PHYSICAL PLANT

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A large portion of the investment in SLAC lies in its physical plant. This chapter describes the planning and management that went into this part of the program. The development and improvement of the site, the structures built, and the utilities installed are discussed.

27-1 Planning and management

The physical plant consists of the site and site improvements, general site utilities, buildings, accelerator equipment and services, and certain initial experimental equipment.

Three broad programs are covered herein as follows:

1. Initial construction of buildings, utilities, and site improvements. This program is discussed at length and referred to briefly in other chapters. It covers the work which was the responsibility of the Aetron-Blume-Atkinson architect–engineer–manager firm.
2. Installation of the accelerator equipment and services. The broad outline of this SLAC-managed program is discussed briefly in this chapter. Detailed discussions of design, procurement, testing and performance of equipment, and equipment services and systems are all covered under appropriate earlier chapters.
3. More recent construction programs, all managed by SLAC. They are discussed at length herein and referred to briefly in other chapters.

Initial construction of buildings, utilities, and site improvements (DB, EPL)

THE JOINT VENTURE. The design, procurement, construction, and acceptance of initial buildings, utilities and site improvements were managed by

Aetron-Blume-Atkinson (ABA), a joint venture, under subcontract to Stanford University. The joint venture consisted of Aetron, a division of Aerojet General Corporation, Covina, California; John A. Blume and Associates, Engineers, San Francisco, California; and the Guy F. Atkinson Company, (constructors), South San Francisco, California.

The selection of ABA was effected by Stanford University and the U.S. Atomic Energy Commission in December 1960, and preliminary design work started in February 1961. Construction of SLAC buildings was started in July 1962, and substantially completed in June 1966. Sub-contract closeout work was essentially complete by March 1967, except for final cost accounting reports. ABA on-site office activity was completed shortly thereafter.

During the design and construction period, ABA was assisted by a number of consultants of whom the following made major contributions:

Architectural design—Charles Luckman & Associates, Los Angeles, California

Concrete mix design—Professor Raymond E. Davis, University of California, Berkeley, California

Electrical consultant—Herman Halperin, Menlo Park, California

Landscaping design—Royston, Hanamoto, Mayes and Beck, San Francisco, California

Soil mechanics engineering—Dames & Moore, San Francisco, California

Organizationally, ABA had three coequal divisions covering engineering design, quality control, and operations. They used critical path method (CPM)

Figure 27-1 Initial construction schedules.

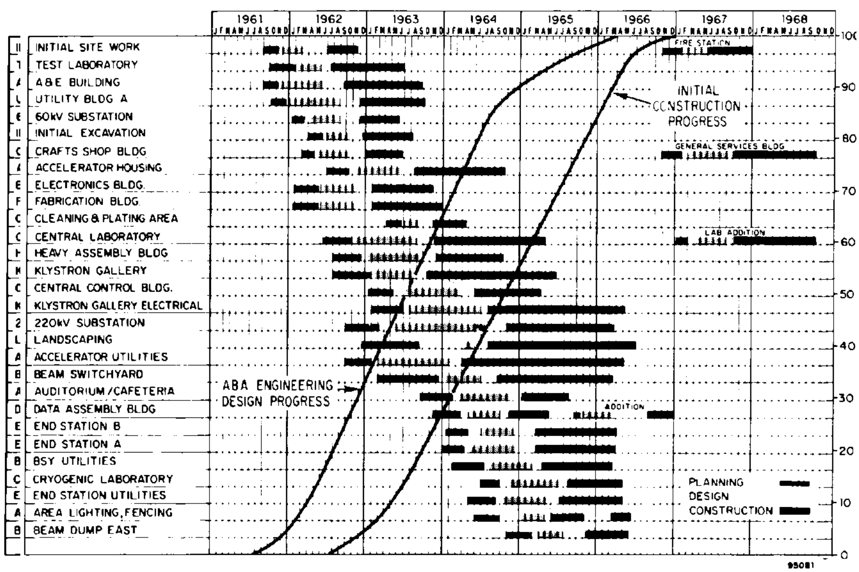


Figure 27-2 SLAC offices, laboratories, and shops.

scheduling for all major subcontracts. The ABA subcontract was administered by the Plant Office of the SLAC Business Services Division and technical liaison between ABA and SLAC was provided by the Plant Engineering Department of the SLAC Technical Division. Detailed descriptions of the conventional buildings, utilities, and site improvements designed and constructed under ABA management follow in subsequent sections of this chapter.

The ABA contractual requirements provided for master planning, architect–engineering design, inspection and quality control, and management of the construction of "conventional facilities" for the project. Prime design areas consisted of engineering studies and development of design criteria, architectural considerations, civil, structural, mechanical, and electrical engineering, general engineering services, planning, and scheduling. The scope of "conventional facilities" included site development, buildings, structures, and on-site utility systems, exclusive of the accelerator proper and its ancillary equipment and services. Figures 5-2, 27-1, and 27-2 and Tables 27-1 and 27-2 provide a synopsis of the ABA program. A comprehensive summation of the ABA designs is furnished in Reference 1.

