962, the Linac could produce 22 MeV and had planned extensions that would bring it up to 40 MeV. However, it was argued that power levels upward of 65 MeV were needed to continue to make progress in experiments.[6] In 1969, a large addition was completed, with both above and underground facilities, to accommodate a new and much more powerful linear accelerator, the 100 MeV Electron-Positron Linear Accelerator, designed by ARCO, one of the premier accelerator engineering firms during the Cold War. The 100 MeV Linac led to a much more expanded experimental program. In addition to the basic photonuclear and neutron time-of-flight studies already being conducted at LLNL, the new Linac made possible investigations into the areas of nuclear shape, positron and electron scattering, fission measurements, radiation damage, and gamma ray absorption.[7] In 1969, the 100 MeV Electron-Positron Linear Accelerator at LLNL was the only electron-positron Linac in the world. The 100 MeV Linac made important contributions to neutron cross-section research in support of weapons development at LLNL in the years 1969-1984.

**1. Early LLNL History**

[5] C. L. Whitten, "Proposed New Electron-Positron Accelerator, 16 March 1962, Subcontract, and 100 MeV Linac specs, Building 194 Files, 1.
[6] San Francisco Operations Office, University of California, Lawrence Radiation Laboratory, "Construction Project Data Sheet," Proposal and Memo, Building 194 Files, 3.
[7] "'Electron-Positron' Linac To Be Built At Livermore Lab," July 1967, *The Magnet,* 4-5.

In September of 1952, the AEC established LLNL as a second nuclear weapons design facility. E. O. Lawrence and Edward Teller, physicists affiliated with the Manhattan Engineer District during World War II (WWII), advocated the founding of a second laboratory to accelerate the design and production of a thermonuclear weapon, arguing that these were the next advance in atomic weaponry. Neither Lawrence nor Teller felt that Los Alamos National Laboratory (LANL)[8] was working aggressively enough to achieve this goal. Their argument was well-received within the AEC, as the Soviet Union had detonated its first atomic weapon in 1949 and a nuclear arms race element was added to the early Cold War. American policymakers, fearing the potential actions of an enemy armed with nuclear weapons, determined to deter their use by significantly increasing the U.S. stockpile.

Although the primary goal of LLNL was to design and develop a hydrogen bomb, Herbert York, the first director, insisted on incorporating non-weapons research into the mission of the laboratory. The four missions he articulated for LLNL were designing thermonuclear weapons, providing diagnostic measurements for weapons tests for LANL and LLNL, developing Controlled Thermal Reaction (CTR) for power sources, and basic physics research. He hoped to attract the brightest young scientists in the country and felt that there should be breadth and depth of research options beyond nuclear weapons investigations to attract them.[9]

Although LANL developed and tested the first thermonuclear device, LLNL was not far behind. Just six months after LLNL opened its doors, they fired their first thermonuclear test device at the Nevada Test Site (NTS). The device, code-named Ruth, fired far below expectations. The next several LLNL test shots also had mixed results. But, by the 1955 test season, LLNL scientists had perfected their designs and produced a successful thermonuclear device during the Teapot test series at NTS. Soon, both laboratories were hard at work designing thermonuclear weapons for the army and navy.[10]

### 2. Early Accelerator Research

One of the key tools for scientists interested in atomic research, both for theoretical and practical purposes, was the accelerator. The development of accelerators, a device that used a concentrated beam of electrons to see smaller

---

[8]The current names of the national laboratories are used throughout this report to avoid repeated explication of titles.

[9]University of California, Lawrence Livermore National Laboratory, *30 Years of Technical Excellence* (Livermore: Lawrence Livermore National Laboratory, 1982), 4; and Herbert York, “Making Weapons, Talking Peace,” *Physics Today* (April 1988): 44–45.

[10]Michael Anne Sullivan and Rebecca Ann Ullrich, Historic Context and Building Assessments for the Lawrence Livermore National Laboratory Built Environment (Livermore: Lawrence Livermore National Laboratory, September 2007), 57-59.

and smaller subatomic particles, began in the 1930s in both Europe and the United States. Early devices accelerated particles through a voltage field. Increasing voltage increased the energy of the particle and increased its usefulness at seeing more precisely the nature of the subatomic world.[11] Two of the first successful American-made accelerators were the Cockcroft Walton and the Van de Graff accelerators. The Cockcroft Walton worked by charging high voltage capacitors and then discharging them across an accelerator tube while injecting a particle beam at one end. The Van de Graff continually deposited a charge into a smooth sphere building voltage up and then discharged particles at an opposite end through a tube. The particles are attracted by the voltage in the sphere and pulled down the tube accelerating as they go.[12] The next breakthroughs in accelerator development were the Cyclotron developed by E.O. Lawrence at the University of Berkeley Radiation Laboratory and the Betatron developed by D. W. Kerst at the University of Illinois. Both of these machines were circular electron accelerators and significantly increased the energy and usefulness of these experimental devices. Linear electron accelerators developed separately from circular ones during the 1930s in Germany and England. Post-WWII American development of linear accelerators occurred primarily at Stanford University and at UC Berkeley.[13]

### 3. Linear Accelerator Operation

The basic plan for a linear accelerator is to place a series of plates in a line with a hole bored in the middle of each one for the particle beams to traverse. Alternate plates are connected together electrically and tied to a radio frequency (RF) generator. Half of the electrodes are positive and the other half negative. Beam particles are placed between every other pair of electrodes and are in a proper voltage gap and accelerated. As they pass through the hole in the second electrode the RF generator cycles and the polarities on the electrodes are reversed. The second set then provides acceleration. The process of electrons traversing gap after gap increases the beam as it travels.[14] The beam is directed via magnets placed along the beamline, causing the beam to stay straight or curve, as desired.

Operating electron linear accelerators requires a great deal of power. All large electronic linear accelerators use klystrons as their RF power generator.[15] Electrons essentially ride along the peak of the RF wave and are accelerated as additional RF power is added in each accelerator section.

---

[11]Douglas Wm. Dupen, “The Story of Stanford’s Two-Mile-Long Accelerator,” May 1966, SLAC-22, USAEC, San Francisco Operations Office, 11.
[12]Ibid, 11-12.
[13]Ibid, 28-33.
[14]Dupen, 28-29.
[15]The Klystron was invented by the Russel Varion and Sigurd Varion (brothers) at Stanford University in the 1930s.

### 4. Accelerator Use at Lawrence Livermore National Laboratory

From its inception, LLNL scientists relied on accelerators as a primary tool in physics research for both theoretical and applied programs. In the early 1950s, the Experimental Nuclear Physics Group at LLNL conducted basic and applied research in medium-energy nuclear physics using both a Cockcroft Walton accelerator and a 90-inch Cyclotron. Both of these accelerators were primarily used for research in the weapons program.[16] Because accelerators were useful in a variety of applications, LLNL constantly upgraded and replaced accelerators with newer models. Accelerator development became an outgrowth of nuclear physics research at LLNL.[17]

The Cockcroft Walton and 90-inch Cyclotron were operated for 10 and 16 years respectively and used for weapon design, testing theoretical predictions, nuclear test diagnostics, and theoretical physics experiments. In 1964, the Physics Department replaced the Cockcroft Walton with a new model and in 1968 they dismantled the 90-inch Cyclotron and remodeled it into a 15 MeV cyclotron with a Van de Graff generator.[18]

Site 300, LLNL's experimental test facility established in 1955 15 miles from the main LLNL site, also utilized accelerators for research purposes. A succession of ever more powerful linear accelerators was developed beginning in 1960 to study the simulated explosions of test devices.[19]

In 1964, the Magnetic Fusion Research Program developed a linear induction magnetic accelerator, Astron, to heat plasma. The fusion program ultimately abandoned Linacs as a viable option for achieving power through fusion. However, the induction Linac proved important in flash radiography and stockpile assessment.[20]

During the 1970s, accelerator scientists built on Astron technology, which led to the creation of the Experimental Test Accelerator (ETA), a proto-type of the first directed energy weapon. In 1983, LLNL built the Advanced Test Accelerator (ATA) at Site 300. The beam of the ATA was used as a driver for a free electron

[16] Sullivan and Ullrich, 84.
[17] University of California Lawrence Radiation Laboratory, *Status Report: Fiscal Year 1963* (Berkeley: University of California Lawrence Radiation Laboratory, 1963), 13.
[18] W. J. Johnston to P. M. Goodbread, letter, 30 January 1964 and R. P. Connell to P. M. Goodbread, letter, 22 July 1968, Administrative Files Donald Cooksey, Lawrence Berkeley Laboratory, 1968, LBNL Archives.
[19] Sullivan and Ullrich, 86-87.
[20] Ibid, 87.

laser (FEL). In 1987, LLNL scientists built ETA II which continued FEL studies and ultimately heated plasma in the Microwave Tokamak experiment (MTX).[21]

### 5. Building 194: The High Flux Facility

In 1957, work was completed on Increment I of Building 194, originally called the High Flux Facility, designed to house a 16 MeV linear accelerator purchased from Varian Associates. The 16 MeV was built with "the primary purpose of developing and testing detectors for use in full scale weapons tests."[22] The 16 MeV Linac created the source of radiation used for testing detector saturation characteristics, determining the behavior of solid state detecting devices in high radiation fields, and calibrating detectors used in nuclear testing. Increment II was added in 1960 to provide a control and counting room for the accelerator, by which point the accelerator could be brought up to 22 MeV in peak conditions.

In addition to the weapons-related work conducted on the 16 MeV, physicists also used the accelerator in Building 194 for experiments in pure physics research. One of the areas of interest in the field of basic research was the measurement of fission cross sections. This information was particularly useful in determining design criteria for facilities using fissionable material. A program for the study of the transuranic elements began at LLNL shortly after the 16 MeV Linac began operating.[23]

Another basic physics research interest was the examination of the details of nuclear shape and structure. This research interest was made possible by the development of a new technique in operating the accelerator. In 1960, LLNL scientists began utilizing the 16 MeV in a tandem arrangement. The first section of the accelerator was used as a positron generator and the second section as a positron accelerator. The positrons were then passed through a thin target and some of them were annihilated in flight. The photons obtained from this annihilation process were monoenergetic and could be used to study photonuclear reactions. This process enabled LLNL and the US to move to the forefront in an important area of nuclear physics.[24]

In the process of using the 16 MeV for photonuclear and fission research, LLNL scientists determined that higher voltage requirements were necessary to continue making progress in these additional areas of research. Essentially, scientists wanted a machine capable of producing both electrons and positrons. The 16

---

[21]Ibid.
[22]This and the following information on the 16 MeV from San Francisco Operations Office, University of California, Lawrence Radiation Laboratory, "Construction Project Data Sheet," Proposal and Memo, Building 194 Files, 3.
[23]"Construction Project Data Sheet," 3.
[24]Ibid.

MeV was designed as an electron linear accelerator and researchers had figured a way to have it produce a positron capability. In 1961, they proposed modifications to the accelerator that would increase its voltage and make it into an electron-positron accelerator capable of reaching 40 MeV.[25] The proposal also included a new underground facility with ample room for the accelerator and other maintenance equipment necessary to operate it.

In 1962, LLNL Linac scientists decided that rather than modify the existing machine a new and significantly more powerful machine should be constructed. They argued that by the time the building was complete many of the components of the current accelerator would be long past their useful lifespan. Therefore, a modified machine would be made of brand new parts and parts that would soon expire. They proposed instead a machine that would reach 100 MeV electron energy output and 150 MeV positron energy output.

### 6. The 16 MeV Electron Linear Accelerator Summary

The 16 MeV Linear Accelerator was mounted in a rigid sheet metal frame shield, 7'x7' in cross section and 20' long. It contained 2 VA-87/C klystron power amplifiers which drove two five-foot sections of accelerator tube at an operating frequency of 2856 megacycles (MC). The accelerator tubes had wave-guides like the type developed at Stanford University.

The 16 MeV Linac proved productive. Researchers conducted nuclear cross section studies of different isotopes, completing series for different energy levels. A variety of publications indicate the rate of productivity. S. C. Fultz and R. L. Bramblett's October 1965 status report to the Nuclear Cross Section Advisory Group, for example, summarizes 16 distinct research efforts covering neutron cross section measurements, fission cross section analysis and other fission measurements, charged particle induced reactions, and photonuclear reactions.[26]

### 7. The 100 MeV Electron Linear Accelerator and Facility

The first written proposals for a new, more powerful accelerator appeared in 1962.[27] In 1965, a 100 MeV Accelerator Steering Committee was established to oversee specifications and proposals, and to participate in procurement.[28] Design

---

[25]"Proposed Extension and Modifications of the 22-MeV Electron Linear Accelerator," 6 June 1961, Proposal and Memo, Building 194 Files.
[26]S. C. Fultz and R. L. Bramblett, "Status Report to the Nuclear Cross Section Advisory Group," October 14, 1965," UCRL-14501-T (Livermore, California: University of California Lawrence Radiation Laboratory, 1965).
[27] C. L. Whitten, "Proposed New Electron-Positron Accelerator," March 16, 1962, Subcontract and 100 MeV LINAC Specs, Building 194 Files; and "Preliminary Proposal for a New Electron-Positron Accelerator," March 19, 1962, Proposal and Memo, Building 194 Files.
[28]C. L. Blue to W. B. Harford, memo re: "Proposed Procurement, 100 Mev Linear Accelerator," January 12, 1966, Proposal and Memo, Building 194 Files.

criteria for Increment III of Building 194 were released in August 1965. By 1966, firm specifications were outlined for the accelerator. They specified an S-band linear accelerator for acceleration of both positrons and electrons. It was to be a variation of the Stanford-developed traveling wave type of accelerator then in wide use.

The accelerator would produce intense bursts of electrons and substantial numbers of positrons, with the ability to also produce intense bursts of Bremsstrahlung or neutrons. Bursts could range in duration from a few nanoseconds to about 3 microseconds. There were several arguments for desirability of such a machine, in addition to extending existing programs of research like calibrating detectors used in nuclear tests. Overall, the new machine would provide greater power and greater flexibility in creating and deploying electrons and positrons in different experiments, both fundamental and applied.

A new machine designed specifically for the purpose would have a higher conversion efficiency for generating positrons and thus increase the positron current by approximately 30 times. The resulting cross section, angular distributions, or energy distributions measurements of the energy reaction products would potentially reveal many nuclear properties.

The new machine would allow for the production of higher intensity and shorter pulses than the older machine. Neutron cross sections could thus be measured with better energy resolution. Experiments could also be extended to higher neutron energies, allowing for measurements on very small samples of materials. The higher intensity would also allow measurements of characteristics of the reaction products from neutron interactions, including mass yields from fissionable nuclei.

The comparison of the proposed new machine to other accelerators was also addressed in the discussion of the need for the new machine. Although other accelerators might have more power and/or conduct similar types of research, the proposed 100 MeV for LLNL would have its flight tubes in the horizontal plane, allowing for no difference in intensity of neutrons along the different flight tubes. It was also noted early on that the "proposed new facility will keep Livermore competitive since it will have about 100 times greater neutron flux than the present one."[29] And, it was an area that was easily secured, should that be required. In general, the machine was seen as very flexible. It has remained useful due to its broad tune-ability (from very low to 150 MeV), the adjustability of its

[29]S. C. Fultz to Distribution, memo re: "New Linear Electron Accelerator Proposal," May 8, 1964, Proposal and Memo, Building 194 Files.

repetition rate (pulses), and the ability to tailor the beam for specific experimental purposes.

In 1967, ARCO announced LLNL had secured a $1.6 million contract with it to "build a 160 million electron volt positron/electron linear accelerator."[30] The press release offered a quick description of the proposed machine, indicating it would be similar in design to the Stanford Linear Accelerator (SLAC), but with a peak pulse power five times greater than SLAC. A few months later, the construction contract for Building 194, Increment III was let to Ralph Larsen & Sons, Inc.

On October 9, 1970, the 100 MeV linear accelerator was fully operational and brought into use. At that point, the beam transport system was showing excellent transmission, the achromatic system bending the beam up into the neutron cell in the silo aboveground was performing well, the optics throughout had been examined, a rabbit system to irradiate samples and quickly move them to a counting room was installed and tested, and neutron time-of-flight experiments were successfully conducted both above and below ground.[31] It was accepted as an electron accelerator later that month.

The Linac was not yet accepted as a positron accelerator, however, due to delays in producing and installing a reliable converter target. That acceptance finally occurred in May 1971.

The accelerator consisted of five 8' sections with an air gap between them. Klystrons fed each section, keeping the electrons moving on the RF wave. Positrons could be generated after the third section.

At the output end of the accelerator, the beam transport system took over, running the beam to a distribution area (magnetic switchyard) and directing it into the different experimental caves or along a 90° bend to the neutron cell in the silo above. Magnets focused the beam and kept it in line, curving it along its appropriate path.

If the beam were directed to the neutron cell in the silo above, it could be sent along different horizontal tubes for neutron time-of-flight measurements. Each tube extended to a target in a detector station (the long tube had two detector stations). The short tube (51') was not used extensively for research. It primarily

---

[30]Applied Radiation Corporation, "($1.6 Million Accelerator Contract Announced by Applied Radiation)," Press Release, January 9, 1967.
[31]S. C. Fultz, "The 100-MeV Electron-Positron Accelerator," in *Semiannual Progress Report of the Physics Department, July through December 1970,* UCRL-50001-70-2 (Livermore: University of California, Lawrence Radiation Laboratory, 1971), 22-23.

served to monitor the beam, ensuring researchers knew what kind of beam they were getting. The medium tube (83') was primarily used for fission measurements. The long tube (830') produced a weak but high-resolution beam at the detector building and proved excellent for neutron cross-section measurements.

Alternatively, the beam could be directed into the 0° cave to generate intense secondary beams of neutrons, bremsstrahlung photons, or positrons. Openings in its walls allowed for directing the resulting beams out through beam tubes to target areas in the 0° inner and outer detector caves for diagnosis and analysis.

To support most of the experimental work going on in the building, the beam could also be directed into the magnet cave where the beamline could be split off to hit targets in the north or south caves.

## 8. 2007 State of the Facility

Research programs at Building 194 still include basic research projects involving the understanding of materials, in particular using positron annihilation techniques to characterize defects and materials' surface properties. Overall, the accelerator continues to prove useful in efforts to characterize materials.

The neutron cell in the silo and the related time-of-flight tubes are no longer in service. That research ended in the 1980s. The neutron cell silo and parts of some of the time-of-flight tubes and detector station are extant at the site.

By 2007, the Falcon laser had been added to the Building 194 capabilities to explore the interaction of laser and accelerated electron beam. It was placed in a room formerly used for diagnostics next to the 100 MeV control room in the central section of the building. Its beam is directed down into the 0° outer detection cave where photonuclear reactions, acceleration of low-mass ions in the laser-plasma interaction, and the generation of ultra-short x-ray pulses from the Thomson scattering of laser light off the relativistic electron bunches of the accelerator's beam can be studied.

In 2001, a photoinjector was added at the north end of the accelerator cave. It is itself a high gradient electron accelerator that produces short-pulse, high-peak current, high quality relativistic electron beams. The beams can be focused into a tight focal spot. It was introduced to support the laser-electron beam interaction studies. In 2007, it was not yet feeding the 100 MeV accelerator, but the expectation was that it would. Like the 100 MeV, the photoinjector is powered by a klystron.

Super EBIT moved into Room 1050 in Increment I in 2000. Located in Building 212 since 1984, EBIT was built to study the x-ray signatures of highly charged ions. It is a very good producer of x-rays with unique signatures. The x-rays are used for calibrating detectors for the National Ignition Facility (NIF), x-ray satellite line experiments, and spectroscopy for astrophysics, among other research purposes. The original EBIT was modified and upgraded into EBIT-II and Super-EBIT. EBIT-II was transferred to LBNL and Super-EBIT is in Building 194.

## Part II. ARCHITECTURAL INFORMATION

### A. General Statement:

1. **Architectural character:** The 100 MeV Linear Accelerator Building (Building 194) is a steel-framed metal and concrete structure, built in three increments during the 1950s and 1960s. Increment I is the original metal building, with Increment II as a concrete block building to the east of the original section and south of the building's central section. Increment III includes the building's central section, housing offices, labs, and control room; an underground complex holding the current accelerator and target chambers known as the 0° cave, north cave, and south cave; the modulator/power supply building to the north of the central section; and the neutron cell silo with time-of-flight tubes and detection stations.

   The building was constructed specifically to house a linear accelerator for basic and applied physics research related to nuclear weapons development (initially a 16 MeV electron linear accelerator later upgraded to 25 MeV and then replaced by the 100 MeV electron-positron linear accelerator). It is an industrial building. Although there is no standard accelerator building type, accelerators are found in a variety of different industrial building designs depending on their shape and size, it is clear that the accelerators housed in Building 194 over time influenced the basic design of the building's increments. Like other industrial buildings, this accelerator building was designed to support and accommodate the machines it housed. This is particularly evident in the concrete shielding, heavy shielding doors, escape routes for personnel potentially caught in the accelerator caves during operations, the connection between the power supply area and the accelerator in the basement, the design of the neutron silo, and the nature of the wall intrusions to support the accelerator beamlines.

2. **Condition of fabric:** The current condition of the 100 MeV accelerator building is good. The building is in active use and is maintained by LLNL's plant engineering organization. Although the earlier experimental set-ups associated with the 100 MeV electron-positron linear accelerator have been removed and a section removed from the aboveground time-of-flight beamlines, the building retains structural and historical integrity.