Installation of accelerator equipment and services (FFH)

SYSTEMS ENGINEERING AND INSTALLATION. The design, procurement, installation, and acceptance testing of accelerator equipment and service systems were managed by SLAC personnel, principally the Business Office of the SLAC Business Services Division, acting as subcontract administrator, and the former Systems Engineering and Installations Department of the SLAC Technical Division, acting as installation manager. These two groups worked closely with a number of SLAC Research Division and Technical Division groups

Table 27-1 Initial construction subcontracts

Contract No.	*Subcontract title*	*Name of subcontractor*	*Date of award*	*Estimated cost*	*Date of beneficial occupancy*	*Actual cost*
1-250	Construction power system	Progress Electric Palo Alto, Calif.	7/62	$ 9,500	11/62	$ 11,858
1-250-2	Accelerator alignment survey towers	Donald C. Pratt Los Altos, Calif.	1/63	10,000	3/63	13,507
1-250-3	12-kV temporary overhead pole line	Bay Area Electric Corp. Redwood City, Calif.	3/63	35,000	9/63	43,063
1-402	Time and materials contract	Hans Stavn Palo Alto, Calif.	7/63	20,000	12/64	51,900
1-402-1	Time and materials contract	Hans Stavn Palo Alto, Calif	1/65	30,000	7/66	150,000
401	Initial site improvements	F F & M Co., Inc. Burlingame, Calif.	6/62	142,160	11/62	129,192
401-1	Loop road and site improvements	L. C. Smith Co. San Mateo, Calif.	6/62	79,400	11/62	87,770
421	New property fence	Embarcadero Fence Co. Mountain View, Calif.	6/62	8,280	7/62	8,272
430-1	Landscaping, increment I	Dennis R. Gibson Palo Alto, Calif.	7/64	32,400	12/64	30,494
430-3	Landscaping, increments II and III	A & J Shooter, Inc. Burlingame, Calif.	4/65	74,200	10/65	61,126
430-4	Landscaping, increment IV	Rudolph Watson, Inc. Redwood City, Calif.	9/65	69,600	1/66	68,505
430-5	Landscaping, increments V and VI	Rudolph Watson, Inc. Redwood City, Calif.	1/66	35,300	5/66	38,487

4-400	Construction office building, parking lot	O. C. Jones & Sons Berkeley, Calif.	8/63	6,070	9/63	8,938
450	Boundary fence construction	Anchor Post Products, Inc. So. San Francisco, Calif.	11/62	9,437	5/63	8,272
450-1	Site fencing	Oakland Fence Co., Inc. San Leandro, Calif.	3/66	70,000	6/66	51,828
501	Accelerator housing, initial excavation	Edwin D. Varwig East Palo Alto, Calif.	12/62	515,914	7/63	459,035
501-1	Equipment rental contract	Edwin D. Varwig East Palo Alto, Calif.	10/62	95,000	2/63	74,879
501-2	Accelerator housing and earthwork contract	Peter Kiewit Sons' Co. Arcadia, Calif.	8/63	4,841,000	10/64	4,387,904
501-3	Initial accelerator housing	Power Construction, Inc. Mountain View, Calif.	6/63	383,000	10/63	313,231
501-4-1	Coating of accelerator housing	Allied Painters & Decorators, Inc. Oakland, Calif.	10/64	44,000	12/65	44,605
502	Klystron gallery	Jasper Construction, Inc. Santa Cruz, Calif.	10/63	3,681,000	6/65	3,804,487
503-435-1	Control building & miscellaneous site improvements	Harrod & Williams, Inc. Sunnyvale, Calif.	6/64	373,700	4/65	418,470
505	Beam switchyard	M. M. Sundt Construction Tucson, Ariz.	9/64	3,608,100	3/66	4,327,411
505-1	Data assembly building	Harrod & Williams, Inc. Sunnyvale, Calif.	11/64	145,900	5/65	141,709
506	Cryogenics facility building	Harrod & Williams, Inc. Sunnyvale, Calif.	8/65	462,000	5/66	470,147

Table 27-1 Initial construction subcontracts (*continued*)

Contract No.	*Subcontract title*	*Name of subcontractor*	*Date of award*	*Estimated cost*	*Date of beneficial occupancy*	*Actual cost*
523-673	Central utility building and heat transfer system	Cortelyou & Cole, Inc. Mountain View, Calif.	12/62	$ 206,900	9/63	$ 242,077
523-4(679)	Cooling tower & cooling tower fire protection system	Fluor Products Co., Inc. Santa Rosa, Calif.	12/62	44,600	4/63	32,006
524-525	Electronics & stores buildings and fabrication building (shops complex)	Cortelyou & Cole, Inc. Mountain View, Calif.	1/63	950,300	12/63	960,830
5-250-2	Plating and cleaning area	Cortelyou & Cole, Inc. Mountain View, Calif.	11/63	166,800	10/64	207,486
525-3-1	Still installation & piping	C. Norman Peterson Co. Berkeley, Calif.	1/64	25,000	4/64	19,017
525-3-2	Cleaning building	Arthur Bros., Inc. San Mateo, Calif.	4/64	39,000	6/64	34,349
525-3-3	Gas storage area	Cortelyou & Cole, Inc. Mountain View, Calif.	12/63	6,000	3/64	8,941
526/540	Research complex—heavy assembly building and central laboratory	Harrod & Williams, Inc. Sunnyvale, Calif	12/63	1,829,800	4/65	2,437,991
535	Construction office building	Arthur Bros., Inc. San Mateo, Calif.	1/63	196,000	6/63	199,892
540-1	Completion of second-story addition to one-story wing of central laboratory	Forrest Anderson Construction Co. Palo Alto, Calif.	4/65	121,000	10/65	95,864