### B. Description of Exterior:

1. **Overall dimensions:** Building 194 exists in several distinct but connected parts (Figures 7 and 8). Altogether it contains approximately 41,543 sq. ft.

**Increment I:** Increment I is a two-story high-bay metal building. It is a rectangle measuring approximately 50'x81'10", with the north and south sides longer than the east and west (Figures 1 and 19).

**Increment II:** Increment II is a rectangular building of 61'5.5"x51'0" to the east of Increment I and connected to it by a small, rectangular passageway (Figures 1, 18, and 19).

**Central section:** This section of Building 194 is rectangular, with its east and west sides longer than its north and south ends (Figures 2 and 17). It is approximately 141'11" x 74'8".

**Underground complex:** The underground complex is an irregular shape, due to the extension of the accelerator cave to the northeast of the central part of the complex and the corridor leading away from the central part of the complex to the stairs and elevator to the south (Figures 4 and 8). The exterior walls are all concrete. It is approximately 14,700 sq. ft.

**Modulator/power supply building:** The building supplying power to the accelerator is roughly rectangular, with the northwest and southeast sides longer than the northeast and southwest sides. The building was originally 107'4"x49'4"; enclosing the central portion of the northwest side caused it to extend out from the main rectangle (Figure 3; Photo 4).

**Neutron cell silo:** The silo is a cylinder extending 20' aboveground and 10' below. The interior neutron cell is 15' diameter and the overall diameter of the building is 35' (Photo 7).

2. **Foundations:** The foundations are all reinforced concrete. The foundation is 2' thick poured concrete in the underground complex.

3. **Walls:** The building's exterior wall design includes concrete and metal surfaces, as well as tall window panels with concrete-asbestos sections.

   **Increment I (western portion of south section):** This is a corrugated metal building with a corrugated metal shed structure attached on the south side and a shed-style addition on the west side (Figure 19).

   **Increment II (eastern portion of south section):** The east, west, and south walls are concrete block with a band of metal coping along the top (Figure 18). The east wall extends beyond the edge of the north wall by approximately 3' (Photo 1). The north wall is window panels with cement-asbestos sections above and below each window (Photo 1).

**Connecting hallway between Increments I and II (center portion of south section):** The south wall is holds three panels of windows with cement-asbestos panels below (Figure 19). The north wall is concrete block.

**Central section:** The north, south, and west sides are concrete block. The east wall consists of 24 panels of windows with cement-asbestos sections. The set-back section at the south end of the east side connects the central section to the south section of the building. This wall is also window panels with cement-asbestos sections along the top and glass double doors entering the building (Figure 17; Photos 1 and 2).

**Modulator/power supply building:** The modulator/power supply building is concrete masonry (concrete block). The northwest side was originally open with chain link fence on its outside edge. That area was enclosed later and now forms a wall similar to the others.

**Neutron cell silo:** The neutron cell silo is a cylinder. Its walls are 10' thick concrete.

**Underground complex:** All exterior walls are concrete.

4. **Structural system, framing:** The individual building elements are all steel-framed.

5. **Porches, stoops, balconies, porticoes, bulkheads**: The central section is connected to the modulator/power supply building to the north by a covered walkway. The walkway is a poured concrete slab, 171" wide. The walkway is open to the east; a steel-framed structure holds metal ribbed panels on the west side and roof, offering protection from the weather. The panels are held up by 8"x5" I-beams.

   There is an awning above the entrance to the neutron cell silo. It is corrugated metal held up with steel poles set into concrete anchors. It is attached to the silo and extends approximately ¼ of the way around it, following the building's curved side (Photo 7).

6. **Chimneys:** There are no chimneys. The modulator building has a 100' exhaust stack made of concrete on the north end of its northwest side.

7. **Openings:**
   a. **Doorways and doors:**

1. **Pedestrian doors:** Due to its size and somewhat complex layout, Building 194 has multiple pedestrian doors.

   **South Section** (Figure 1): The south section may be accessed by two-leaf metal pedestrian doors with windows on the east side, slightly north of center (Photo 1). There are also two-leaf metal doors into the mechanical room (Room 1017) on the east end of the south side of Increment II. Increment I has a single metal door on its east wall, leading into Room 1051, and similar single metal doors leading into Room 1050 on the south side and Rooms 1055 and 1057 on the north side. There is also a tall, two-leaf metal door leading into the west end of Room 1057; this door has no exterior handles or knobs.

   **Central Section** (Figure 2): The main pedestrian doors to the building are on the east side, near the south end of Corridor 2 of the central section (Figure 2). These are two-leaf glass doors in metal frames surrounded by windows (Photo 1).

   In addition to the main entrance doors, the central section has two sets of two-leaf metal pedestrian doors on the west side and two-leaf metal pedestrian doors near the east end of the south wall. There are two-leaf metal doors with windows on the west side of the north wall and two-leaf metal pedestrian doors and a single metal pedestrian door on the east side of the north wall.

   **Modulator/power supply building** (Figure 3): The northwest side of the building (Photo 4) has two metal pedestrian doors and one set of two-leaf metal pedestrian doors with windows. There is also a metal roll-up door for equipment access. The northeast side of the building has no exterior doors. The southeast side of the building holds the main entrance from the walkway from the central section. This is a metal pedestrian door with windows on each side, set into a metal frame (Photo 3). There are no exterior doors on the southwest side of the building.

   **Neutron Cell Silo**: The silo has one door. It is a 10' thick concrete shielding door that is track mounted and operated by a hydraulic piston (Photos 8 and 9).

**Underground Complex** (Figures 4 and 8): There are no exterior pedestrian doors to the underground complex. There is a large door opening in the 10' thick ceiling of the underground area above Corridor 1 (Figures 4 and 16; Photo 20). This opens at ground level to allow equipment movement into and out of the building. There are also six personnel emergency evacuation exits that open from the north and south caves into ladders leading to covered ground-level exits (Figure 15; Photo 5). These are accessed via circular concrete and steel doors (Photos 30 and 31). Those with doors placed higher on the wall have access ladders (Photo 32).

2. **Roll-up doors:** The opening for the original roll-up door on the west side of Increment I has been covered with corrugated metal panels. The door is still installed and visible in the interior.

b. **Windows and shutters:** There are no shutters on Building 194.

**Increment I:** There are no windows in Increment I.

**Increment II:** The north side of Increment II holds panels of single-light windows with cement-asbestos sections above and below the window in each panel.

**Connecting hallway between Increments I and II** (central portion of south section): The south wall holds three panels of windows 5' tall and 58" wide with cement-asbestos sections 45" tall below.

**Central section:** There are 24 panels of single-light windows with cement-asbestos sections above and below the window in each panel on the east exterior of the central section. The windows are 75" high and 63" wide, including 4" metal frames (Photos 1 and 2).

The exterior wall of the main entrance on the east side of the connecting hallway between Increment II and the central section has two-leaf glass doors in the center with cement-asbestos panels above. A panel on each side of the doors holds a cement-asbestos panel above a 63" high window pane above a 39" pane. The windows are in steel frames.

**Modulator/power supply building:** There are no windows in the walls of the modulator/power supply building. The main entrance doors on the southeast side do have windows, as do the wall panels surrounding them.

**Neutron cell silo:** There are no windows in the silo. There are wall openings for the time-of-flight tubes (Photo 10).

**Underground complex:** There are no windows in the underground complex.

8. **Roof:** The roofs of Increments II and III are flat. Increment I has a pitched metal roof.

   **Increment I:** This is a pitched corrugated metal roof with a very slight (approximately 5") overhang.

   **Increment II:** The roof on this increment is flat, built-up roofing. There is a large air conditioning unit on the roof. There is an overhang of approximately 2.5' on the north side.

   **Connecting hallway between Increments I and II (central portion of south section):** The roof of the connecting hallway is lower than those of Increments I and II. It is a flat metal roof.

   **Central section:** The central section has a steel roof deck, fiberglass roof insulation, and tar-and-gravel roofing. The roof overhangs on the east side of the central section. This is a 5.5' corrugated metal overhang held up by steel beams. The metal roof overhang above the main entrance extends approximately 2.5'.

   **Modulator/power supply building:** Built-up roofing on 2" rigid insulation on a metal roof deck.

   **Neutron cell silo:** Built-up roofing on a 4" concrete slab.

   **Underground complex:** The underground complex has a concrete ceiling under a 12' blanket of compressed gravel.

**C. Description of Interior:**

1. **Floor plans:** Current floor plans are shown in Figures 1, 2, 3, and 4.

   The plan for Building 194's ground floor is most easily understood as three sections: south, central, and north (Figure 7). A north-south corridor runs through the central section, intersecting on the south with the east-west corridor in the south section and on the north with the exterior walkway extending north to the modulator/power supply building in the north section (Figures 1, 2, and 3).

   The south section (Increments I and II) houses the 1000-series room numbers. This section originally housed the 16 MeV Linac (Rooms 1055 and 1057) and, after Increment II was completed, the 16 MeV control room (Room 1033). Currently, the section comprises shops (Rooms 1033, 1055, and 1057), EBIT (Rooms 1050 and 1051), restrooms (Rooms 1034 and 1040), and offices (Rooms 1020, 1024, 1028, and 1042). A corridor runs east-west through Increment II into the enclosed passageway connecting it to Increment I (Figure 1; Photo 11). The north-south corridor from the central section enters Increment II on the north side through a space that was formerly a janitor's room and closet and intersects with the east-west corridor.

   The central section (Figure 2) is a long rectangle housing the 1100-series room numbers, including offices, the 100 MeV control room (Room 1117A), diagnostics construction (Room 1131), and the Falcon laser (Room 1117B) and its controls. Offices (Rooms 1106, 1108, 1110, 1112, 1114, 1116, 1118, 1120, 1122, 1124, 1126, and 1128) extend along the east side of the corridor, giving them windows on the exterior wall and clear access to the rest of the building. A copy/supply/file room (Room 1103A), conference room (Room 1103), and break area (Room 1105) are at the south end of the west side of the corridor (Figure 2). An elevator and a concrete stairwell outside of the control room (Room 1117A) connect the central section to the underground complex below.

   The modulator/power supply building and the neutron cell silo with its related time-of-flight tubes and detector stations form the north section of the ground level portion of the building (Figure 3). The modulator/power supply building houses a mechanical equipment room, the modulators, power supplies, electronic racks, wave guides, and heat exchangers. Seven access tubes and a concrete stairway connect the building to the accelerator cave of the underground complex below.

   The neutron cell is a cylindrical room 15' in diameter inside of the silo (Figure 3). The beamline from the accelerator cave in the underground complex below extends up into the center of the room where a neutron source was placed when time-of-flight studies were being conducted (Photo 10). There is no pedestrian corridor or walkway explicitly connecting the neutron cell silo to the rest of the building. It is part of Building 194 by virtue of the beamline from the accelerator cave. Workers access the silo by walking across the open area between it and the modulator/power supply building (Figure 3; Photo 4).

The underground complex (Figures 4 and 8) houses the accelerator cave (Room B130), which holds the accelerator itself and the beam handling tubes and bending magnets that direct the beam into the different detector caves. The detector caves include the 0° outer detector cave (Room B120), the 0° inner detector cave (Room B122), the 0° cave (Room B122A), the south cave (Room B124), the magnet cave (Room B132), and the north cave (Room B134).

2. **Stairways:** The building has two concrete stairways extending down three flights from the ground floor to the underground complex, one from the central section and one from the modulator/power supply building (Figures 2 and 3).

   A combination freight/passenger elevator also operates between the central section and the underground complex (Figures 2 and 4).

   Room 1050 in Increment I is a high-bay housing EBIT. A mezzanine is accessed via a single-flight metal stairway at the east end of the room (Figure 5). The mezzanine extends over Rooms 1051 and 1055.
   There is also a mezzanine in the southwest corner of the modulator/power supply building. It is accessed by a single flight of metal stairs (Figure 5).

3. **Flooring:**
   a. **Increment I (west portion of south section):** The floor in Increment I is concrete.

   b. **Increment II (east portion of south section):** The corridor flooring is 12"x12" industrial tile (Photo 11). Room 1033, housing the electrical shop, also has 12"x12" industrial tile flooring. The offices (Rooms 1020, 1024, and 1028) are carpeted with low-pile industrial carpet.

   c. **Central section:** The floor in the central section is concrete covered with 12"x12" industrial tile in the corridors and lab spaces (Photo 12). The control room (Room 1117A) has a raised floor with 2'x2' cable flooring (each panel is made up of four 12"x12" floor tiles), as does the space north of the elevator. The twelve offices along the east side of the corridor are carpeted with low-pile, industrial carpeting in a blue shade with tan specks. The supply room (Room 1103A) has older 9"x9" floor tiles. Room 1103 has low-pile blue industrial carpet. The office in Room 1105 has older 9"x9" floor tile. Room 1131 has 12"x12" floor tiles.

d. **Modulator/power supply building:** The modulator/power supply building floor is concrete.

e. **Neutron cell silo:** The floor of the neutron cell silo is concrete.

f. **Underground complex:** The floor at the base of the south stairway and the corridor (Corridor 1) from the south stairway is concrete covered in 12"x12" industrial tile (Photo 19). The remainder of the floors in the basement are concrete.

4. **Wall and ceiling finish:**

a. **Increment I (west portion of south section):** Room 1055 has plastic panels on the ceiling. Room 1057 has gypsum board walls. Room 1050, which houses EBIT is a high bay with the steel frame and the exterior metal wall panels visible. The original roll-up door on the west wall is still installed; it is rolled up and the exterior wall has a replacement metal panel in place. The mezzanine accessed on the east end of Room 1050 is metal, as is the stairway to it.

b. **Increment II (east portion of south section):** Interior walls of Increment II are 2"x4" wood studs covered with gypsum board and painted (Photo 11). The corridor ceiling is unfinished; offices have suspended acoustical tile ceilings.

c. **Central section:** Partitions of wood studs covered with gypsum board painted white divide offices and create the corridors of the central section. Rooms and corridor have suspended acoustical drop-in 2'x4' tile ceilings (Photo 12). The exterior west wall is concrete block and the rooms on that side have painted concrete walls (Rooms 1101, 1101A, 1105, 1111, 1117A, 1117B, 117C, and 1131). These include the office in Room 1105, which has standing cloth cubicle panels dividing its interior space; its north and west walls are concrete block. Room 1111 is currently unoccupied. It has a solid ceiling (not tiles). The south and west walls are concrete block. It opens into Room 1131 (diagnostics), which has all concrete block walls.

d. **Modulator/power supply building:** The ceiling and outer northwest wall are metal. Other walls are concrete block painted white (Photos 15, 16, and 17).

e. **Neutron cell silo:** Floor and ceiling are concrete (Photo 10).

f. **Underground Complex:** The underground complex ceilings are 10' thick painted concrete. The walls are also concrete. All are painted to seal the concrete and "to prevent it from giving off calcium dust which becomes radioactive in these areas of high radiation intensity."[32]

The wall separating the accelerator cave from the experimental caves is 10' thick concrete block. This serves to shield the experiments from the high background radiation created by the accelerator.

5. **Openings:**
   a. **Doorways and doors:** There are both wood and metal doors providing pedestrian access to offices and labs throughout the building. There are also large shielding doors in the underground complex.
      1. **South section (Increments I and II):** There are double metal doors with clear wire glass in the corridor connecting Increment I to Increment II and the door to Room 1042 is metal. Doors to the shop (Rooms 1033 and 1023), offices (Rooms 1020, 1024, 1028), and restrooms (Rooms 1034 and 1040) are wood.

      2. **Central section:** Office doors are wood in wood frames throughout. Room 1111 has double pedestrian metal doors to Room 1131. It also has double metal doors into the control room (Room 1117A). The door between Rooms 1103 and 1103A has wire glass in the top half. Room 1113 has a metal door. Doors of the elevator are metal. Double metal pedestrian doors with windows lead into Room

[32] S. C. Fultz to John F. Burdoin, Memo re: "Advantages and Disadvantages of painting Concrete Walls in Cave Areas," October 28, 1965, Proposal and Memo, Building 194 Files.

1117A (control room) from the corridor outside of the stairway and elevator.

3. **Modulator/power supply building:** There are double metal doors from the assembly room (Room 1201) to the mechanical room (Room 1220). Interior openings between Rooms 1201 and Room 1211 do not have doors.

4. **Neutron cell silo:** There are no interior doors in the neutron cell. It is a single open cylindrical space within the silo's walls (Photo 10).

5. **Underground complex:** The mechanical room (B110) and stairwell in Corridor 1 are accessed via metal doors (Figure 4; Photo 19). Concrete shielding doors manufactured by Allied Manufacturing and weighing approximately 84,000 lbs. close off each of the caves in the underground complex (Figure 4; Photos 21, 25, and 26).

b. **Windows:** There are few interior windows in Building 194. The double doors in the corridor connecting Increment I to Increment II have clear wire glass in the tops. Room 1103 in the central section has three 28" wide x 47" high windows in the center section of the wall facing the corridor. The door between Rooms 1103 and 1103A in the central section has wire mesh glass in the top half. Room 1117A (control room) has one window to the north of the entrance and two 40" high x 39" wide windows to the south of the entrance. It also has windows in its double metal pedestrian doors from the corridor outside of the stairway and elevator. The window in the top half of the south door is wire glass while the window in the top half of the north door is plain glass.

6. **Decorative features and trim:** There are no decorative architectural features on the building. The control room colors, rack designs, and accelerator schema reflect the era in which the room was built (Figures 13 and 14; Photos 13 and 14).

The extensive use of concrete in the building's foundation and in the underground complex give the interior of the building a heavy, industrial appearance. Its exterior is a mix of the basic, practical designs of Increments I and II (pre-fabricated metal and concrete block, respectively), and the modern office appearance of the late-1950s, early-

1960s apparent in the east side of the central office section (Figure 17; Photos 1 and 2), which holds the building's main entrance.

7. **Hardware:** There is no historic hardware in the building.

8. **Mechanical Equipment:**
   a. **Heating, air conditioning, ventilation**: Central fan-coil units, remote reheat coils, and a central hot water and chilled water installation serve Building 194.

      The underground caves have a once-through, outside-air system, with hot water coils in central fan-coil units.

      The central section has central fan-coil units with chilled water coils to provide cool primary air. The primary air is then provided, via ducts, to various areas and reheated.

      The modulator/power supply building has a central fan-coil unit with a tempering hot water coil. The exhaust stack on the north end of its northwest side allows purging of the underground complex.

      Exhaust air systems are coordinated with the supply systems with the goal of obtaining differential air pressures within the buildings that air movement is always from low radioactive areas to highly radioactive areas. The underground cave complex has three types of ventilation that may be controlled by the machine operators: (1) normal fan speeds providing specified air changes every hour; (2) HEPA filters used when exhaust fan speed is increased; and (3) both supply and exhaust fans at high speed, to provide maximum air flow in case of gaseous contamination.

   b. **Lighting:** There are no historically significant lighting fixtures. Fluorescent lighting is used throughout the building.

   c. **Plumbing:** There are no historically significant plumbing fixtures. Water is supplied via LLNL's infrastructure.

   d. **Safety systems:** Due to the hazardous nature of the radiation involved when the accelerator is operating, there are safety controls in place in the building. These include processes, regulations, and training, as well as personnel-operated safety systems. There are two personnel-operated safety systems: Hazard/Safe Box System and Emergency Call Station System.[33]

**Hazard/Safe Boxes:** These are located near the entrances to the underground complex and the aboveground time-of-flight areas, as well as near potential work areas. When set to the SAFE position, the boxes render the accelerator inoperable in any mode that could generate a radiation hazard.

**Emergency Call Stations:** Emergency Call Stations include a red alarm button that activates a flashing red light and a Klaxon in emergencies. It also disables the accelerator. The stations also have sound-powered telephones referred to as "growlers" that allow communication with the control room when the hand-crank is operated (Photo 15).

9. **Original Furnishings:** There is no historic furniture in the building. In terms of historic equipment, the 25 MeV accelerator has been removed; the 100 MeV accelerator is described below.

10. **Description of 100 MeV Electron-Positron Accelerator:** The 100 MeV accelerator is a variable energy RF linear accelerator. It produces electron beams with energies ranging from 10 MeV to 165 MeV at average beam power up to 45 kilowatts (kW) (600 milliamperes [mA] at 75 MeV). The pulse structure of the beam is also variable, ranging from a short-pulse mode (2-20 nanosecond [ns] long pulses, 10 ampere [A] peak current, 1440 pulses per second) to a long-pulse mode (3 microsecond (μs) pulses, 700 mA peak, at 300 pulses per second).