541	Administration & engineering building	Morris Daley, Inc. Burlingame, Calif.	9/62	772,300	9/63	774,910
542-1	Shops dining room	Harrod & Williams, Inc. Sunnyvale, Calif.	8/64	22,400	10/64	27,214
542-543	Cafeteria-auditorium	Vanderson Construction, Inc. San Jose, Calif.	1/64	383,600	8/64	373,054
544	Test laboratory building	Cortelyou & Cole, Inc. Mountain View, Calif.	7/62	370,000	6/63	479,036
544-1	Test laboratory electrical	Trans-Pacific Electric, Inc. San Leandro, Calif.	7/62	187,200	6/63	154,606
544-2	Test laboratory mechanical	Nagel Associates, Inc. Redwood City, Calif.	7/62	218,000	6/63	141,939
544-3	Test laboratory fire protection system	California Automatic Sprinkler Co. San Francisco, Calif.	7/62	23,700	6/63	26,013
544-9	Test laboratory cranes	Lypta Cranes, Inc. Houston 36, Texas	12/62	59,500	9/63	37,815
561-1	Beam dump east structure	Harrod & Williams, Inc. Sunnyvale, Calif.	11/65	250,000	6/66	350,782
561-562	End station A and B, buildings and utility housings	M. M. Sundt Construction Tucson, Ariz.	3/65	3,846,000	5/66	3,392,106 (claims not settled)
600-X	Initial site utilities	Cortelyon & Cole, Inc. Mountain View, Calif.	12/62	388,500	7/63	433,785
600Y-1	Klystron gallery utilities, piping, & site improvements	C. R. Fedrick, Inc. Novato, Calif.	4/64	747,000	9/65	693,497
600Y-2	Klystron gallery utilities	C. R. Fedrick, Inc. Novato, Calif.	10/64	819,700	1/66	617,536

Table 27-1 Initial construction subcontracts (*continued*)

Contract No.	*Subcontract title*	*Name of subcontractor*	*Date of award*	*Estimated cost*	*Date of beneficial occupancy*	*Actual cost*
600Y-3	Cooling towers	Ets-Hokin Corp. San Francisco, Calif.	5/64	$ 202,000	12/64	$ 206,656
600Z-1	Beam switchyard site improvements and utilities	Harrod & Williams, Inc. Sunnyvale, Calif.	4/65	975,400	5/66	916,449
600Z-2	End station site improvements and utilities	Cortelyou & Cole, Inc. Mountain View, Calif.	7/65	1,464,000	6/66	1,311,268
615	Area lighting	Golden Gate Electric Co. San Francisco, Calif.	6/65	32,700	11/65	25,644
616-1	Master substation	S & Q Construction Co. So. San Francisco, Calif.	12/64	853,700	1/66	846,828
616-2	Switch house	Arthur Bros., Inc. San Mateo, Calif.	10/64	55,600	5/65	68,941
617	60/12-kV substation	Westinghouse Electric Corp. San Francisco 8, Calif.	11/62	80,000	6/63	75,539
7-925-1	Concrete doors	TRG, Incorporated Menlo Park, Calif.	10/65	203,000	9/66	119,000
7-930-X	Target area cranes	Crane Hoist Engineering & Manufacturing Co. San Leandro, Calif.	6/65	256,000	8/66	254,867
7-931-2	Cranes for shop complex	American MonoRail Co. c/o Buehrer, Inc. Oakland, Calif.	9/63	43,500	2/64	36,700

7-932-2	Heavy assembly building cranes (design)	Crane Hoist Engineering & Manufacturing Co. San Leandro, Calif.	9/64	16,000	2/65	7,289
7-932-3	50-ton crane for heavy assembly building	Crane Hoist Engineering & Manufacturing Co. San Leandro, Calif.	2/65	61,900	8/65	62,300
7-932-4	Cranes for heavy assembly building and cryogenics building	Crane Hoist Engineering & Manufacturing Co. San Leandro, Calif.	2/65	72,435	7/65	66,208
7-936	Beam switchyard materials handling system	American Crane & Hoist Corp. Downey, Calif.	7/64	198,866	4/66	294,016
544-6 (613)	Substation control power battery for test laboratory substation	Nife Incorporated Copiague, Long Island, N.Y.	7/62	4,000	4/63	1,554
544-7 (544)	Control centers for test laboratory	General Electric Co. Schenectady, N.Y.	8/62	6,000	7/63	4,857
544-8 (613)	Distribution center for test laboratory substation	Federal Pacific Electric Co. Newark, N.J.	8/62	4,500	12/62	3,210
613-X-1	Unit substations	Federal Pacific Electric Co. Burlingame, Calif.	11/63	306,900	9/66	330,059
613-Z-1	Indoor electrical switchgear and substations	Federal Pacific Electric Co. Burlingame, Calif.	3/65	379,500	2/67	421,417
792-1	Shielding blocks	Dean C. Buehler, Inc. Palo Alto, Calif.	12/62	13,600	2/63	12,080

Table 27-2 Initial construction costs

Breakdown of Aetron-Blume-Atkinson costs	
Engineering, design, and inspection	$3,776,900
Construction management	1,583,600
Indirect costs	3,093,900
Fee	1,236,500
	$9,690,900
Cost breakdown of conventional facilities	
Site improvements	$ 2,206,500
Accelerator housing	4,710,400
Klystron gallery	3,604,300
Control building	288,300
Beam switchyard	4,257,500
Cryogenic facility	295,700
Central utility building	63,200
Electronics building	341,200
Fabrication building	751,000
Heavy assembly building	764,500
Construction office building	188,300
Central laboratory	1,582,300
Administration & engineering building	774,600
Cafeteria and auditorium	316,500
Test laboratory	892,100
End station A	2,562,500
End station B	988,000
Plant utilities: Electrical	4,033,900
Mechanical	2,664,200
Equipment	857,300
	$32,142,300

having prime responsibility for the design and fabrication of mechanical and electronic components of the accelerator and its beam switchyard, and with the Purchasing Department of the SLAC Business Services Division.

Prior to initiating a SLAC-managed installation program, it was necessary to determine the scope of the program and then obtain approval from the U.S. Atomic Energy Commission to carry out the work. The desirability of having a SLAC-managed installation program for the accelerator equipment and its critical service systems was based on the following considerations:

1. This arrangement would allow design decisions to be deferred in those cases where it would be desirable to do so without disrupting the work of outside agencies.

2. It would provide flexibility to include or not to include specific work items in a given subcontract as information firmed up.
3. It would allow maximum coordination of the activities of SLAC component designers and SLAC installation planners.
4. It would permit SLAC installation supervisors to schedule work in various accelerator areas so as to best meet short-term objectives.
5. It would allow close SLAC control of subcontractor work in the vicinity of critical SLAC equipment, as well as direct SLAC supervision of the installation of such critical equipment.

A report, "Installation Program for the Two-Mile Accelerator" (dated May 14, 1963), was prepared by the Systems Engineering and Installations Department in collaboration with all SLAC technical groups having primary interest in one or more phases of the work. This report was reviewed at length with the U.S. Atomic Energy Commission and their approval to proceed was received. The program may be summarized as follows: (a) SLAC would act as its own general contractor for the accelerator installation; (b) a number of lump-sum installation subcontracts would be awarded "by trade," principally for electrical work and plumbing work; (c) installation of critical accelerator equipment and instrument and control wiring at primary machine control consoles would be accomplished using subcontractors retained on a "time and materials" basis.

Organizationally the work was programmed so as to use a minimum number of people. All lump-sum installation subcontracts were handled through two contract administrators. A third contract administrator handled time and material subcontracts. Overall direction and coordination were handled by the installation manager, an office engineer, a field superintendent, and an assistant field superintendent. Each component or system group furnished a cognizant field engineer together with the necessary number of inspectors to follow properly the group's field work. Component groups also furnished field superintendents and test personnel to direct the installation of critical accelerator equipment, such as the following:

Klystron tubes
Rectangular waveguide assemblies
Main injector
Beam-analyzing station No. 1
Standard 40-ft accelerator assemblies
Sector drift section assemblies
Positron source
Positron solenoid section assemblies
Beam-analyzing station No. 2
Beam switchyard drift tubes
Pulsed magnet assembly No. 1
Special instrument section assemblies
Main beam collimator

Main divergent chamber
Beam tune-up dumps
Beam scrapers
Beam bending magnets
Main beam slits
Main beam dumps
Photon beam section assembly
Magnetic slit
Pulsed magnet assembly No. 2
B-beam divergent chamber

SUBCONTRACTS. Working drawings and specifications were prepared for the following lump-sum installation subcontracts:

Accelerator ac electrical services
Accelerator cooling-water systems
Accelerator high vacuum system
Sectors 1 and 2, electronic equipment rack assembly
Sectors 3–30, electronic fiat rack assembly
Sectors 3–30, electronic control alcove rack assembly
Accelerator instrumentation and control (I & C) cable plant
Accelerator electronic equipment rack installation
Beam switchyard electrical work
Beam switchyard cooling-water systems
Beam switchyard equipment installation

Specifications and instructions were prepared for the following time and materials installation subcontracts:

Accelerator and klystron installation
Electronic control room wiring
Beam switchyard completion work

The accelerator ac electrical services subcontract also provided for the installation of the SLAC-furnished accelerator modulators, personnel communications equipment, main drive line, subdrive line, main trigger line, and I & C battery plants.

The accelerator cooling-water systems subcontract also provided for the installation of compressed air piping in the klystron gallery, the installation of supports for klystron tubes and accelerator girders, as well as pumps and heat exchangers furnished by SLAC.

The accelerator high vacuum system subcontract included the installation of SLAC-furnished gauges, valves, and pumps, but did not include installation of the accelerator alignment vacuum system.

The beam switchyard electrical work subcontract provided for the installation of SLAC-furnished dc magnet power supplies, but did not include installation of the Data Assembly Building control room wiring.

The beam switchyard cooling-water systems subcontract also provided for the installation of compressed air and inert gas systems piping.

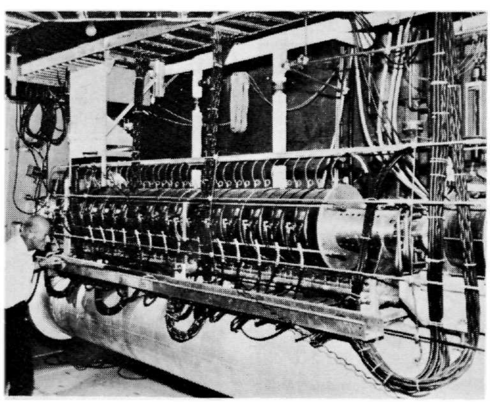
The beam switchyard equipment installation lump-sum subcontract provided for the installation of high vacuum pumping systems, chambers and drift tubes and for the delivery of all major equipment to the site prior to June 1966. Equipment delivered later was installed using time and materials subcontractors.

SCHEDULES. The installation of the accelerator and beam switchyard equipment started in April 1964 and was substantially completed in August 1966. Thereafter, a few pieces of equipment were delivered and installed, and by December 1966 only one initial piece of equipment for the beam switchyard had not been delivered. It was installed during January 1967.