    The accelerator is housed in the accelerator cave in the underground complex of Building 194. The accelerator cave is 147'x11'; its floor is 26' below ground level. The basic operation is: power comes from the modulator/supply room above the accelerator cave, the trigger generates a beam of electrons that moves along the first three accelerator sections, to which power is being fed via the modular tubes from above, if desired the beam hits a target and generates positrons, which proceed through the final sections and out into the beamline to be focused and directed by magnets into the 0° cave or along the magnet cave to be distributed to experiments

[33]"Facility Safety Procedure 194, Appendix D: Safety Systems and Work Regulations for Hazardous Areas," rev. May 2, 1980, Binder: FSP, Building 194 Files. This and other safety documents emphasize awareness of and responses to potential hazards. The risks are underlined in the statement on page D-1 of the document, "It should be emphasized that a single pulse from the accelerator can deliver a potentially lethal dose of radiation."

in the north or south cave. The accelerator also supplies neutrons and gamma rays that are similarly directed to experiments in the caves.

a. **Photoinjector:** The original electron gun (Figure 11) used to achieve the short pulses of high current to begin the beam is no longer in place. It was replaced in the 1970s and has more recently been superseded by a thermionic gun. In 2001, a photoinjector was added (Photos 22 and 23).

b. **Accelerator Sections:** The five accelerator sections are 8' in length. Modulator tubes run from the modulator/power supply building above the accelerator cave to the beginning of each accelerator section, feeding RF power to the accelerator.

c. **Beam Transport System:** The beam transport system runs from the output end of the accelerator to a distribution area referred to as a magnetic switchyard immediately in front of it. From that point, the beam can be directed to the appropriate cave(s) for diagnosis and/or experimentation.

   Magnets direct the beam and focus it, keeping it aligned and curving it, as needed. They are installed along the beamline (Figure 9).

   Although the neutron cell is no longer operating in the silo above the output end of the accelerator, the hardware for the beamline from the distribution area curving up toward the silo is still in place and clearly visible at the south end of the accelerator cave (Photo 24).

d. **0° Outer Detector Cave:** The Falcon laser was introduced to operate with the accelerator. It is housed in Room 1117B in the central section above. It provides an intense, short pulse laser light where the optical pulse is compressed to 30 femtoseconds (fs) ($3x10^{-14}$ seconds) with focal intensities up to 10+20 Watts per square meter (W/cm2) at 820 nanometer (nm) wavelength. The laser light is transported underground to the 0° outer detector cave (Room B120) to an interaction chamber where the beam can be used in experiments to study the interaction between the laser and the accelerated electron beam. The 0° outer detector cave is approximately 15'x70' (Figure 4).

e. **0° Inner Detector Cave:** Room B122 on the floor plan (Figure 4). Not currently in use. It is a small space just outside of the 0° cave. It is possible to direct beams from the 0° cave into target areas in this space through beam tubes in wall openings.

f. **0° Cave:** Identified as Room B122A on the floor plan (Figure 4), the 0° cave was not in use during the building tours. It is approximately 26'x28'. When the accelerator beam is directed into it, it can be used to generate intense secondary beams of neutrons, bremsstrahlung photons, or positrons. Openings in its walls allow for directing the resulting beams out through beam tubes to target areas in the 0° detector caves for diagnostic or other experimental work (Photo 27).

g. **South Cave:** Room B124 on the floor plan (Figure 4), the south cave is a large (39'x73') space, allowing multiple experiments (Photo 28). During the building tours, it was indicated that the Pelletron, an electrostatic 3 MV accelerator manufactured by NEC, would be moving from the north cave into this space.

h. **North Cave:** Identified as Room B134 on the floor plan (Figure 4), the north cave is approximately 31'x72' (Photo 30). During the building tours it housed the Pelletron, which was expected to move to the south cave in the near future. The Pelletron generates very high resolution electron beams (0.l6 – 3.2 MeV at DC currents up to 100 μA) and can be configured to generate a high-resolution positron beam. Its beam can be directed through the magnet cave to a target in the south cave. Like the south cave, the north cave exists to house experimental set-ups, including targets for the beamline(s) and appropriate data capture capabilities.

i. **Magnet Cave:** The magnet cave, Room B132 (Figure 4), houses the beamline as it proceeds from the magnetic switchyard in the accelerator output area to feed into the north and/or south caves. It allows the beamline to branch, as needed, as the magnets direct and focus the beam (Figure 9; Photo 29). It is a long room (11'x94'), appropriate to housing a beamline.

j. **Control/Diagnostics:** The accelerator is controlled from the control room in the central section at ground level. While much of the original hardware remains in place, it has slowly been converted to computer-based controls. The control racks still reflect the original design and it still operates reliably and well (Figures 13 and 14; Photos 13 and 14).

11. **Accelerator Power Supply:** The modulator/power supply building houses the klystrons and modulators that provide microwave power to the Linac accelerator sections. The klystrons are 60 kW, S-band, manual-tuned, pulsed amplifiers with coaxial input, coaxial output, integral permanent magnet focusing, and liquid cooling. Modulators pulse the klystrons and supply all klystron power (both high voltage and filament power) and cooling interfaces. The modulator assembly houses the klystron; these are in Room 1211 (Photos 17 and 18).

    Power supplies feed the klystrons, which amplify the power before sending it down to the accelerator sections in the cave below the modulator/power supply building (Photo 16).

    As the klystron operation generates x-rays and bremsstrahlung, there is lead shielding in the klystron mounting assemblies. Additionally, sheets of lead on the modulator cabinet doors provide shielding.

    The control system for the power supply has been upgraded in recent years. The building still houses both old and new control racks, demonstrating the change (Photo 15).

**D. Site:** Building 194 is located in the northwest corner of LLNL's main site in Livermore. The longest time-of-flight tube extended out to the northwest with no other buildings to impede it. The other facilities along Eighth Street and Avenue B also support research activities.

1. **Historic landscape design:** Building 194 does not have a historic landscape design. On the building's east side a lawn surrounds a concrete path leading to the main entrance. Beyond the lawn, to the north and south, is small gravel spread thinly; a concrete path leads to a pedestrian door on the north end of the central section. There is an unpaved gravel area with a variety of trees on the building's south side; employees park under the trees there or on the street on the east side. The building's west side is not landscaped. There is a poured concrete pad off of the south section and paved storage areas off of the central section. In the north section the areas around the silo and beamline are cleared, and the ground around the walkway to the modulator/power supply building is paved. The paving extends around to the north of the modulator/power supply building.

2. **Outbuildings:** Building 194A sits to the north of the modulator/power supply building. Building 198, a small storage building, sits to the west of the central section of Building 194. In addition, the time-of-flight tubes extend from the neutron cell in the silo to detector stations at 51', 83', 208', and 830' (Figures 7 and 10; Photos 5 and 6).

**Part III. SOURCES OF INFORMATION**

A. **Architectural Drawings:** Architectural drawings and key plans are held in the LLNL Plant Engineering Library's (PEL) electronic system.

"Building 194 (South)," Facility Key Plan, 2000, PKB96-194-001BE.

"Building 194 (Mezzanine)," Facility Key plan, 2000, PKB96-194-005BC.

"Building 194 (Central)," Facility Key Plan, 2002, PKB96-194-002BE.

"Building 194 (North)," Facility Key Plan, 1998, PKB96-194-003BC.

"Building 194—Basement," Facility Key Plan, 1998, PKB96-194-004BC.

"Building 194A," Facility Key Plan, 1996, PKB96-194A-001BA.

"High Flux Building—194, Site & Plot Plans, Grading, Paving & Drainage Details," 1957, PLZ57-194-001JA.

"High Flux Building—194, Sections, Elevations & Details," 1957, PLZ57-194-002JA.

"High Flux Building—194, Floor & Roof Plans & Details," 1957, PLZ57–194–003JA.

"High Flux Building—194, Steel Framing, Elevations, Sections, & Details," 1957, PLZ57-194-004JA.

"High Flux Building 194—Increment 2, Floor Plan, Exterior Elevations, Finish Schedule, Door Schedule," 1959, PLZ59-194-002JA.

"LINAC Shielding—Building 194, Access Door, Safety Bar," 1959, 7RL-7883.

"Building 194—Time of Flight Facility, Installation of Metal Building, Plan, Elevation, & Details," 1964, PLA64-194-005D.

"Building 194—Increment 3, Site Plan & Location Map, Civil," 1967, PLZ66-194-002J.

"Building 194—Increment 3, Plot Plan, Civil," 1967, PLZ66-194-003J.

"Building 194—Increment 3, Office—Laboratory Building, Floor Plan & Elevations," 1967, PLZ66-194-007JA.

"Building 194—Increment 3, Modulator Building & Neutron Cell, Floor Plan, Elevations 7 Section," 1967, PLZ66-194-015J.

"Building 194—Increment 3, Underground Structure, Floor Plan," 1967, PLZ66-194-018J.

"Building 194—Increment 3, Underground Structure, Special Systems," 1967, PLZ66-194-068J.

"Building 194—Increment III, Floor Plan—Underground Structure," 1969, PLZ69-194-002B.

"Building 194—Room 1042, Construct Addition, Plans & Details," 1977, PLA77-194-005D.

**B. Early Views:** Historic photographs of the 100 MeV electron-positron accelerator reside in the LLNL Archives and Records Center (ARC).

**C. Interviews:** No recorded oral history interviews were conducted.

**D. Bibliography:** Primary source material is held in the LLNL ARC and in the LLNL Building 194 Records Room (Building 194 Files). Specific documents used from those collections are cited below along with published sources.

Alvarez, R. A. "Characteristics of the LLL 100-MeV Linac." 1972. Research Programs at LLL Linac, Building 194 Files.

Alvarez, R. A. "Pb Collimator Pig." *Engineering Note.* July 21, 1982. MOIR LANL, Building 194 Files.

Alvarez, R. to Paul Lawrence. Memo re: "F.Y. '77 Equipment Budget." February 19, 1975. Neutron Yield, Stelts' Measurement, Building 194 Files.

Alvarez, R. to Distribution. Memo re: "A Sixth Accelerator Section." December 4, 1975. Proposed 6th Section, Building 194 Files.

Alvarez, R. A., P. Meyer, R. Booth, and R. M. Johnson to Distribution. Memo re: "Possible Improvements in Primary and Secondary Linac Beams." October 14, 1981. Linac Upgrade Possibilities Memo 10-14-81, Building 194 Files.

Applied Radiation Corporation. "($1.6 Million Accelerator Contract Announced by Applied Radiation)." Press Release. January 9, 1967.

Applied Radiation Corporation. "Proposed Factory and Acceptance Test Program for LRL 100 MEV LINAC." L-2018. July 9, 1966. Subcontract and 100 MeV LINAC Specs. Building 194 Files.

Bauer, R. W. "The LLL 100-MeV Linear Accelerator." Draft. July 21, 1977. Copy provided by R. Bauer.

Bauer, R. W. "Program Review: Physics Department, E-Division." April 7, 1976. Research Progress at LLL Linac, Building 194 Files.

Blue, C. L. to P. M. Goodbread, Memo re: "Electron-Positron Linear Accelerator, 100 MeV." February 28, 1966. Proposal and Memo, Building 194 Files.

Blue, C. L. to W. B. Harford. Memo re: "Proposed Procurement, 100 MeV Linear Accelerator." January 12, 1966. Proposal and Memo, Building 194 Files.

B. D. Bohna & Co., Inc. "Electron-Positron Accelerator Facility, Building 194 Increment 3, Lawrence Radiation Laboratory, Livermore Site. Section 5.0 Preliminary Cost Estimate." January 12, 1966. Proposal and Memo, Building 194 Files.

Bowman, Charles D. to NCSAC Members and Contributors. Memo re: Status Report to NCSAC. UCID-15529. September 4, 1969. Proposal and Memo, Building 194 Files.

Brim, G. V. to Mr. Dexter Dawes, Treasurer, Applied Radiation Corporation. Subject: "Subcontract 341, 100 MeV Linear Accelerator System, $1,599,353.00." May 25, 1971. Proposal and Memo, Building 194 Files.

"'Electron-Positron' Linac to be built at Livermore Lab." *The Magnet,* 11:7 (July 1967): 1, 4.

"Facility Safety Procedure 194, Appendix D: Safety Systems and Work Regulations for Hazardous Areas." Revised May 2, 1980. Binder: FSP, Building 194 Files.

Fultz, Stanley C. "Characteristics of the New 100 MeV Linear Electron Accelerator at Livermore." Prepared for Gordon Conference, August 16-20, 1971. UCRL-73313. July 15, 1971.

Fultz, S. C. "The 100-MeV Electron-Positron Accelerator." In Harry F. Lutz, ed. *Semiannual Progress Report of the Physics Department, July through December 1970.* UCRL-50001-70-2. Livermore: University of California, Lawrence Radiation Laboratory, Livermore, April 12, 1971. Pp. 22-23.

Fultz, S. C. *Research Program for the 16 MeV Electron Linear Accelerator.* Internal Report. Livermore: Lawrence Radiation laboratory, Linac Research Group, 1958.

Fultz, S. C. to C. Blue. Memo re: "Technical Assessment of the 100 MeV Electron Accelerator." May 19, 1971. Proposal and Memo, Building 194 Files.

Fultz, S. C. to Distribution. Memo re: "New Linear Electron Accelerator Proposal." May 8, 1964. Proposal and Memo, Building 194 Files.

Fultz, S.C. to E. Goldberg. Memo re: "Positron Beam from 100 MeV Linac." November 25, 1970. Proposal and Memo, Building 194 Files.

Fultz, S. C. to John F. Burdoin. Memo re: "Advantages and Disadvantages of painting Concrete Walls in Cave Areas." October 28, 1965. Proposal and Memo, Building 194 Files.

Fultz, S. C., C. L. Whitten, and W. J. Gallagher. "The LRL (Livermore) 100-MeV Linear Electron Accelerator and Facility." IEEE Transactions on Nuclear Science, NS-18 (July 1971): 533-537.

Fultz, S. C., R. Alvarez, and D. Moyer to E. Goldberg. Memo re: "Subcontract 341, Applied Radiation Corporation." July 14, 1970. Subcontract and 100 MeV LINAC Specs. Building 194 Files.

Fultz, S. C., R. Alvarez, and D. Moyer to E. Goldberg. Memo re: "Subcontract 341." July 24, 1970. Subcontract and 100 MeV LINAC Specs. Building 194 Files.

Fultz, S. C. and R. L. Bramblett. "Status Report to the Nuclear Cross Section Advisory Group." UCRL-14501-T. Livermore: California: University of California Lawrence Radiation Laboratory, October 14, 1965.

Fultz, S. C., C. L. Whitten, and W. J. Gallagher, "The LRL (Livermore) 100-MeV Linear Electron Accelerator and Facility." Paper presented at the 1971 National Particle Accelerator Conference, Chicago, March 1-3, 1971. UCRL-73075. March 2, 1971.

Goldberg, Eugene to C. L. Blue. Memo re: "Performance of 100 MeV Electron Accelerator as a Positron Accelerator." May 21, 1971. Proposal and Memo, Building 194 Files.

Goldberg, Eugene to W. B. Harford. Memo re: "100-MeV Electron Accelerator." October 16, 1970. Proposal and Memo, Building 194 Files.

Goldberg, E. and S. C. Fultz to J. Hulse. Memo re: "Ventilation in Accelerator Cave at Bldg. 194." December 8, 1970. Proposal and Memo, Building 194 Files.

Hulse, J. to S. C. Fultz and E. Goldberg. Note. December 10, 1970. Proposal and Memo, Building 194 Files.

Kulke, B., A.Brooks, and R. A. Fontaine. "ELF Note #110 P&E: Beam Spill Activation on the FEL Wiggler Magnet." October 8, 1984. Prosnitz et al., Building 194 Files.

Lara, M. C. to J. Panton. Memo re: "Request to Purchase Used RF Windows from SLAC." June 17, 1977. Transmission w/g and RF Windows, Building 194 Files.

Lara, M. C. and H. E. Brooks. "LLL 100 MeV Electron LINAC: Design Considerations and Performance of the Beam-Transport Vacuum System." Presented at the Washington Meeting of the American Physical Society, Washington, D. C., March 12-14, 1975. UCRL-76138. March 18, 1975.

Lawrence Livermore National Laboratory. "Physics Department Program Review, April 1981: Summary Information." Collection 073.01.06 Physics Department Director's Program Reviews 1985-1988, Box 1, Folder 0.2 Physics Dept. Directors Program Review—Summary Info. April 1981, LLNL Archives.

*Linac.* Livermore: Lawrence Livermore Laboratory, 1972.

Linac Physicists to Carl Poppe. Memo: no subject. September 1, 1978. Loose papers between files, Building 194 Files.

McGregor, John to Bart Czirr. Memo re: "Installation of the Silo Neutron Target." June 11, 1976. Time-of-Flight Facility, Building 194 Files.

Mendonca, Mark L. "Microprocessor Control and Data Acquisition at the LLNL 100 MeV Accelerator." Prepared for the Topical Conference on Computerized Data Acquisition in Particle and Nuclear Physics, Oak Ridge, Tennessee, May 2-30, 1981. UCRL-86097. May 26, 1981.

Michael, K. "Sub-Booster Modulator for Linear Accelerator [specification]." August 23, 1979. Cober Bids, Building 194 Files.

Moyer, D. R. to C. L. Blue and C. A. Cowan. Memo re: "Request for Special Purchase—High Current Electron Gun for Evaluation." Ref EE-2450. August 14, 1972. Proposal and Memo, Building 194 Files.

"Preliminary Proposal for a New Electron-Positron Accelerator." March 19, 1962. Proposal and Memo, Building 194 Files.

Servas, R. "LINAC: The Livermore Linear Accelerator." A movie for television script. DRAFT. April 13, 1976. Linac "Propaganda" Presentation Material, Building 194 Files.

"Subcontract No. 341 between The Regents of the University of California and Applied Radiation Corporation for 100 MeV Electron-Positron Linear Accelerator." October 1966. Subcontract and 100 MeV LINAC Specs. Building 194 Files.

"Subtle Nuclear Scalpel Unveiled in Livermore." *The Independent.* January 13, 1971, p. 2.

"Third Amendment to Subcontract 341 between the Regents of the University of California and Applied Radiation Corporation." October 9, 1970. Proposal and Memo, Building 194 Files.

University of California, Ernest O. Lawrence Radiation Laboratory. *Status Report: Fiscal Year 1962.* Livermore: Ernest O. Lawrence Radiation Laboratory, 1963.

University of California, Ernest O. Lawrence Radiation Laboratory. *Status Report: Fiscal Year 1963.* Livermore: Ernest O. Lawrence Radiation Laboratory, 1964.

University of California, Ernest O. Lawrence Radiation Laboratory. *Status Report: Fiscal Year 1965.* Livermore: Ernest O. Lawrence Radiation Laboratory, 1966.

University of California, Lawrence Livermore Laboratory. *30 Years of Technical Excellence*. Livermore: Lawrence Livermore National Laboratory, 1982.

University of California, Lawrence Livermore Laboratory. *Linac.* Brochure. 1972.

University of California, Lawrence Livermore Laboratory. *The LLL Electron Linear Accelerator (LINAC).* Brochure. Livermore: Lawrence Livermore Laboratory, 1977.

University of California, Lawrence Radiation Laboratory, Livermore. "Construction Completion Report: Electron-Positron Accelerator Facility, Building 194—Increment III." Livermore: University of California, Lawrence Radiation Laboratory, Livermore, ca. 1971. Building 194 Files.

Whitten, C. L. "100 MeV Linac [specification]." February 2, 1966. Subcontract and 100 MeV LINAC Specs, Building 194 Files.

Whitten, C. L. "Proposed New Electron-Positron Accelerator." March 16, 1962. Subcontract and 100 MeV LINAC Specs, Building 194 Files.

Whitten, C.L., to Distribution, Memo re: "100 MeV Linac Procurement," February 23, 1966, Ref. EE-1216. Proposal and Memo, Building 194 Files.

Whitten, C. L. to E. Goldberg and W. B. Harford. Memo re: "100-MeV Linac Acceptance." Ref. EE-2037. October 15, 1970. Proposal and Memo, Building 194 Files.

York, Herbert. "Making Weapons, Talking Peace." *Physics Today* (April 1988): 40–52.

**E. Likely Sources Not Yet Investigated:**

There is extensive detailed technical information on accelerator research, time-of-flight studies, recent studies using the accelerator in B194, and related research in technical reports issued by LLNL. The scientific literature on accelerators in general is extensive.

**F. Supplemental Material:** None.

Figures 1 through 5 are Key Plans of Building 194; Figure 6 is the Key Plan of Building 194A. Original engineering drawings are located in the LLNL Plant Engineering Library. Figures 7 through 13 are digital images and historical drawings and photographs of Building 194.

Figure 1 Drawing PKB1996-194-001BE, Rev. December 2000.
FACILITY KEYPLAN, BUILDING 194, FIRST FLOOR (SOUTH).