On January 7, 1965, a temporary injector delivered an electron beam to Sectors 1 and 2 over a length of 666 ft, 4 in., into a temporary dump. On April 21, 1966, the "permanent" injector delivered an electron beam into beam-analyzing station No. 2 over a distance of about 6400 ft. On May 21, 1966, an electron beam was delivered into a beam tune-up dump in the SLAC beam switchyard, having traveled a distance of almost 11,000 ft. Note the adherence to schedule in that the original planning called for beam tune-up checkout tests during April, May, and June of 1966. As of August 1966, the initial project physical plant was essentially complete. There remained, of course, a lengthy checkout of machine performance and the completion of initial experimental equipment layouts. An overall concept of the SLAC accelerator installation is given in Figs. 5-14, 10-3, 15-16, and 27-3 through 27-8 and in Table 27-3.

It is worth noting that on Friday, April 3, 1964, the first building areas for installation of the machine structures were accepted for SLAC occupancy and that 3 days later, on Monday, April 6, 1964, both electrical and cooling-water subcontractors for installation of these accelerator systems were aboard

Figure 27-3 Main injector.



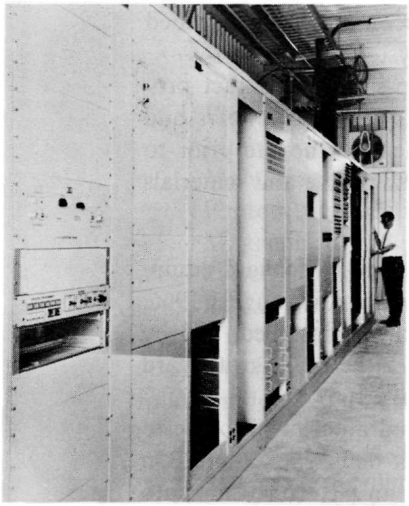


Figure 27-4 Typical sector alcove control room.

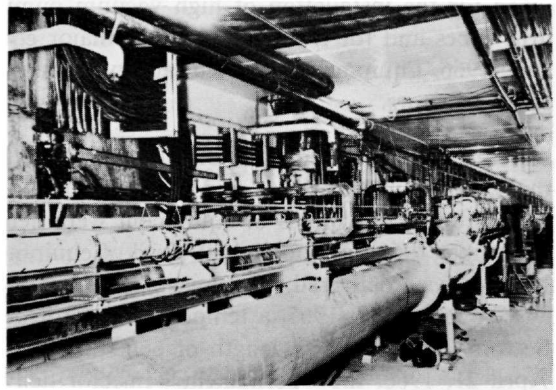


Figure 27-5 Positron source services.

Figure 27-6 First bending magnets upon arrival.

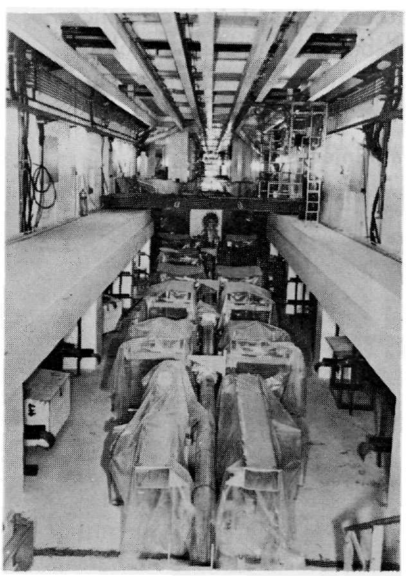


Figure 27-7 Data assembly building control room electronic equipment racks.

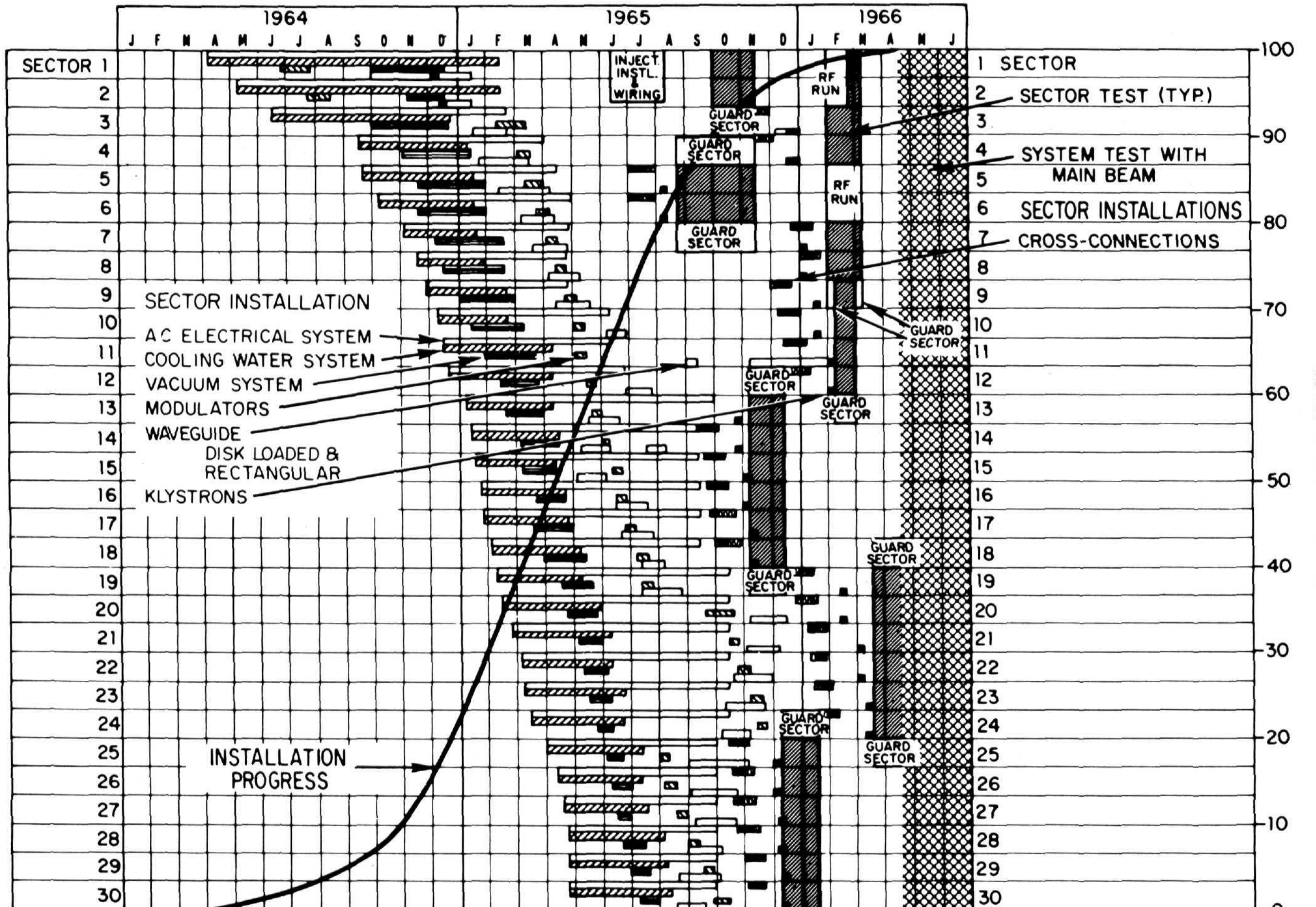


Figure 27-8 SLAC installation schedules.

Table 27-3 SLAC installation subcontract data

Subcontract No.	*Title*	*Subcontractor*	*Engineer's estimate*	*Original bid*	*Final cost*	*Date started*	*Date accepted*
400-S-39	Accelerator ac electrical services	Brayer Electric San Francisco, Calif.	$1,490,400	$999,900	$1,324,940	Mar 64	May 66
400-S-46	Accelerator cooling water	Monterey Mechanical Oakland, Calif.	1,580,000	1,568,000	1,699,018	Mar 64	Sep 66
400-S-40	Accelerator high vacuum system	Cosmodyne Corp. Torrance, Calif.	1,415,900	796,250	1,034,967	Feb 64	Aug 65
400-S-68	Sectors 1 and 2 electronic equipment rack assembly	Ets-Hokin & Galvin San Francisco, Calif.	76,800	40,000	83,000	Jun 64	Apr 65
400-S-71	Time & material, accelerator & klystron installation	Wismer & Becker Sacramento, Calif.	500,000	500,000	405,557	Jul 64	Jun 66
400-S-71R	Time & material, beam switchyard completion	Wismer & Becker Sacramento, Calif.	50,000	50,000	56,525	Jan 66	Jul 66
400-S-92	Sectors 3-30 electronic equipment rack assembly	Keltec Industries, Inc. Santa Clara, Calif.	354,389	163,618	218,662	Jan 65	Jan 66
400-S-111	Accelerator I & C cable plant	Brayer Electric San Francisco, Calif.	714,000	455,555	623,644	Mar 65	Apr 67
400-S-132	Time & material, control room wiring	T. L. Rosenberg Oakland, Calif.	200,000	200,000	200,000	May 65	Apr 66
400-S-135	Time & material, beam switchyard completion	Rosendahl Los Angeles, Calif.	0	0	183,721	Apr 66	Dec 66
400-S-149	Beam switchyard cooling-water systems	Natkin & Co. Santa Clara, Calif.	468,000	482,400	785,568	Aug 65	Apr 67
400-S-155	Beam switchyard electrical work	Trans-Pacific Electric Seattle, Wash.	605,000	944,900	1,201,098	Sep 65	Mar 67
400-S-160	Accelerator electronic equipment rack installation	Brayer Electric San Francisco, Calif.	183,310	217,777	256,006	Jul 65	May 66
400-S-179	Beam switchyard equipment installation	Natkin & Co. Santa Clara, Calif.	84,000	139,540	167,218	Sep 65	Jun 66
			$7,721,799	$6,557,940	$8,239,924		

and underway. For the next 2 yr, SLAC subcontractors entered each increment of construction accepted for beneficial occupancy in periods measured in hours to days, but not in weeks. The installation of the SLAC machine followed very closely the completion of its buildings and utilities.

More recent construction programs (FFH, EPL)

PLANT ENGINEERING. As the construction of initial buildings and utilities and the installation of the accelerator equipment and services approached completion, it was recognized that a revised organization would be needed for the technical management of further modifications and extensions of the SLAC physical plant. During 1966, the former Plant Engineering Department, which had been responsible for SLAC liaison with ABA activities and for initial changes to conventional buildings and utilities, was combined with the Systems Engineering and Installations Department, which was responsible for the installation of accelerator equipment and services, into a single Plant Engineering Department. This department is now responsible not only for completion of initial construction and equipment installation but also for minor modifications to buildings and utilities, general plant projects, new buildings funded under the original construction contract with the U.S. Atomic Energy Commission, and new buildings authorized from subsequent construction funding.

MODIFICATIONS TO EXISTING BUILDINGS. Fiscal year 1967 was the first year of operation and maintenance of the completed SLAC physical plant. Prior to July 1966, changes to SLAC conventional facilities were funded from SLAC initial construction funds, with each change being declared capitalized or not, based on the nature of the change. These changes were managed technically by the plant engineering liaison group, often using the former Systems Engineering Department as its architect–engineer, working in collaboration with the SLAC Plant Office. Since July 1966, the program has been split, with capitalized projects being funded as general plant projects and noncapitalized minor modifications to buildings and utilities being funded as operating costs.