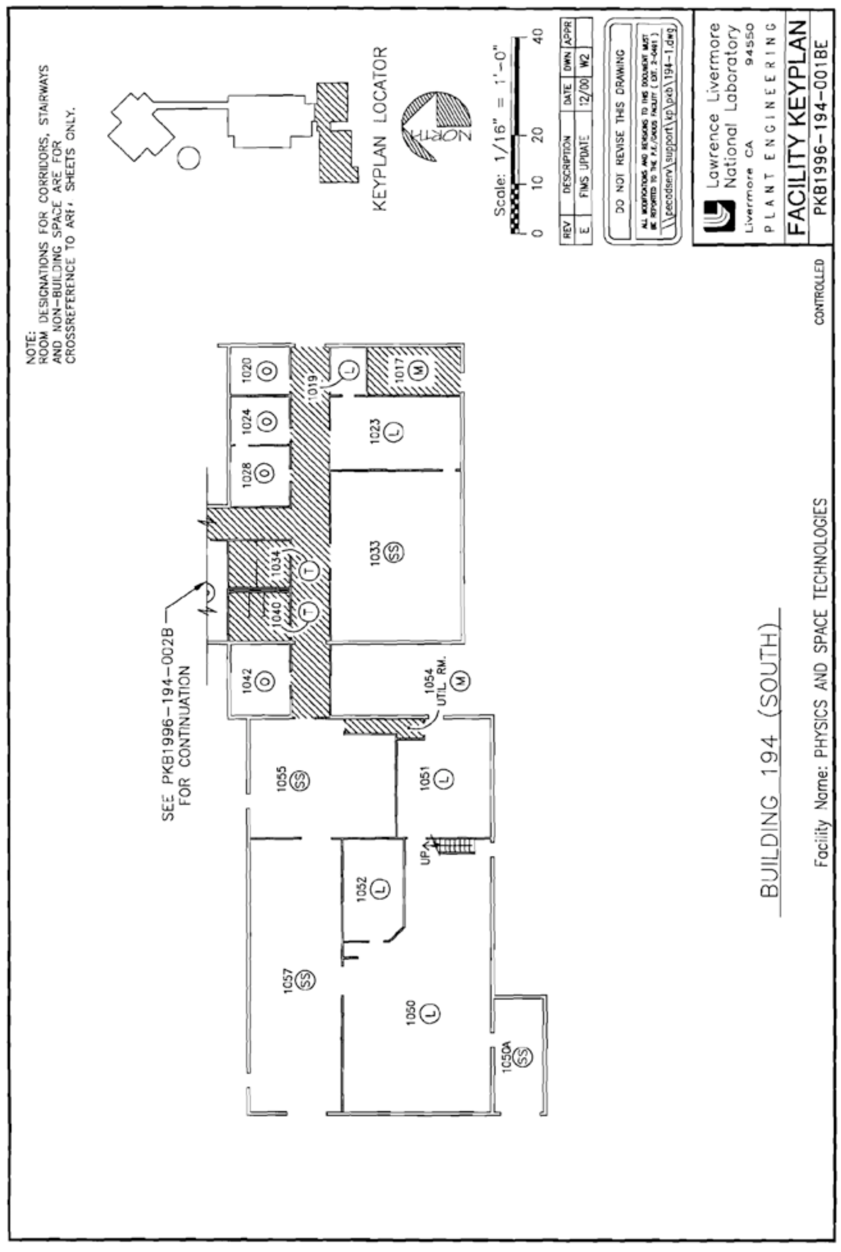


Figure 2 Drawing PKB1996-194-002BE, Rev. July 2002.
FACILITY KEYPLAN, BUILDING 194, FIRST FLOOR (CENTRAL).

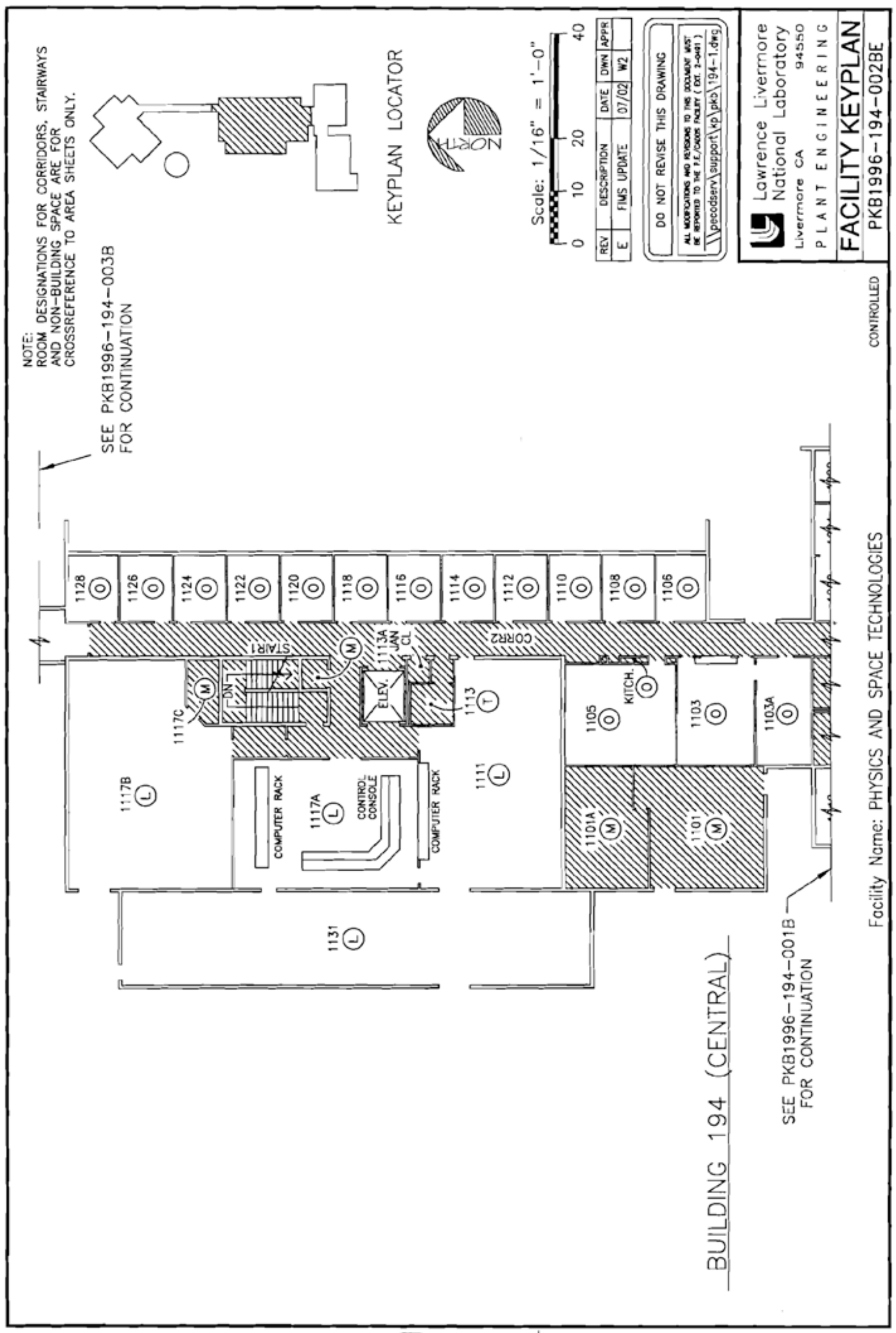
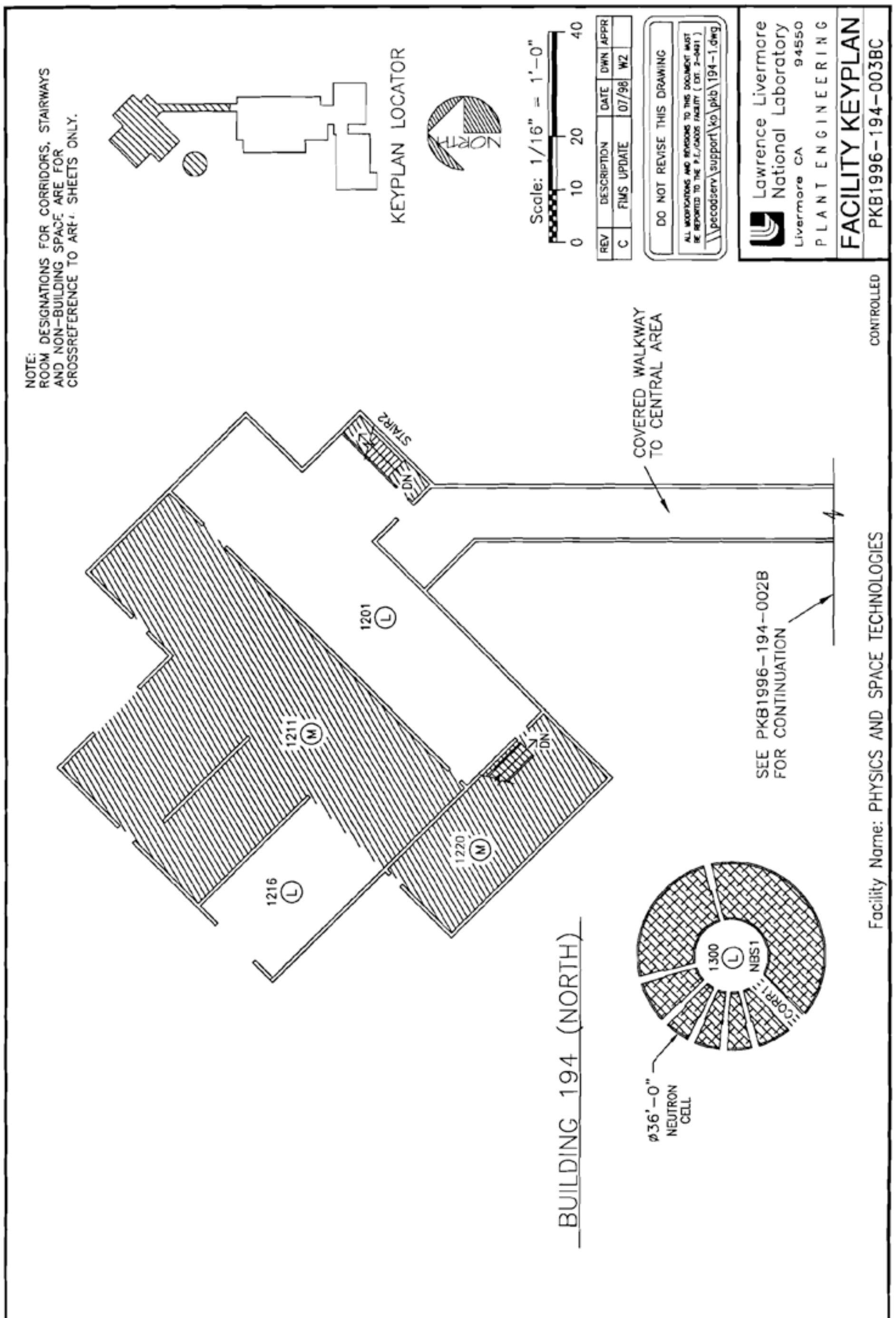


Figure 3 Drawing PKB1996-194-0003BC, Rev. July 1998.
FACILITY KEY PLAN, BUILDING 194, FIRST FLOOR (NORTH).




3

Figure 4 Drawing PKB1996-194-0004BC, Rev. July 1998.
FACILITY KEYPLAN, BUILDING 194, BASEMENT

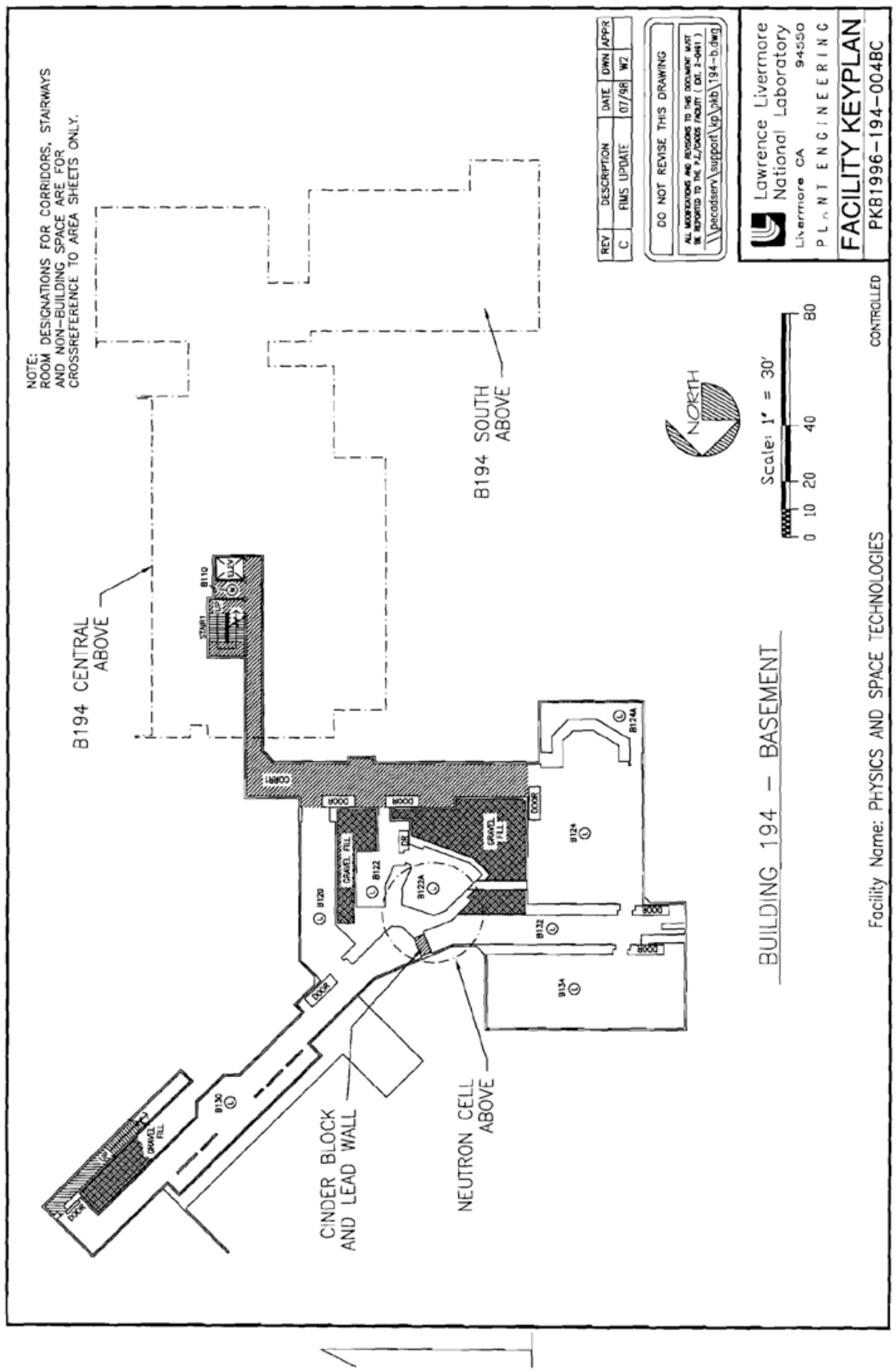


Figure 5 Drawing PKB1996-194-0005BC, Rev. July 1998.
FACILITY KEYPLAN, BUILDING 194, MEZZANINE

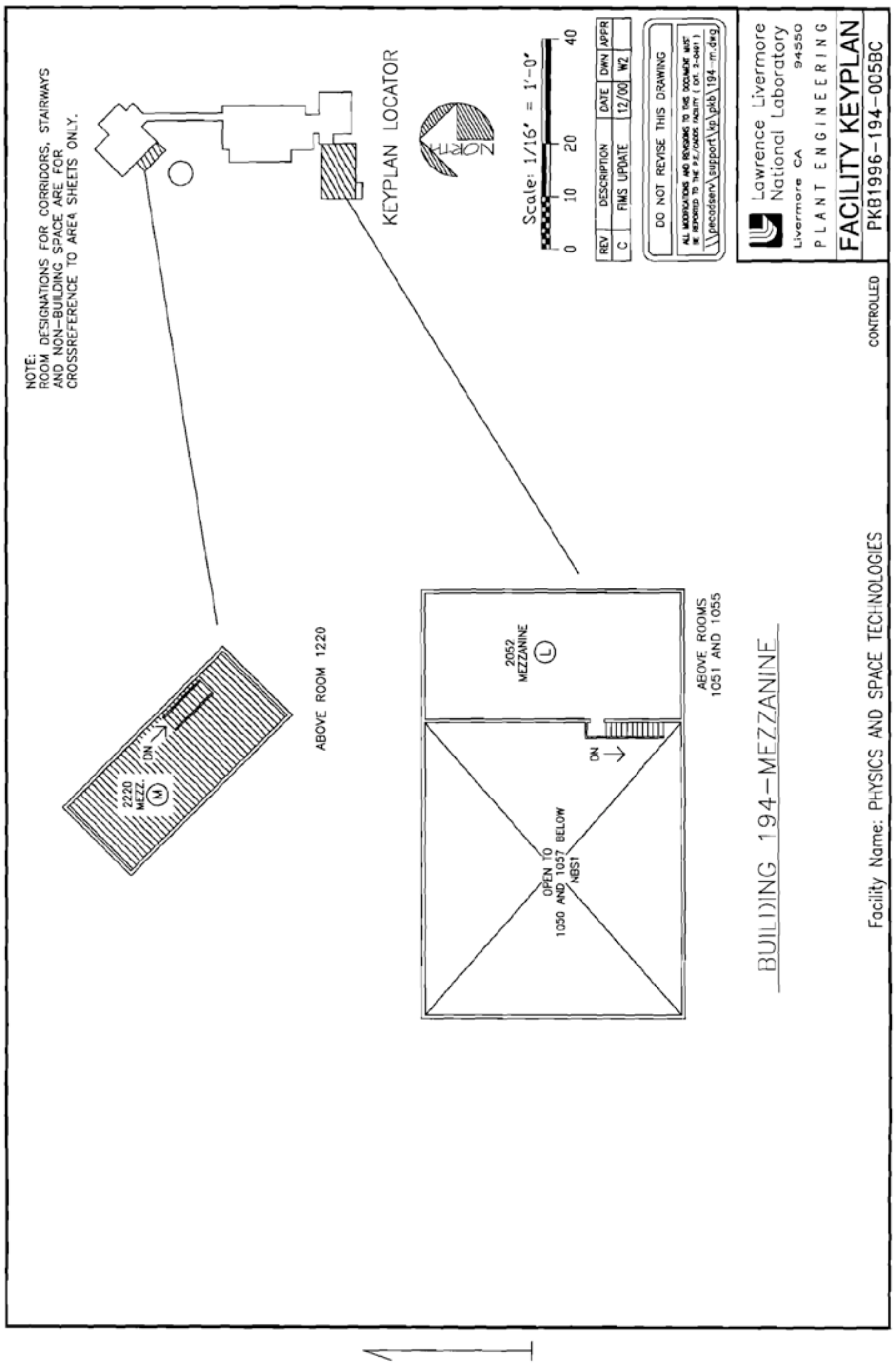


Figure 6 Drawing PKB1996-194A-0001BA, Rev. August 1996.
FACILITY KEYPLAN, BUILDING 194A

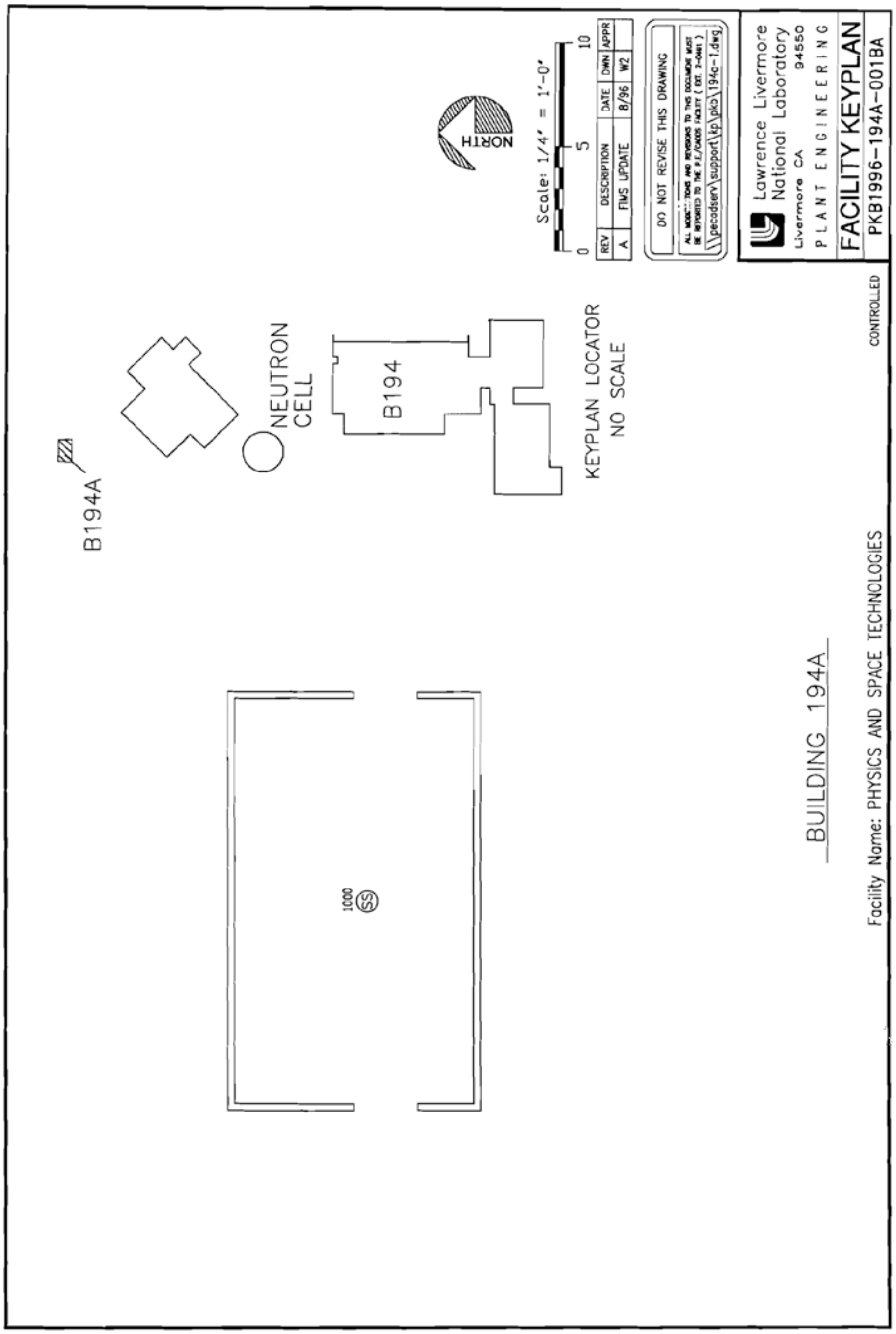


Figure 7 LLNL Archives, Box 021, Folder 10110 “Electron Linac”
DRAWING OF ABOVEGROUND LAYOUT, BUILDING 194

Figure 8 LLNL Archives, Box 021, Folder 10110 "Electron Linac"
DRAWING OF UNDERGROUND LAYOUT, BUILDING 194.