Minor modifications to existing buildings and utilities have been needed from the date of beneficial occupancy of each facility. Reasons for such modifications include the following:

1. Organization of laboratories, workshops, and offices to allow maximum use of space upon initial occupancy by SLAC forces.
2. Change of space requirements by SLAC groups during the initial machine installation period.
3. Change of space utilization as SLAC evolved from the phase of machine installation into the phase of machine operation support of basic research.
4. Conversion of space usage for new SLAC activities not foreseen in detail during the initial scoping of project work.

Table 27-4 Estimated scope of minor modifications projects

Fiscal Year	*Capitalized projects*	*Noncapitalized costs—buildings*	*Noncapitalized costs—utilities*	*Total costs*
1964	$ 20,000	$140,000	$ 30,000	$190,000
1965	190,000	360,000	50,000	600,000
1966	225,000	300,000	75,000	600,000
1967	0	300,000	200,000	500,000
1968	0	300,000	200,000	500,000

Expressed as a percentage of total SLAC construction value, minor modifications to the existing SLAC physical plant have amounted to about 3% to date. Nonetheless, when considered as an annual program, these changes have ranged up to as much as $600,000 a year. For a long time, about $16,000 per month has been expended on an average number of about twenty projects, each of which has an average installed cost of about $800. The balance of work has consisted of a few projects which required the expenditure of about $9000 per month.

The estimated scope of minor modification projects tabulated by fiscal year is shown in Table 27-4.

Looking ahead, the need for minor modifications to existing physical plant is likely to remain constant in the area of modifications to buildings, and to grow slowly in the area of utilities as the scope of SLAC research programs is expanded.

GENERAL PLANT PROJECTS. With the advent of operational budgets starting in fiscal year 1967, it became necessary to segregate projects that must be capitalized and are not properly a part of the initial construction program as general plant projects.

In practice, such projects range in scope from $5000 to approximately $100,000 in installed cost. These projects fall into several categories which include (a) facility conversion which may be considered as an upgrading of space usage, (b) new space, and (c) projects that require additional equipment which, per se, is to be capitalized. The fiscal year 1967 program totaled $350,000 and was carried out as shown in Table 27-5. The fiscal year 1968 program totaled $245,000 and was planned as shown in Table 27-6. Looking ahead, there remain a number of desired projects which properly are to be classified as general plant projects, together with still other projects not being given detailed consideration as of this date. At the present time, the gross scope of these projects, if built, would cost just under $2,000,000, based on current construction costs.

The continuing backlog of projects for both general plant and minor modifications overtaxed the permanent plant engineering staff. In order to

Table 27-5 1967 General plant projects

Description of project	*Engineering costs*	*Construction costs*	*Total costs*
54-in. spark chamber enclosure	$ 300	$ 19,900	$ 20,200
Fire alarm system—target area	1,100	13,600	14,700
Temporary computer facility	27,000	169,000	196,000
Loop road resurfacing	1,000	12,100	13,100
Welding shop	4,700	38,300	43,000
Power supply enclosures	500	15,300	15,800
Power factor correction	0	2,100	2,100
Emergency oil catchment basin	1,400	4,500	5,900
Intercept storm drains	400	0	400
South boundary fence	2,800	24,900	27,700
	$39,200	$299,700	$338,900
Indirects			11,100
			$350,000

obtain increased flexibility, the services of an outside architect–engineer firm were sought to augment the in-house engineering capability. The first such subcontract for architect–engineer assistance was awarded in 1966 to Ackerman-Aronoff-Ruth-Going and Beck, a joint venture, Palo Alto, California. This firm has been very helpful in the execution of medium-sized projects and their work period at present extends through fiscal year 1968.

Table 27-6 1968 General plant projects

Description of project	*Engineering costs*	*Construction costs*	*Total costs*
Chilled water headers	$ 3,200	$ 36,800	$ 40,000
Sand blast facility	1,000	15,000	16,000
Power supply enclosures	0	9,000	9,000
North yard paving	1,500	10,500	12,000
Counting house extension	10,000	83,000	93,000
Addition to temporary computer building	3,900	59,100	63,000
	$19,600	$213,400	$233,000
Indirects			12,000
			$245,000

NEW BUILDINGS. Even as the initial project construction drew to a close, a number of new buildings and facilities were under consideration and these included: a laser room, a fire station, a general services building, an extension to the Central Laboratory, an electron–positron colliding beam storage ring, and a computation building.

To date, the first four items listed above have been authorized from initial SLAC construction funds. The other items are on future funding appropriation lists and are not discussed further. The laser room was designed by the former Systems Engineering Department.

In 1966 the architectural firm of Rockwise and Watson, San Francisco, California, assisted by Gilbert Associates, structural engineers, and Bentley Engineers, electrical and mechanical engineers, also of San Francisco, California, was retained to design the Fire Station and the General Services Building. The Fire Station is scheduled for completion late in 1967 and the General Services Building in mid-1968.

Also in 1966, the engineering firm of John A. Blume Associates, San Francisco, California, assisted by Charles Luckman & Associates, architects, Los Angeles, California, and Keller and Gannon, electrical-mechanical engineers, San Francisco, California, was retained to design the Central Laboratory Extension. This extension to the Central Laboratory will be substantially completed in September 1968.

Looking ahead, it is planned to retain qualified architect–engineer firms for the design of future buildings and facilities as construction is authorized. Daily inspection and coordination of construction subcontractor activities on the SLAC site have been and will be handled by Plant Engineering Department personnel since it is firmly believed that a continuing capability in this area of physical plant work is of importance and value.