Figure 9 LLNL Archives, Box 214, Folder 2079 “LINAC Pamphlet and Photos”
MAGNET SCHEMATIC, 100 MeV LINAC, BUILDING 194.

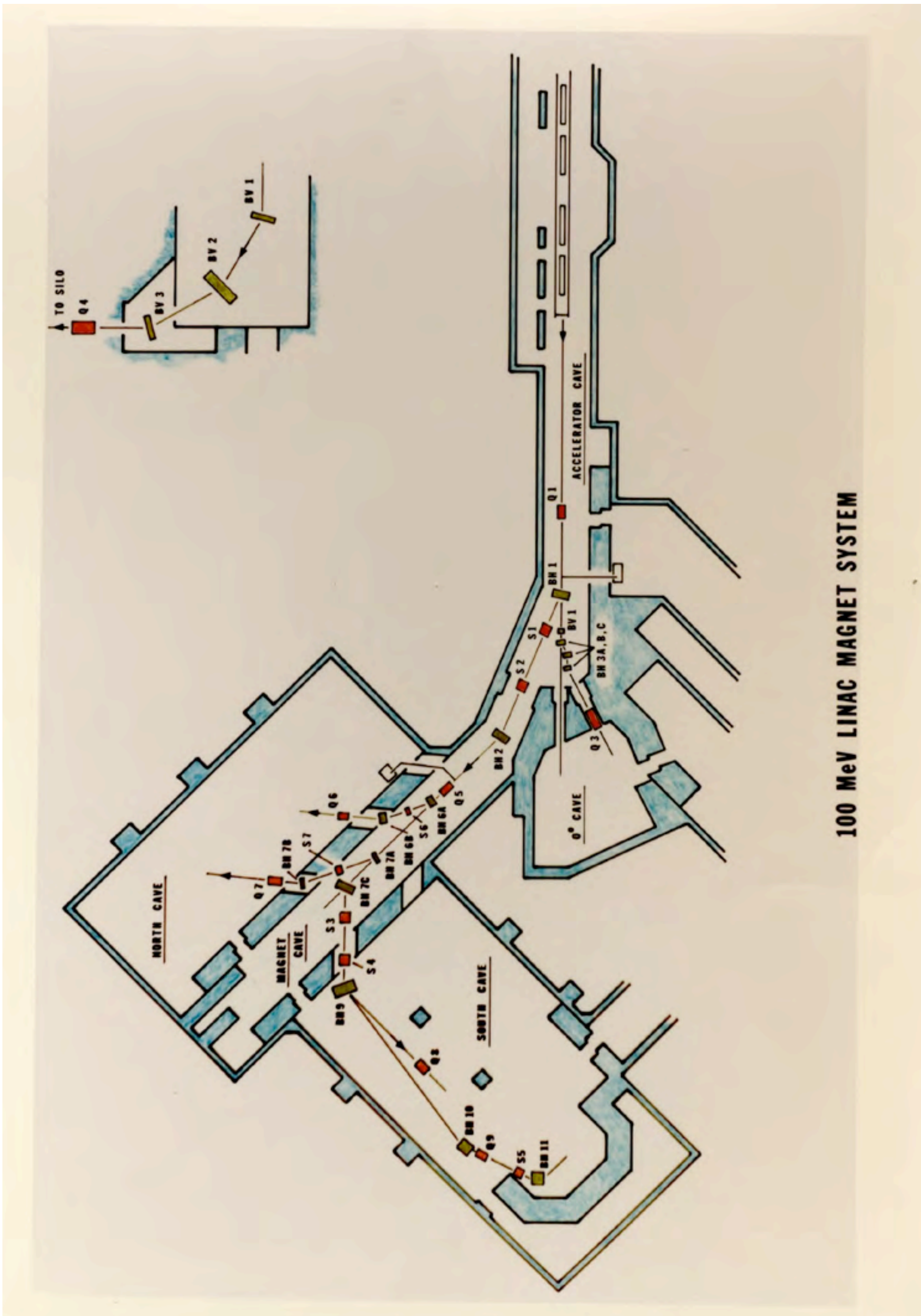
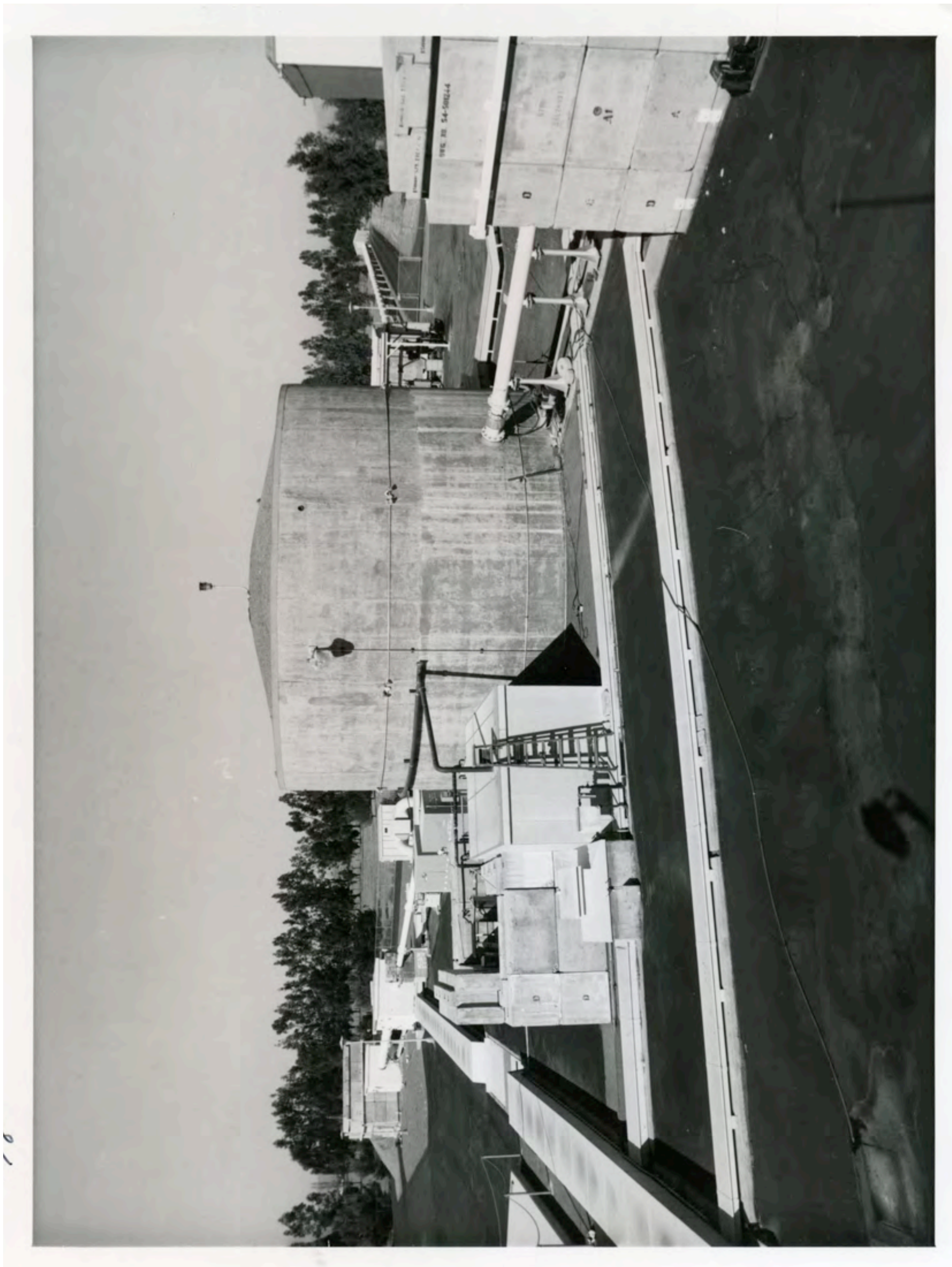


Figure 10 LLNL Archives, Box 021, Folder 10110 “Electron Linac”
EXTERIOR OF SILO (NEUTRON CHAMBER), 1978, BUILDING 194.



π

Figure 11 LLNL Archives, Box 030, Folder 10132
INJECTOR POWER SUPPLY, 100 MeV LINAC, BUILDING 194.

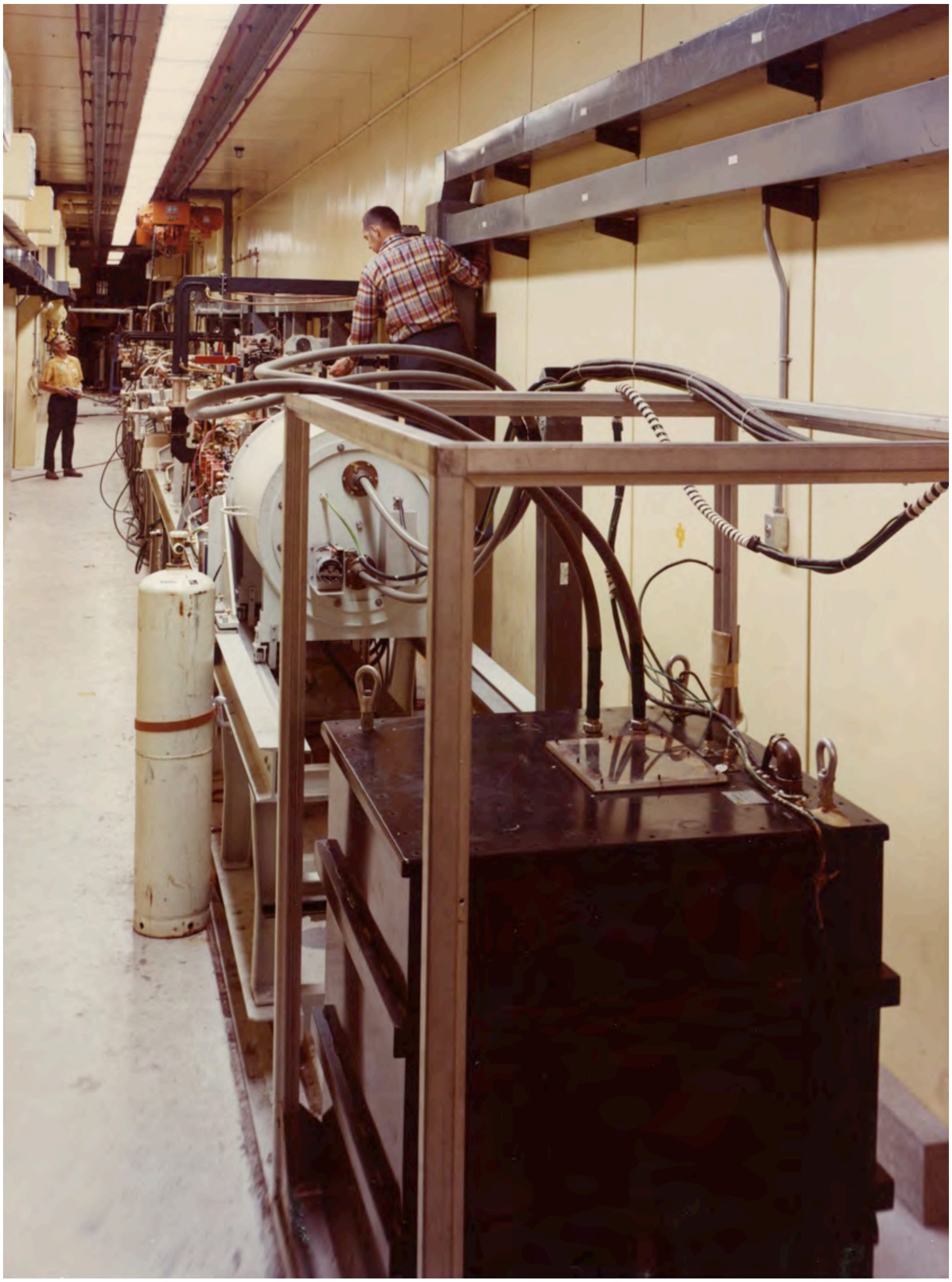


Figure 12 LLNL Archives, Box 030, Folder 10132
MAGNETIC SWITCH YARD AT FAR END OF ACCELERATOR, SILO IS ABOVE, UNDERGROUND CAVES ARE TO RIGHT, AND HIGH-INTENSITY UNDERGROUND CAVE IS STRAIGHT AHEAD.

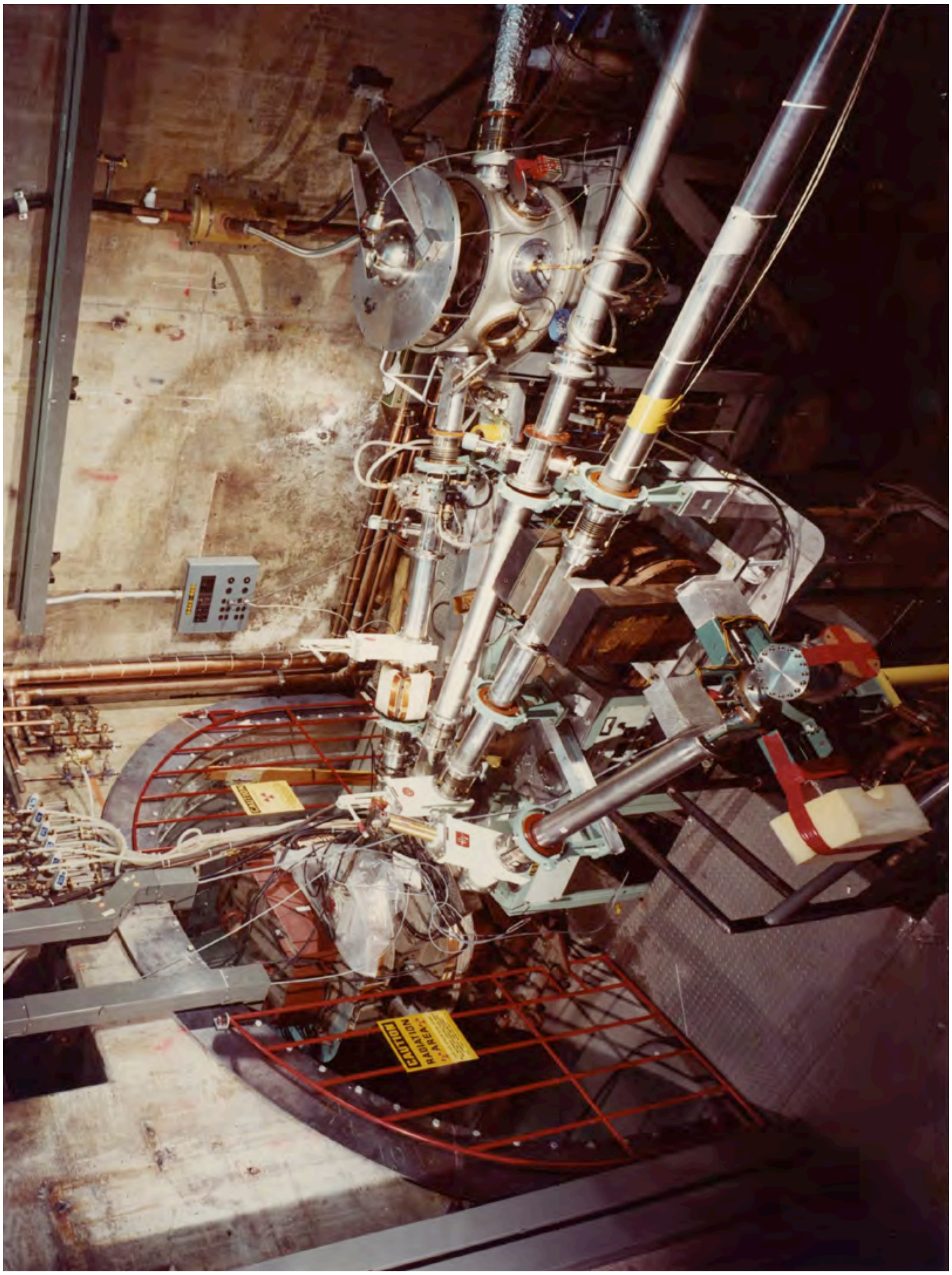


Figure 13 LLNL Digital Images, Building 194
100 MeV LINAC SCHEMATIC ON CONTROL PANEL IN CONTROL ROOM, BUILDING 194. Don Gonzalez, Photographer.

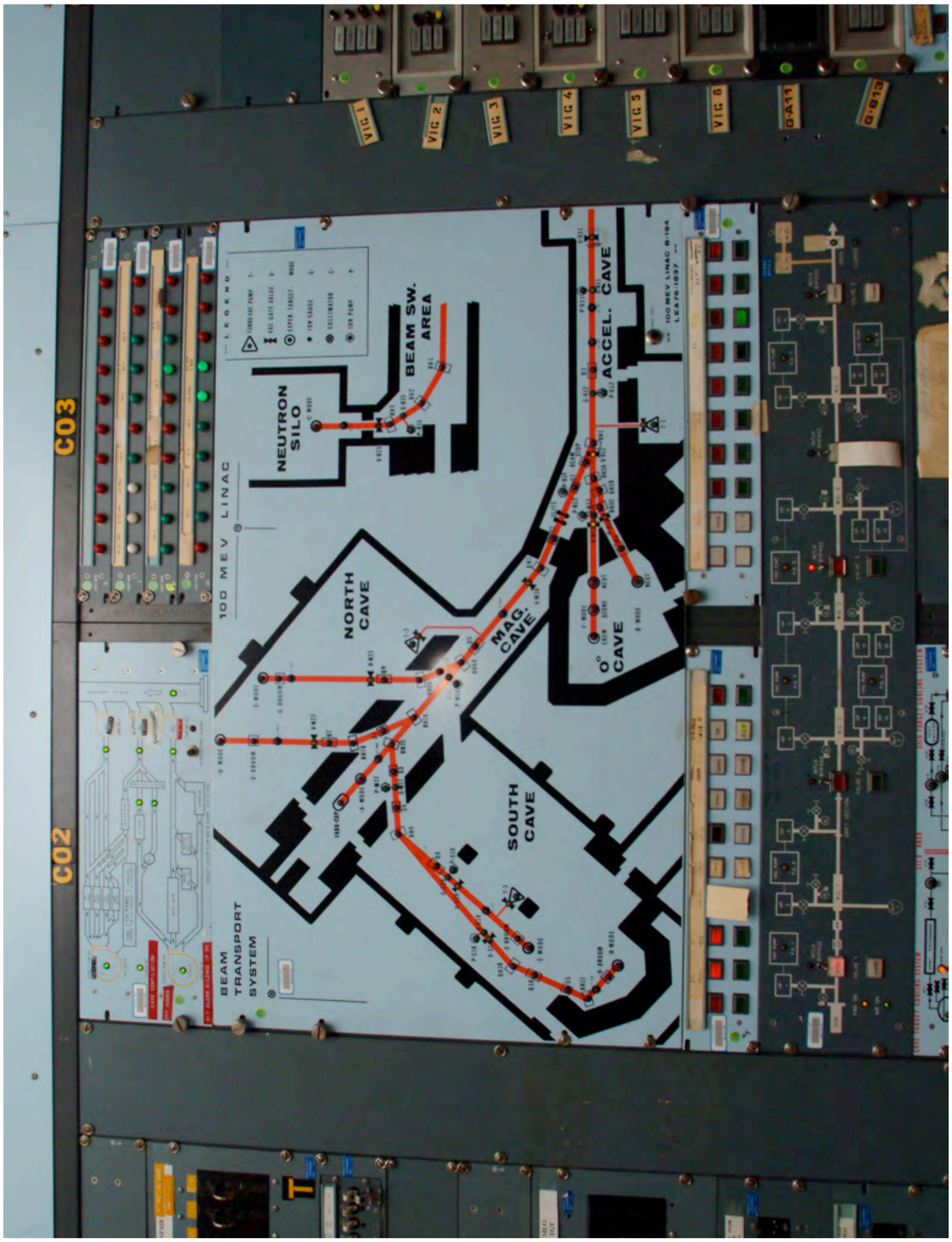


Figure 14 LLNL Digital Images, Building 194
OPERATOR CONTROL CONSOLE, 100 MeV LINAC CONTROL ROOM, BUILDING 194. Don Gonzalez, Photographer.

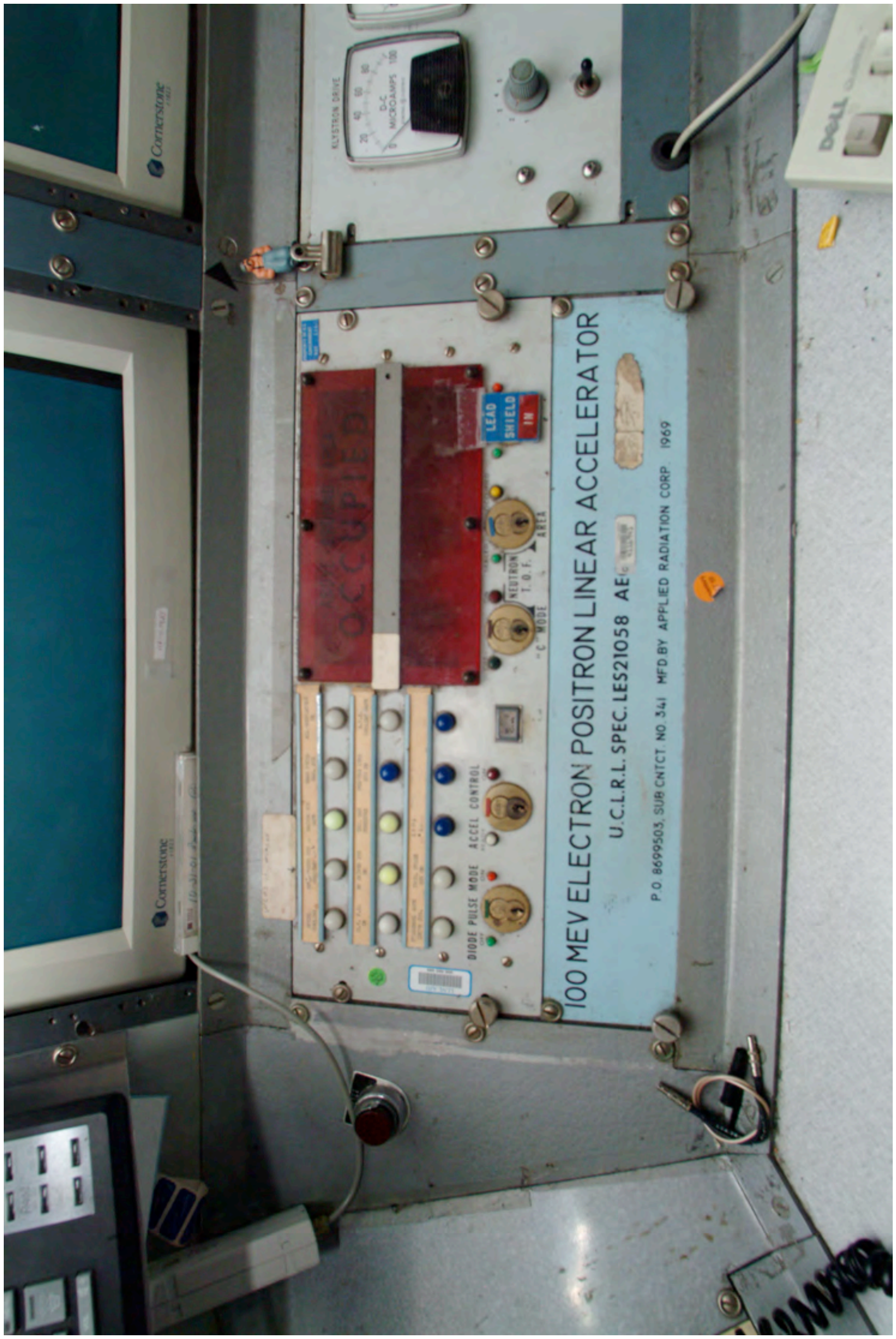


Figure 15 LLNL Facility Safety Procedure 194, Appendix D, 05-02-80
UNDERGROUND EMERGENCY EXITS, BUILDING 194.

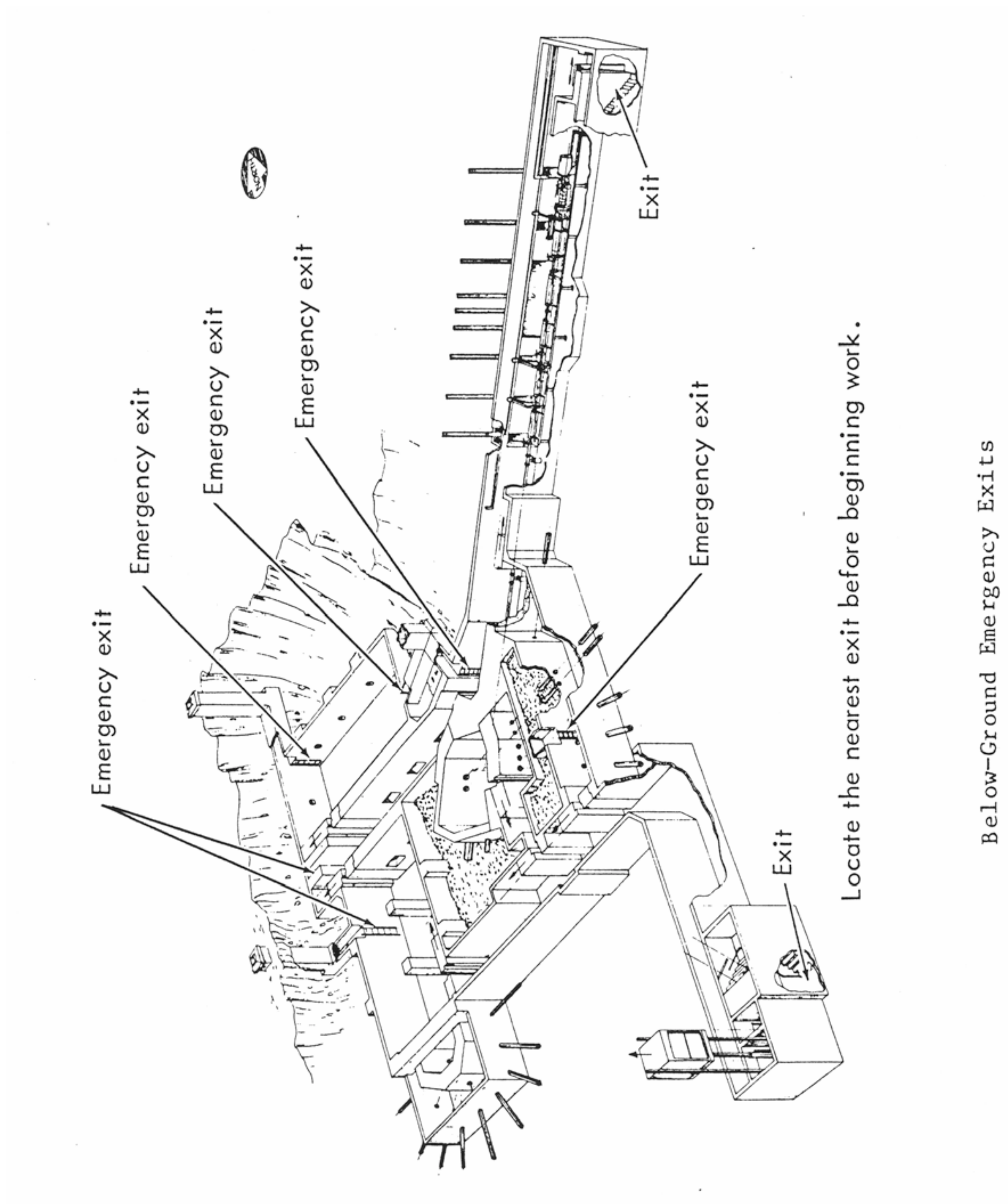


Figure 16 LLNL Archives, Box 021, Folder 10110 “Electron Linac”
PHOTOGRAPH OF NEUTRON SILO WITH BEAMLINES EXTENDING TO DETECTOR STATIONS, TOP OF SKYLIGHT ABOVE UNDERGROUND ACCESS PANELS VISIBLE ON GROUND BEHIND BEAMLINE TO RIGHT OF SILO, 1978, BUILDING 194, VIEW FROM SOUTH.

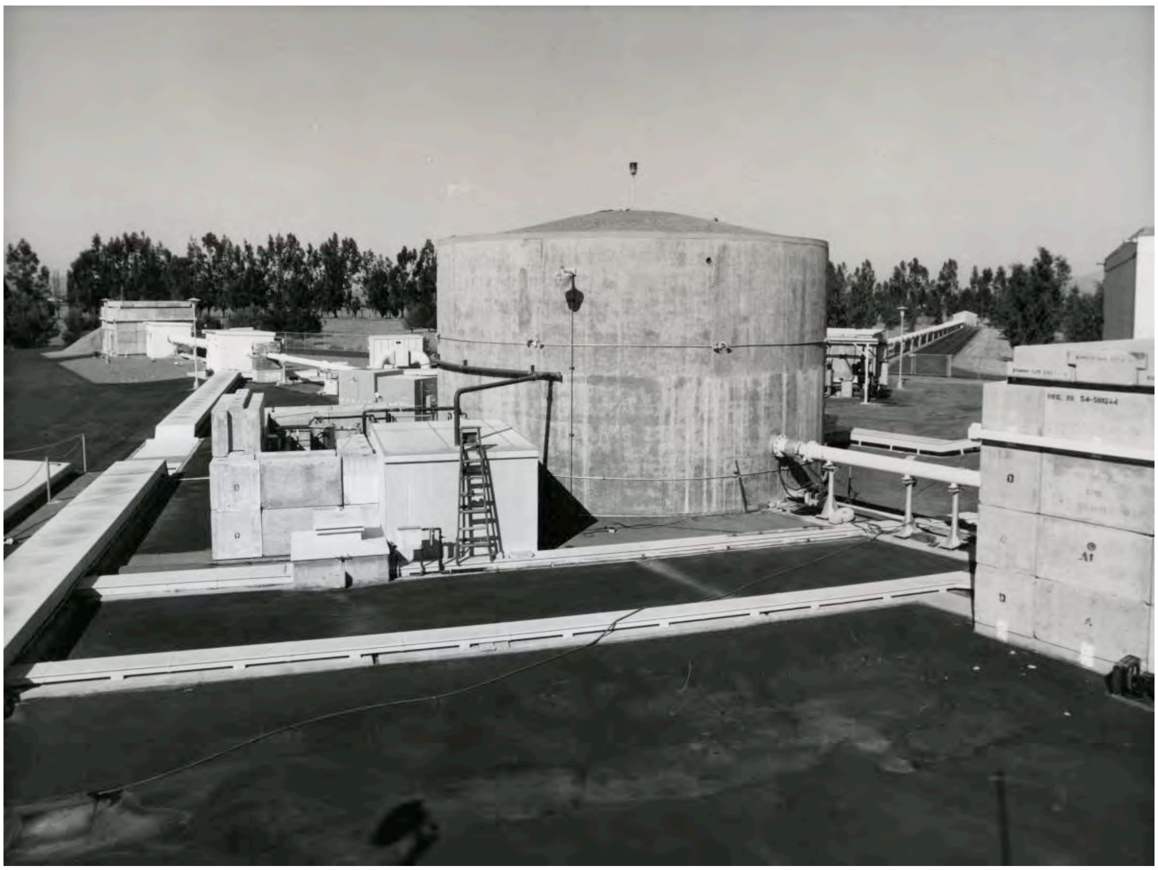


Figure 17 LLNL Digital Images, Building 194
EAST SIDE OF CENTRAL SECTION OF BUILDING 194; VIEW FROM EAST. Don Gonzalez, Photographer.

Figure 18 LLNL Digital Images, Building 194
SOUTH END AND SOUTH PORTION OF EAST SIDE (INCREMENT II) OF BUILDING 194; VIEW FROM SOUTHEAST.
Don Gonzalez, Photographer.

Figure 19 LLNL Digital Images, Building 194
SOUTH SIDE OF INCREMENT II (WEST PORTION OF SOUTH SECTION) WITH CONNECTING HALLWAY LEADING TO INCREMENT I OF BUILDING 194; VIEW FROM SOUTHEAST.
Don Gonzalez, Photographer.

**HISTORIC AMERICAN ENGINEERING RECORD**

**INDEX TO PHOTOGRAPHS**

LAWRENCE LIVERMORE NATIONAL LABORATORY, 100 MeV LINEAR ACCELERATOR BUILDING (BUILDING 194)
7000 East Avenue
Livermore
Alameda County
California



Don Gonzalez, Photographer

| | |
|---|---|
| CA-2354-1 | August 23, 2006.<br>MAIN ENTRANCES TO SOUTH AND CENTRAL SECTIONS OF BUILDING 194; VIEW FROM EAST. WITH 10’ SCALE. |
| CA-2354-2 | August 23, 2006.<br>MAIN ENTRANCES TO SOUTH AND CENTRAL SECTIONS OF BUILDING 194; VIEW FROM EAST. WITHOUT 10’ SCALE. |
| CA-2354-3 | August 23, 2006.<br>COVERED WALKWAY BETWEEN CENTRAL AND NORTH SECTIONS AND SOUTH SIDE OF NORTH SECTION OF BUILDING 194; VIEW FROM SOUTH. |
| CA-2354-4 | August 22, 2006.<br>WEST SIDE OF NORTH SECTION, INCLUDING FILTRATION STACK; NEUTRON SILO ON FAR RIGHT; BUILDING 194. VIEW FROM EAST. |
| CA-2354-5 | August 22, 2006.<br>NEUTRON SILO AND REMAINS OF BEAMLINE LEAVING SILO FOR TARGET TO WEST; TOP OF ESCAPE HATCH FROM LOWER LEVEL VISIBLE ON GROUND IN FRONT OF SILO; BUILDING 194; VIEW FROM NORTHWEST. |
| CA-2354-6 | August 22, 2006.<br>REMAINS OF BEAMLINE EXTENDING FROM NEUTRON SILO (NOT VISIBLE IN PHOTOGRAPH) TO WEST; BUILDING 194; VIEW FROM NORTHEAST. |

| | |
|---|---|
| CA-2354-7 | August 22, 2006.<br>NEUTRON SILO; ENTRANCE ON SOUTHWEST; DOOR CLOSED; RAILS FOR DOOR VISIBLE IN FOREGROUND; BUILDING 194; VIEW FROM SOUTHWEST. |
| CA-2354-8 | August 23, 2006.<br>NEUTRON SILO WITH DOOR OPEN; BUILDING 194; VIEW FROM SOUTHWEST. |
| CA-2354-9 | August 23, 2006.<br>NEUTRON SILO WITH DOOR OPEN; NOTE THICKNESS OF DOOR; BUILDING 194; VIEW FROM SOUTHWEST. |
| CA-2354-10 | August 23, 2006.<br>INTERIOR OF NEUTRON SILO WITH EMPTY SOURCE CONTAINER (PURPLE PIG) ON RIGHT AND ONE BEAMLINE EXIT PORT VISIBLE ON LEFT; BUILDING 194; VIEW FROM SOUTH. |
| CA-2354-11 | August 22, 2006.<br>EAST-WEST CORRIDOR OF SOUTH SECTION; UTILITY PIPING RUNNING ALONG CEILING; BUILDING 194; VIEW FROM EAST. |
| CA-2354-12 | August 22, 2006.<br>NORTH-SOUTH CORRIDOR OF CENTRAL SECTION; BUILDING 194; VIEW FROM SOUTH. |
| CA-2354-13 | August 22, 2006.<br>CONTROL ROOM (ROOM 1117A) WITH CONTROL CONSOLE FOR 100-MeV LINEAR ACCELERATOR; BUILDING 194; VIEW FROM NORTHEAST. |
| CA-2354-14 | August 22, 2006.<br>CONTROL ROOM (ROOM 1117A) WITH CONTROL CONSOLE FOR 100-MeV LINEAR ACCELERATOR; BUILDING 194; VIEW FROM EAST. |

| | |
|---|---|
| CA-2354-15 | August 23, 2006.<br>OLD (ON RIGHT) AND NEW (IN CENTER) POWER SUPPLY CONTROL RACKS; EMERGENCY PHONE (“GROWLER”) ON END OF RACK AT RIGHT; ROOM 1201, NORTH SECTION, BUILDING 194; VIEW FROM SOUTH. |
| CA-2354-16 | August 23, 2006.<br>POWER SUPPLY RACKS (ON LEFT) THAT SUPPLY POWER TO THE KLYSTRON GENERATORS IN ROOM 1211; THE AMPLIFIED POWER FROM THE KLYSTRON GENERATORS FEEDS DOWN TO THE INDIVIDUAL MAGNETS OF THE ACCELERATOR IN THE BASEMENT VIA LINES THROUGH CONCRETE –BASED PILLARS ON RIGHT; ROOM 1201, NORTH SECTION, BUILDING 194; VIEW FROM NORTH. |
| CA-2354-17 | August 23, 2006.<br>MODULATOR CABINETS HOUSING KLYSTRON GENERATORS AND ASSOCIATED EQUIPMENT; ROOM 1211, NORTH SECTION, BUILDING 194; VIEW FROM NORTH. |
| CA-2354-18 | August 23, 2006.<br>INTERIOR OF MODULATOR CABINET WITH KLYSTRON GENERATOR (ON LEFT), CONTROL RACKS (CENTER), AND VENTILATION EQUIPMENT (ON RIGHT); ROOM 1211, NORTH SECTION, BUILDING 194; VIEW FROM NORTH. |
| CA-2354-19 | August 22, 2006.<br>BASEMENT; NORTH-SOUTH CORRIDOR FROM ELEVATOR TO CORRIDOR 1; LASER DROP FROM FIRST FLOOR THROUGH CEILING IS VISIBLE IN BACK LEFT; BUILDING 194; VIEW FROM SOUTH. |
| CA-2354-20 | August 22, 2006.<br>SKYLIGHT IN CEILING OF BASEMENT LEVEL; OPENS AT GROUND LEVEL TO ALLOW EQUIPMENT TO MOVE IN AND OUT OF BASEMENT; 10’ CONCRETE CEILING; CORRIDOR 1, BUILDING 194. |

| | |
|---|---|
| CA-2354-21 | August 22, 2006.<br>ENTRANCE TO ROOM B130 FROM STAIRWELL DOWN FROM BUILDING’S NORTH SECTION; SHIELDING DOOR; THERMIONIC GUN IS VISIBLE IN ROOM BEYOND DOOR; BASEMENT, BUILDING 194; VIEW FROM EAST. |
| CA-2354-22 | August 22, 2006.<br>THERMIONIC GUN FOR 100-MeV LINEAR ACCELERATOR; GUN SITS ON ALUMINUM STAND; ROOM B130, BASEMENT, BUILDING 194; VIEW FROM NORTHEAST. |
| CA-2354-23 | August 22, 2006.<br>BEAMLINE OF LINEAR ACCELERATOR EXTENDING SOUTH FROM THERMIONIC GUN AREA; ROOM B130, BASEMENT, BUILDING 194; VIEW FROM NORTH. |
| CA-2354-24 | August 22, 2006.<br>CEILING OPENING AND COMPONENTS THAT ANGLE BEAMLINE FROM BASEMENT TO GROUND LEVEL (IN NEUTRON SILO); SECTION OF BEAMLINE ON RIGHT GOES INTO THE 0° CAVE; ROOM B130, BASEMENT, BUILDING 194; VIEW FROM NORTH. |
| CA-2354-25 | August 22, 2006.<br>8’ THICK, 84,000 LBS, CONCRETE SHIELDING DOOR BETWEEN ROOMS B130 AND B120; ROOM B130, BASEMENT, BUILDING 194; VIEW FROM SOUTH. |
| CA-2354-26 | August 22, 2006.<br>DOORWAY BETWEEN ROOM B120 (DIAGNOSTICS) AND ROOM B122A (0° CAVE); 8’ THICK, 120,000 LBS, SHIELDING DOOR (ON LEFT) MOVES ON TRACKS TO INTERLOCK WITH 8’ THICK WALL OF CAVE; PORTHOLES IN RIGHT FOREGROUND ALLOW BEAMLINE TO EXIT CAVE TO DIAGNOSTICS AREA; ROOM B120, BASEMENT, BUILDING 194; VIEW FROM EAST. |

| | | |
|---|---|---|
| CA-2354-27 | August 22, 2006.<br>INTERIOR, 0° CAVE (ROOM B122A), CIRCULAR ROOM, BEAMLINE ENTERS FROM RIGHT AND CAN BE REDIRECTED AND SENT TO DIAGNOSTICS AREA (ROOM B120) OR TO OTHER EXPERIMENTS VIA BEAMLINE PORTHOLES VISIBLE IN WALL; ROOM B122A, BASEMENT, BUILDING 194; VIEW FROM SOUTH. |
| CA-2354-28 | August 22, 2006.<br>SOUTH CAVE (ROOM B124) WITH POSITRON; BEAMLINE ENTERS FROM 0° CAVE (NEAR FAR CORNER) AND SPLITS TO DIFFERENT LINES FOR DIFFERENT EXPERIMENTS; ROOM B124, BASEMENT, BUILDING 194; VIEW FROM SOUTHWEST. |
| CA-2354-29 | August 22, 2006.<br>MAGNET CAVE (ROOM B132); VIEW TOWARD 0° CAVE WHERE BEAMLINE ENTERS; ROOM B132, BASEMENT, BUILDING 194; VIEW FROM WEST. |
| CA-2354-30 | August 22, 2006.<br>NORTH MAGNET CAVE (ROOM B134); VIEW OF BEAM DUMP WITH COVER CLOSED (CIRCULAR CONCRETE NEAR CENTER) ON NORTH WALL; LADDER TO EMERGENCY ESCAPE HATCH IN CENTER BACKGROUND; WARNING HORN NEAR TOP OF LADDER; ROOM B134, BASEMENT, BUILDING 194; VIEW FROM SOUTHEAST. |
| CA-2354-31 | August 22, 2006.<br>NORTH MAGNET CAVE (ROOM B134); VIEW OF BEAM DUMP WITH COVER OPEN ON NORTH WALL; LADDER TO EMERGENCY ESCAPE HATCH IN CENTER BACKGROUND; WARNING HORN NEAR TOP OF LADDER; ROOM B134, BASEMENT, BUILDING 194; VIEW FROM SOUTHEAST. |
| CA-2354-32 | August 22, 2006.<br>NORTH MAGNET CAVE (ROOM B134); VIEW OF EMERGENCY ESCAPE LADDER AND HATCH ON EAST WALL; BEAMLINE ENTRY IS ON RIGHT (EAST END OF SOUTH WALL); ROOM B134, BASEMENT, BUILDING 194; VIEW FROM WEST. |

**HISTORIC AMERICAN ENGINEERING RECORD**

**INDEX TO PHOTOGRAPHS**

LAWRENCE LIVERMORE NATIONAL LABORATORY, 100 MeV LINEAR ACCELERATOR BUILDING (BUILDING 194)
7000 East Avenue
Livermore
Alameda County
California

HAER No. CA-2354


Don Gonzalez, Photographer

| | |
|---|---|
| CA-2354-1 | August 23, 2006. MAIN ENTRANCES TO SOUTH AND CENTRAL SECTIONS OF BUILDING 194; VIEW FROM EAST. WITH 10’ SCALE. |
| CA-2354-2 | August 23, 2006. MAIN ENTRANCES TO SOUTH AND CENTRAL SECTIONS OF BUILDING 194; VIEW FROM EAST. WITHOUT 10’ SCALE. |
| CA-2354-3 | August 23, 2006. COVERED WALKWAY BETWEEN CENTRAL AND NORTH SECTIONS AND SOUTH SIDE OF NORTH SECTION OF BUILDING 194; VIEW FROM SOUTH. |
| CA-2354-4 | August 22, 2006. WEST SIDE OF NORTH SECTION, INCLUDING FILTRATION STACK; NEUTRON SILO ON FAR RIGHT; BUILDING 194. VIEW FROM EAST. |
| CA-2354-5 | August 22, 2006. NEUTRON SILO AND REMAINS OF BEAMLINE LEAVING SILO FOR TARGET TO WEST; TOP OF ESCAPE HATCH FROM LOWER LEVEL VISIBLE ON GROUND IN FRONT OF SILO; BUILDING 194; VIEW FROM NORTHWEST. |
| CA-2354-6 | August 22, 2006. REMAINS OF BEAMLINE EXTENDING FROM NEUTRON SILO (NOT VISIBLE IN PHOTOGRAPH) TO WEST; BUILDING 194; VIEW FROM NORTHEAST. |

| | |
|---|---|
| CA-2354-7 | August 22, 2006.<br>NEUTRON SILO; ENTRANCE ON SOUTHWEST; DOOR CLOSED; RAILS FOR DOOR VISIBLE IN FOREGROUND; BUILDING 194; VIEW FROM SOUTHWEST. |
| CA-2354-8 | August 23, 2006.<br>NEUTRON SILO WITH DOOR OPEN; BUILDING 194; VIEW FROM SOUTHWEST. |
| CA-2354-9 | August 23, 2006.<br>NEUTRON SILO WITH DOOR OPEN; NOTE THICKNESS OF DOOR; BUILDING 194; VIEW FROM SOUTHWEST. |
| CA-2354-10 | August 23, 2006.<br>INTERIOR OF NEUTRON SILO WITH EMPTY SOURCE CONTAINER (PURPLE PIG) ON RIGHT AND ONE BEAMLINE EXIT PORT VISIBLE ON LEFT; BUILDING 194; VIEW FROM SOUTH. |
| CA-2354-11 | August 22, 2006.<br>EAST-WEST CORRIDOR OF SOUTH SECTION; UTILITY PIPING RUNNING ALONG CEILING; BUILDING 194; VIEW FROM EAST. |
| CA-2354-12 | August 22, 2006.<br>NORTH-SOUTH CORRIDOR OF CENTRAL SECTION; BUILDING 194; VIEW FROM SOUTH. |
| CA-2354-13 | August 22, 2006.<br>CONTROL ROOM (ROOM 1117A) WITH CONTROL CONSOLE FOR 100-MeV LINEAR ACCELERATOR; BUILDING 194; VIEW FROM NORTHEAST. |
| CA-2354-14 | August 22, 2006.<br>CONTROL ROOM (ROOM 1117A) WITH CONTROL CONSOLE FOR 100-MeV LINEAR ACCELERATOR; BUILDING 194; VIEW FROM EAST. |

| | | |
|---|---|---|
| CA-2354-15 | August 23, 2006.<br>OLD (ON RIGHT) AND NEW (IN CENTER) POWER SUPPLY CONTROL RACKS; EMERGENCY PHONE (“GROWLER”) ON END OF RACK AT RIGHT; ROOM 1201, NORTH SECTION, BUILDING 194; VIEW FROM SOUTH. |
| CA-2354-16 | August 23, 2006.<br>POWER SUPPLY RACKS (ON LEFT) THAT SUPPLY POWER TO THE KLYSTRON GENERATORS IN ROOM 1211; THE AMPLIFIED POWER FROM THE KLYSTRON GENERATORS FEEDS DOWN TO THE INDIVIDUAL MAGNETS OF THE ACCELERATOR IN THE BASEMENT VIA LINES THROUGH CONCRETE –BASED PILLARS ON RIGHT; ROOM 1201, NORTH SECTION, BUILDING 194; VIEW FROM NORTH. |
| CA-2354-17 | August 23, 2006.<br>MODULATOR CABINETS HOUSING KLYSTRON GENERATORS AND ASSOCIATED EQUIPMENT; ROOM 1211, NORTH SECTION, BUILDING 194; VIEW FROM NORTH. |
| CA-2354-18 | August 23, 2006.<br>INTERIOR OF MODULATOR CABINET WITH KLYSTRON GENERATOR (ON LEFT), CONTROL RACKS (CENTER), AND VENTILATION EQUIPMENT (ON RIGHT); ROOM 1211, NORTH SECTION, BUILDING 194; VIEW FROM NORTH. |
| CA-2354-19 | August 22, 2006.<br>BASEMENT; NORTH-SOUTH CORRIDOR FROM ELEVATOR TO CORRIDOR 1; LASER DROP FROM FIRST FLOOR THROUGH CEILING IS VISIBLE IN BACK LEFT; BUILDING 194; VIEW FROM SOUTH. |
| CA-2354-20 | August 22, 2006.<br>SKYLIGHT IN CEILING OF BASEMENT LEVEL; OPENS AT GROUND LEVEL TO ALLOW EQUIPMENT TO MOVE IN AND OUT OF BASEMENT; 10’ CONCRETE CEILING; CORRIDOR 1, BUILDING 194. |

| | |
|---|---|
| CA-2354-21 | August 22, 2006.<br>ENTRANCE TO ROOM B130 FROM STAIRWELL DOWN FROM BUILDING'S NORTH SECTION; SHIELDING DOOR; THERMIONIC GUN IS VISIBLE IN ROOM BEYOND DOOR; BASEMENT, BUILDING 194; VIEW FROM EAST. |
| CA-2354-22 | August 22, 2006.<br>THERMIONIC GUN FOR 100-MeV LINEAR ACCELERATOR; GUN SITS ON ALUMINUM STAND; ROOM B130, BASEMENT, BUILDING 194; VIEW FROM NORTHEAST. |
| CA-2354-23 | August 22, 2006.<br>BEAMLINE OF LINEAR ACCELERATOR EXTENDING SOUTH FROM THERMIONIC GUN AREA; ROOM B130, BASEMENT, BUILDING 194; VIEW FROM NORTH. |
| CA-2354-24 | August 22, 2006.<br>CEILING OPENING AND COMPONENTS THAT ANGLE BEAMLINE FROM BASEMENT TO GROUND LEVEL (IN NEUTRON SILO); SECTION OF BEAMLINE ON RIGHT GOES INTO THE 0° CAVE; ROOM B130, BASEMENT, BUILDING 194; VIEW FROM NORTH. |
| CA-2354-25 | August 22, 2006.<br>8' THICK, 84,000 LBS, CONCRETE SHIELDING DOOR BETWEEN ROOMS B130 AND B120; ROOM B130, BASEMENT, BUILDING 194; VIEW FROM SOUTH. |
| CA-2354-26 | August 22, 2006.<br>DOORWAY BETWEEN ROOM B120 (DIAGNOSTICS) AND ROOM B122A (0° CAVE); 8' THICK, 120,000 LBS, SHIELDING DOOR (ON LEFT) MOVES ON TRACKS TO INTERLOCK WITH 8' THICK WALL OF CAVE; PORTHOLES IN RIGHT FOREGROUND ALLOW BEAMLINE TO EXIT CAVE TO DIAGNOSTICS AREA; ROOM B120, BASEMENT, BUILDING 194; VIEW FROM EAST. |

CA-2354-27 August 22, 2006.
INTERIOR, 0° CAVE (ROOM B122A), CIRCULAR ROOM, BEAMLINE ENTERS FROM RIGHT AND CAN BE REDIRECTED AND SENT TO DIAGNOSTICS AREA (ROOM B120) OR TO OTHER EXPERIMENTS VIA BEAMLINE PORTHOLES VISIBLE IN WALL; ROOM B122A, BASEMENT, BUILDING 194; VIEW FROM SOUTH.

CA-2354-28 August 22, 2006.
SOUTH CAVE (ROOM B124) WITH POSITRON; BEAMLINE ENTERS FROM 0° CAVE (NEAR FAR CORNER) AND SPLITS TO DIFFERENT LINES FOR DIFFERENT EXPERIMENTS; ROOM B124, BASEMENT, BUILDING 194; VIEW FROM SOUTHWEST.

CA-2354-29 August 22, 2006.
MAGNET CAVE (ROOM B132); VIEW TOWARD 0° CAVE WHERE BEAMLINE ENTERS; ROOM B132, BASEMENT, BUILDING 194; VIEW FROM WEST.

CA-2354-30 August 22, 2006.
NORTH MAGNET CAVE (ROOM B134); VIEW OF BEAM DUMP WITH COVER CLOSED (CIRCULAR CONCRETE NEAR CENTER) ON NORTH WALL; LADDER TO EMERGENCY ESCAPE HATCH IN CENTER BACKGROUND; WARNING HORN NEAR TOP OF LADDER; ROOM B134, BASEMENT, BUILDING 194; VIEW FROM SOUTHEAST.

CA-2354-31 August 22, 2006.
NORTH MAGNET CAVE (ROOM B134); VIEW OF BEAM DUMP WITH COVER OPEN ON NORTH WALL; LADDER TO EMERGENCY ESCAPE HATCH IN CENTER BACKGROUND; WARNING HORN NEAR TOP OF LADDER; ROOM B134, BASEMENT, BUILDING 194; VIEW FROM SOUTHEAST.

CA-2354-32 August 22, 2006.
NORTH MAGNET CAVE (ROOM B134); VIEW OF EMERGENCY ESCAPE LADDER AND HATCH ON EAST WALL; BEAMLINE ENTRY IS ON RIGHT (EAST END OF SOUTH WALL); ROOM B134, BASEMENT, BUILDING 194; VIEW FROM WEST.

HISTORIC AMERICAN ENGINEERING RECORD
SEE INDEX TO PHOTOGRAPHS FOR CAPTIONS

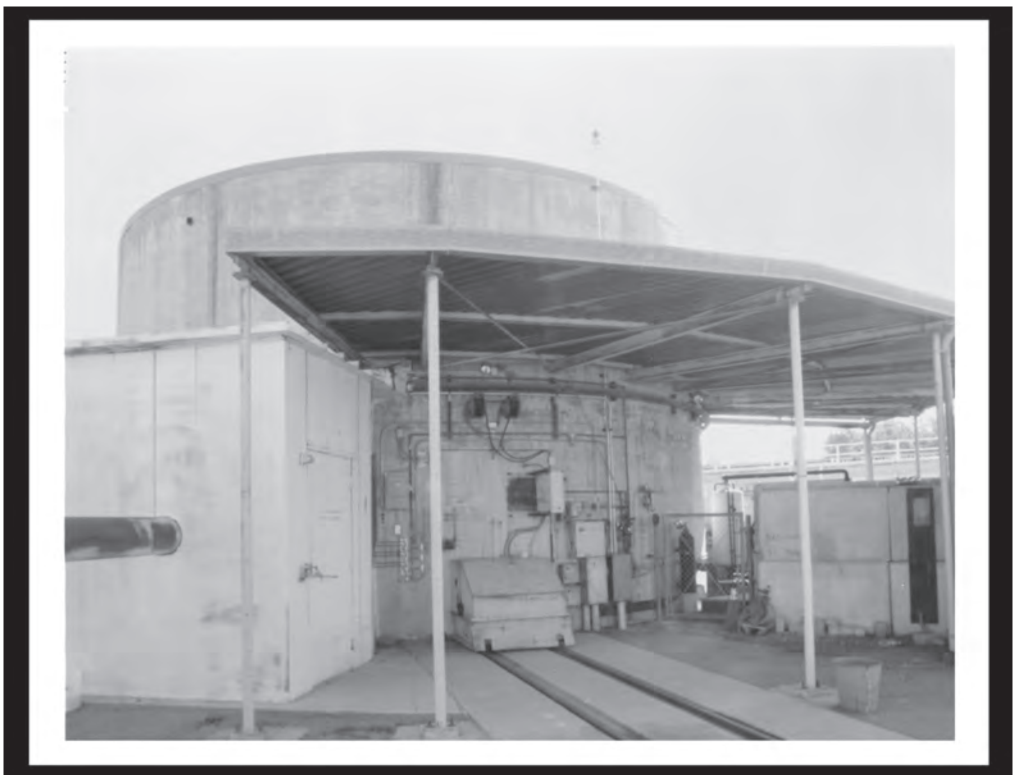
HAER No. CA-2354 - 1

HISTORIC AMERICAN ENGINEERING RECORD
SEE INDEX TO PHOTOGRAPHS FOR CAPTIONS

HAER No. CA-2354 - 5

HISTORIC AMERICAN ENGINEERING RECORD
SEE INDEX TO PHOTOGRAPHS FOR CAPTIONS

HAER No. CA-2354 - 6



HISTORIC AMERICAN ENGINEERING RECORD
SEE INDEX TO PHOTOGRAPHS FOR CAPTIONS

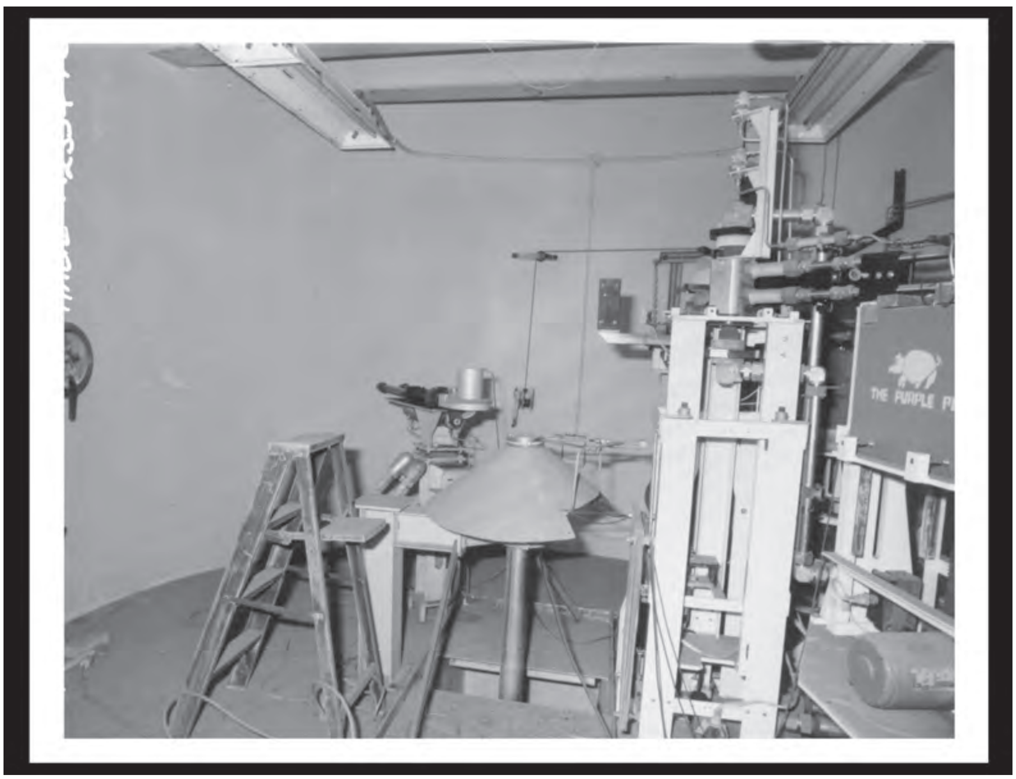
HAER No. CA-2354 - 8

HISTORIC AMERICAN ENGINEERING RECORD
SEE INDEX TO PHOTOGRAPHS FOR CAPTIONS

HAER No. CA-2354 - 9

HISTORIC AMERICAN ENGINEERING RECORD
SEE INDEX TO PHOTOGRAPHS FOR CAPTIONS

HAER No. CA-2354 - 10



HISTORIC AMERICAN ENGINEERING RECORD
SEE INDEX TO PHOTOGRAPHS FOR CAPTIONS

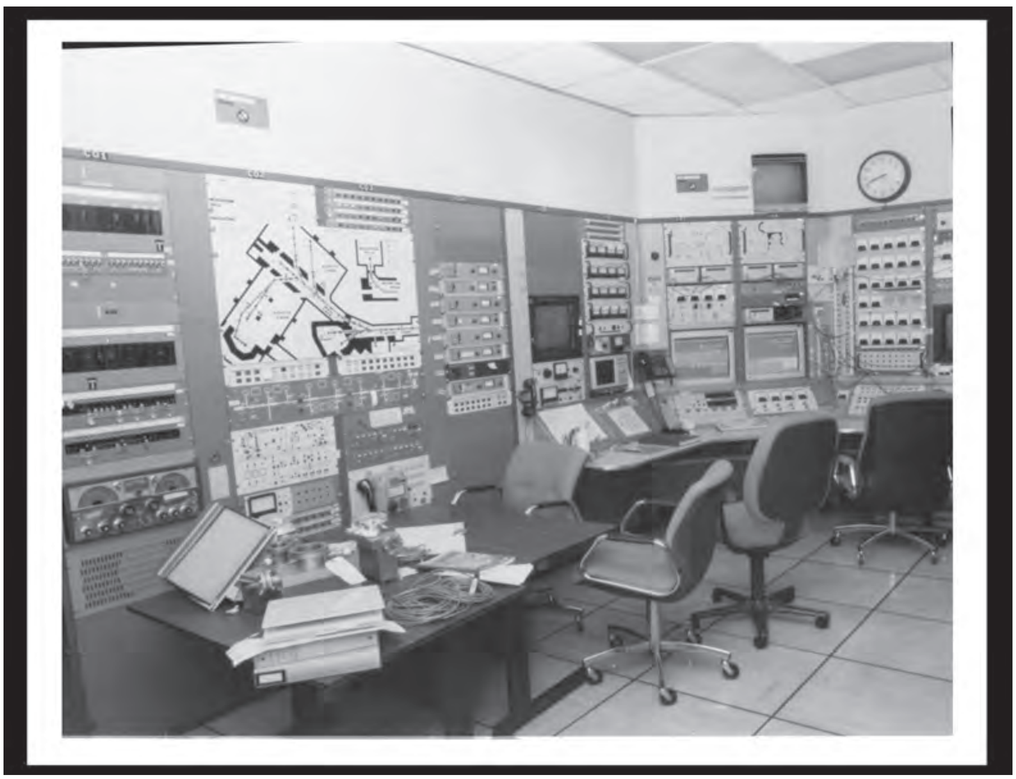
HAER No. CA-2354 - 11

HISTORIC AMERICAN ENGINEERING RECORD
SEE INDEX TO PHOTOGRAPHS FOR CAPTIONS

HAER No. CA-2354 - 12

HISTORIC AMERICAN ENGINEERING RECORD
SEE INDEX TO PHOTOGRAPHS FOR CAPTIONS

HAER No. CA-2354 - 13

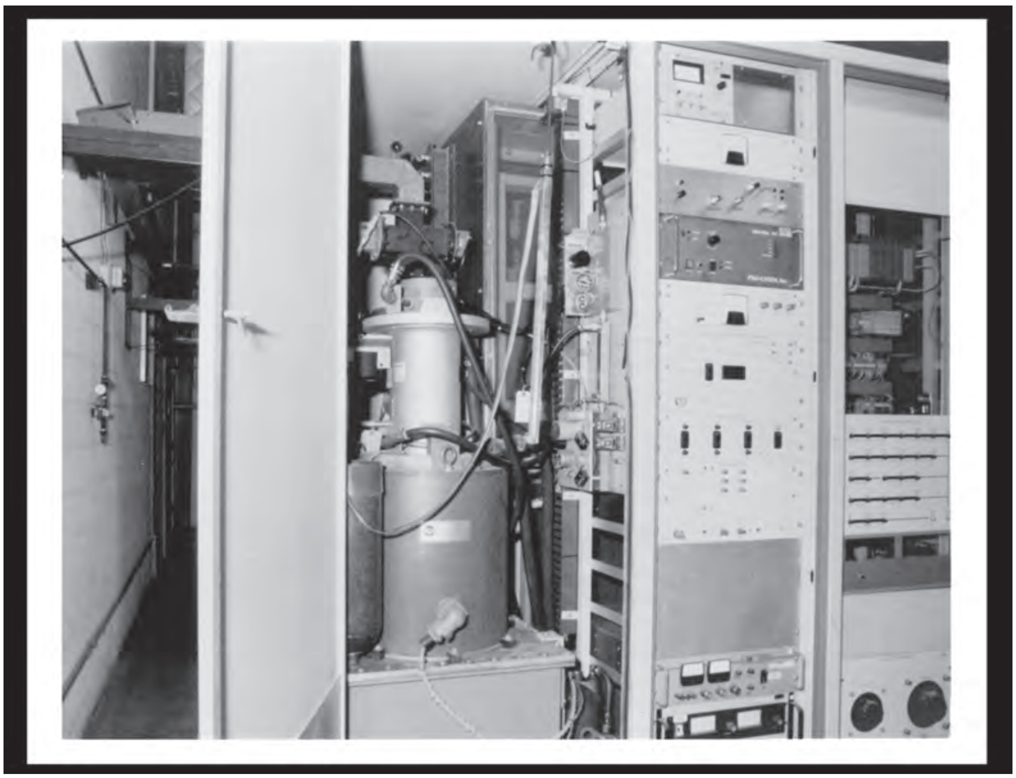


HISTORIC AMERICAN ENGINEERING RECORD
SEE INDEX TO PHOTOGRAPHS FOR CAPTIONS

HAER No. CA-2354 - 15

HISTORIC AMERICAN ENGINEERING RECORD
SEE INDEX TO PHOTOGRAPHS FOR CAPTIONS

HAER No. CA-2354 - 18

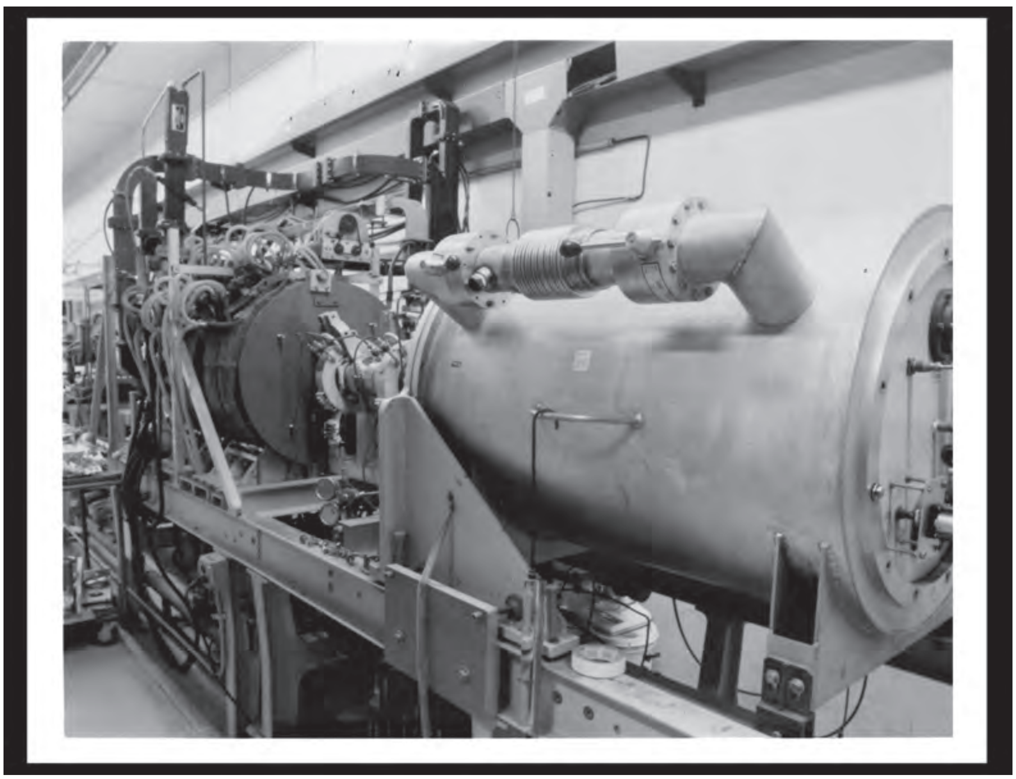


HISTORIC AMERICAN ENGINEERING RECORD
SEE INDEX TO PHOTOGRAPHS FOR CAPTIONS

HAER No. CA-2354 - 19

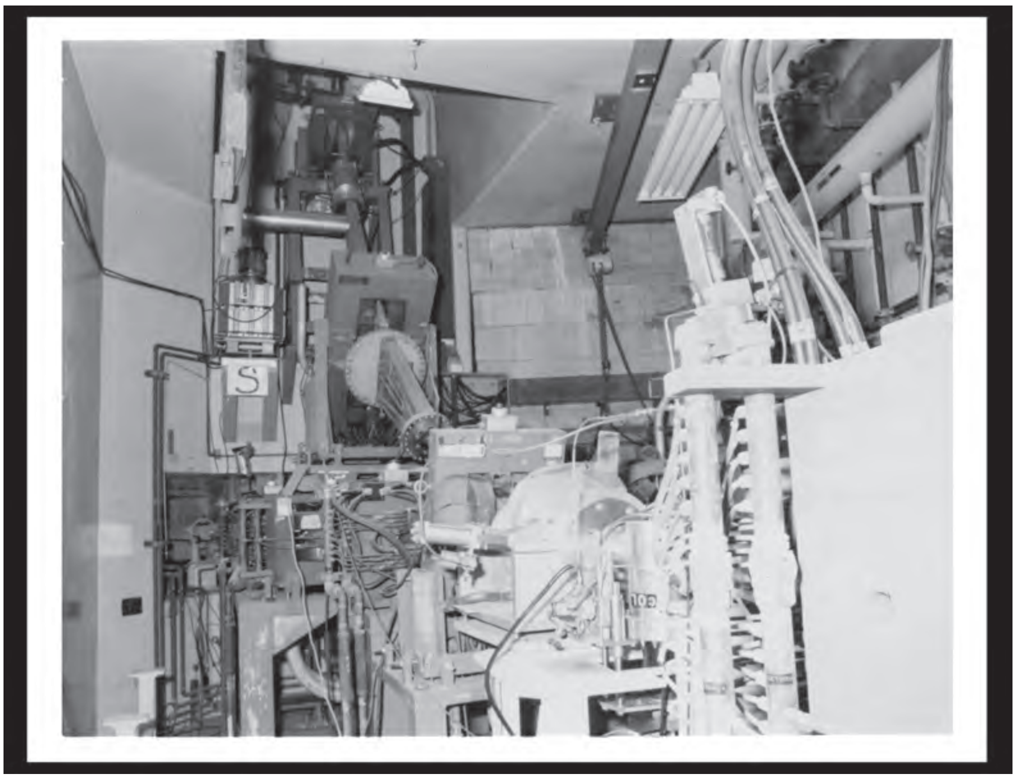
HISTORIC AMERICAN ENGINEERING RECORD
SEE INDEX TO PHOTOGRAPHS FOR CAPTIONS

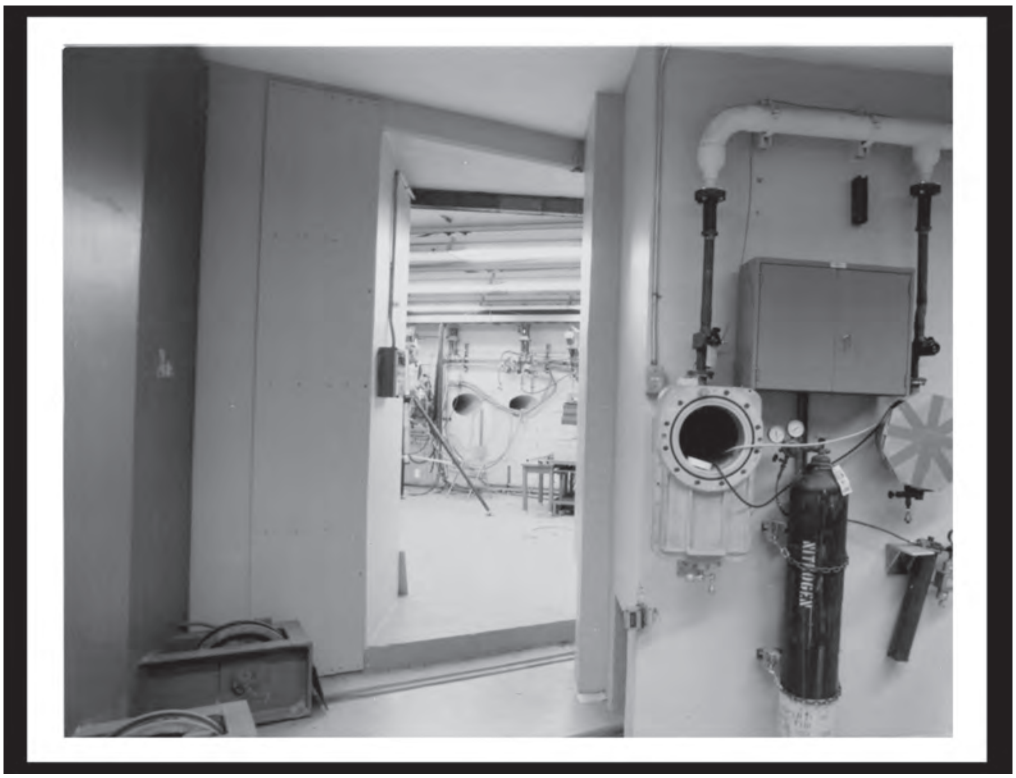
HAER No. CA-2354 - 21



HISTORIC AMERICAN ENGINEERING RECORD
SEE INDEX TO PHOTOGRAPHS FOR CAPTIONS

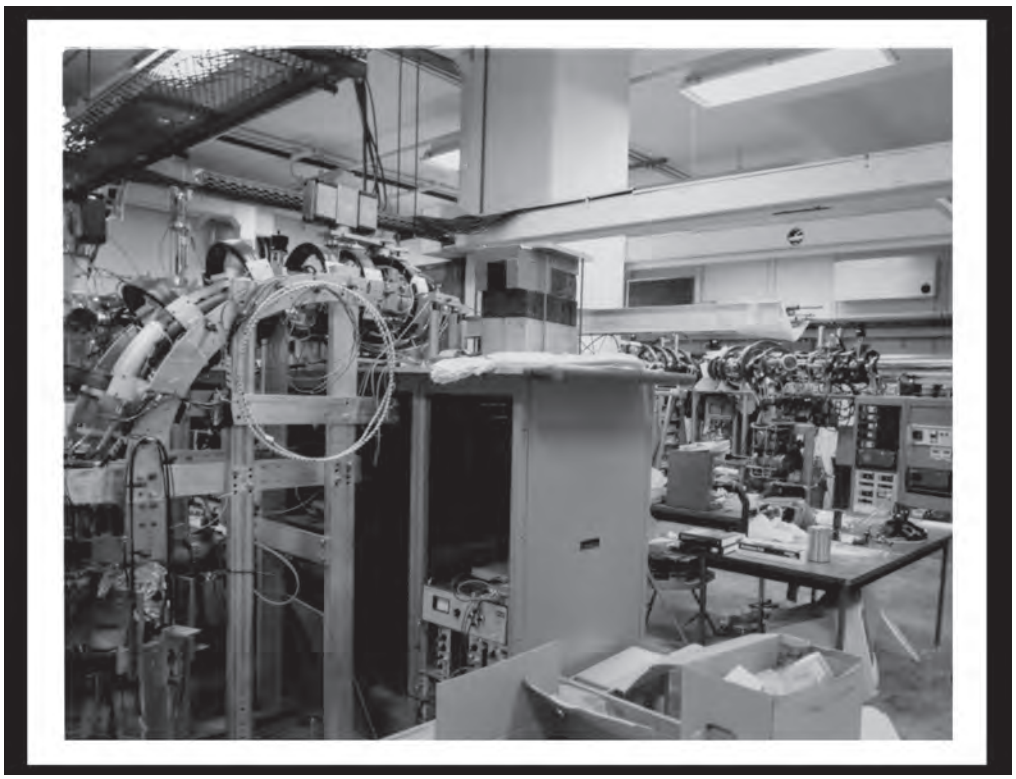
HAER No. CA-2354 - 24




NITROGEN

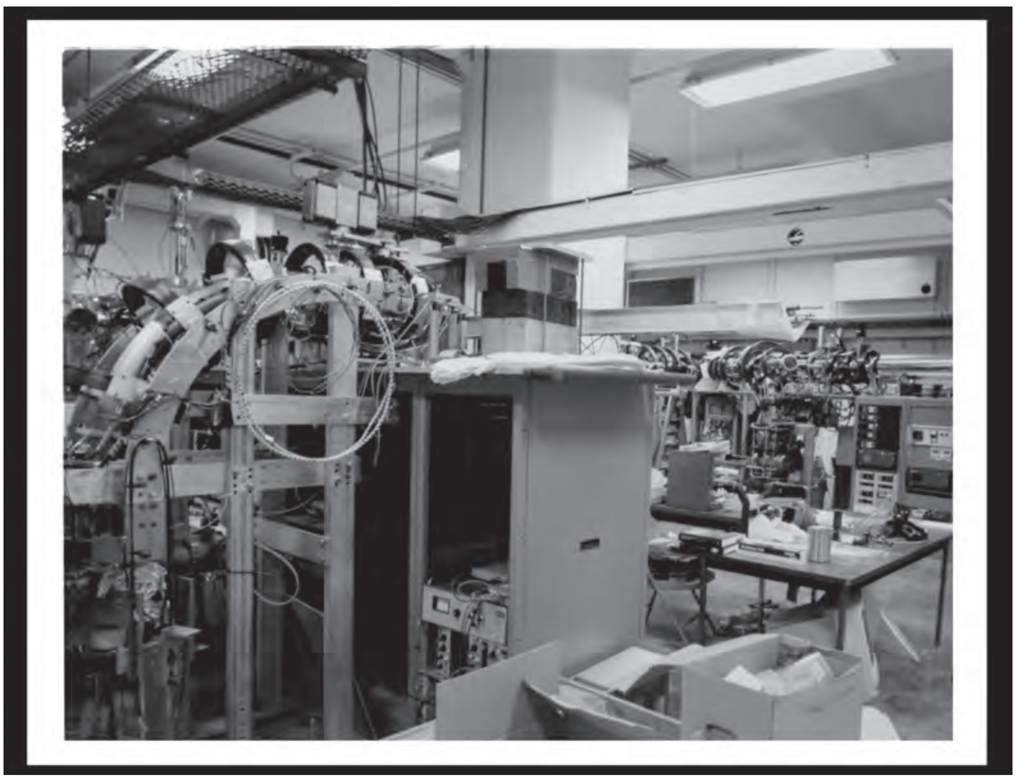
HISTORIC AMERICAN ENGINEERING RECORD
SEE INDEX TO PHOTOGRAPHS FOR CAPTIONS

HAER No. CA-2354 - 27



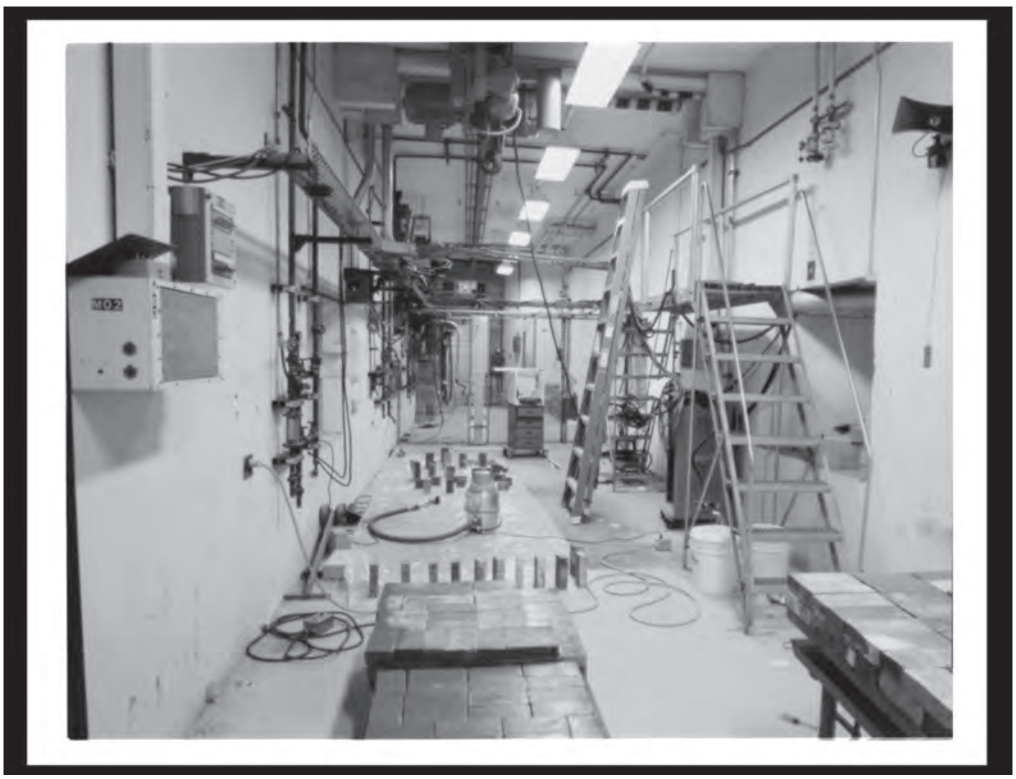
HISTORIC AMERICAN ENGINEERING RECORD
SEE INDEX TO PHOTOGRAPHS FOR CAPTIONS

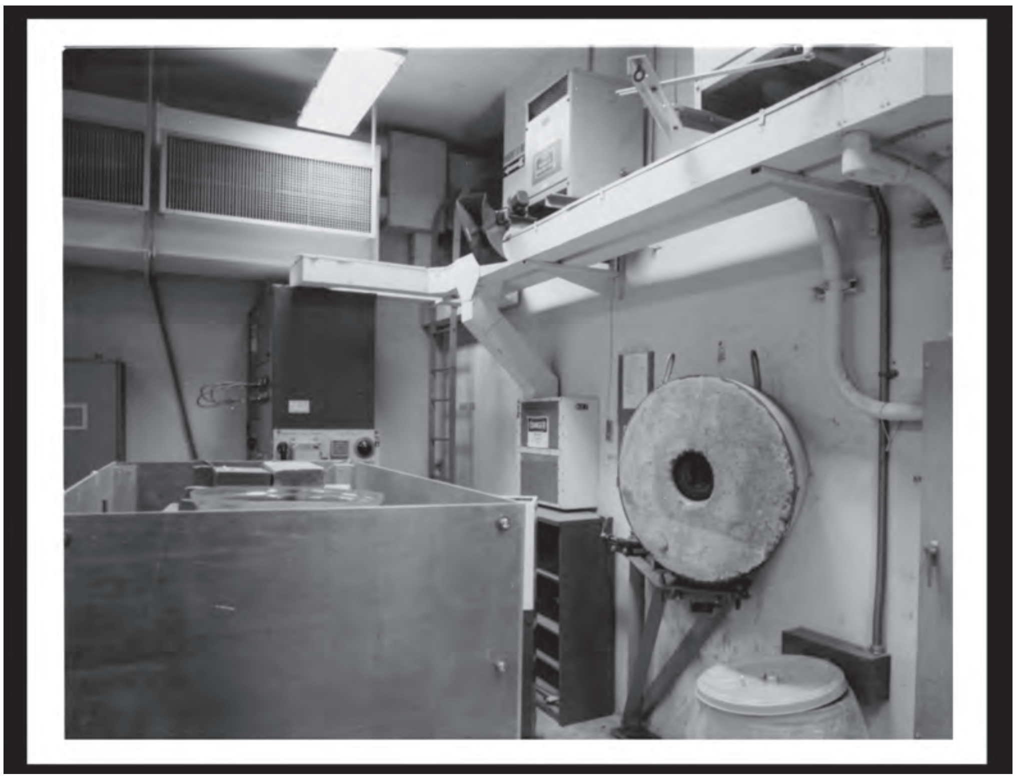
HAER No. CA-2354 - 28



HISTORIC AMERICAN ENGINEERING RECORD
SEE INDEX TO PHOTOGRAPHS FOR CAPTIONS

HAER No. CA-2354 - 29





HISTORIC AMERICAN ENGINEERING RECORD
SEE INDEX TO PHOTOGRAPHS FOR CAPTIONS

HAER No. CA-2354 - 32