27-2 Site and site improvements

Site investigation program (RSG)

At no time during the selection of the site and subsequent design was it assumed that the accelerator would remain in a permanently stable, straight-line condition. Movement is to be expected from seismic and tectonic factors, settlement and consolidation of soils, and the effects of variations in ground water conditions.

The basic task of the site investigation carried out by the Aetron-Blume-Atkinson joint venture was to determine the nature of movements and to predict their magnitudes during the useful life of the machine. Such a program is properly of concern in the early development of any large accelerator project, because of the magnitude of the weights which will be placed on the existing soils. In the case of SLAC, there was also concern because of the nearness of the San Andreas fault.

The basic items of this site investigation program are outlined here.

1. General geology: regional geomorphology, stratigraphy, structure, and paleontology.
2. Engineering geology: Eocene and Miocene rocks; alluvium; soil overburden; soil profile; earthwork; preloading—surcharge and preload fills for minimizing consolidation of foundation materials; ground water.
3. Ground movement and seismic studies: review of previous regional surveys; measurement of slow deformation—horizontal, vertical, tilt; movements caused by construction—rock rebound, settlement, consolidation; seismic studies—seismic design considerations; design parameters for various rock types.

Minor movements which might affect the day-to-day operation of the machine, such as small seismic tremors, traffic-induced vibrations, and earth tides, were investigated. It was concluded that their effect would not be great enough to influence design and no extensive study of them was made.

Means of effecting the program included trenching, bore hole drilling of various types, ground water wells, geologic maps, precise alignment and levels surveys, tilt meters, temperature-measuring devices in backfills and structural concrete, settlement markers (plates at the bases of fills with pipe risers), fluid level settlement indicators, soil moisture instrumentation, deep strata bench marks, and "inverted plumb bobs."*

The largest short-term movements were associated with vertical soil changes. In the measurement of these movements, plates and pipe risers in fills proved more reliable than fluid level indicators, although they were subject to some damage at times during embankment construction.

Other movements can be determined by precise measurements over long time periods (or after earthquakes). SLAC's instrumentation has been designed to provide information on the nature of significant movements occurring during the accelerator's useful life so that effective countermeasures may be devised.

In addition to many private consultants engaged by ABA for this program, a number of institutions, including the University's School of Mineral Sciences, the U.S Coast and Geodetic Survey, and the U.S. Geological Survey, provided valuable data. The subject is covered in detail in References 1, 2, and 3.

Geology (RSG)

The injector end of the accelerator lies about $\frac{1}{2}$ mile from the edge of the San Andreas rift zone running through Portola Valley. Hence, a careful geophysical examination was necessary before a final decision was made on

* Devices patterned after those developed by DeCae at CERN, consisting of floats in vertical wells filled with water, anchored by wires to fixed bases at the well bottoms, to measure relative horizontal shifting of strata.

site selection. Several reports were made by Dr. Perry Byerly and assistants of the University of California in 1959 and 1960 and are included in the report by John A. Blume and Associates.[4] Byerly concluded that the 2-mile original straight line of the accelerator could be expected to curve at a rate producing a displacement of about 2 mm/yr at mid-length. Byerly's conclusion was based largely on triangulation surveys made before and after the 1906 earthquake which disclosed the pattern of elastic strain buildup. It was also based on later surveys showing relative movement between blocks on either side of the fault.

The general geology of the region was described by Atchley and Dobbs in 1960 in their report "Geological Investigation of the Stanford Two-Mile Linear Accelerator Site," and in two subsequent reports by Atchley in the same year. These also are included in Reference 4. Byerly had stated that there appeared to be no geologically recent fault activity within the site boundaries. Atchley, and subsequently Dr. Parker Trask (1961), confirmed this view.[5]

The machine is located, for the most part, in formations of Eocene and Miocene sandstones, the former predominating in the west, and the latter in the east and in the target area. The Eocene is in a chaotic condition in some sections of the machine's length. This necessitated careful engineering geology studies before undertaking final design of the accelerator housing and klystron gallery. The Miocene is superior for engineering purposes and its uniformity and great bearing capacity have made it an excellent base in the end station area* for supporting the massive research equipment.

The physical plant and equipment mountings for the project have been designed to withstand, without major damage, an earthquake with a nearby epicenter and having a Richter scale magnitude of 8.0. The accelerator's lateral alignment adjustment allowance of 12 in. in any direction is expected to be sufficient to permit realignment after such a quake.

For a detailed summary of SLAC's geology, see Reference 2.

Soil mechanics (RSG)

The problem of volumetric changes in soils surrounding the accelerator was critical. It became apparent in the planning stages that the Accelerator Housing would have to be constructed to grades established in accordance with settlement predictions. Accordingly, SLAC established settlement criteria in the fall of 1962 as follows:

> Construct the Accelerator Housing to grades established in accordance with predicted settlement, consolidation and rebound. Regardless of these predicted movements, however, no point along the housing floor is to depart more than four inches above nor two inches below a straight line in October

* During excavation for the end station area, workmen uncovered the near-complete fossil remains of a 9-ft, ½-ton, Miocene age mammal called *Paleoparadoxia*.

1965. Hence, the accelerator tube could be aligned at that time with no point more than four inches below, nor two inches above the optimum position. These departures from straightness should be in directions such that movements during at least the succeeding ten years, due to soil changes only, will be toward straightening of the housing.

If settlement and consolidation during the period is expected to be of a magnitude which would cause movement to pass through a condition of maximum straightness and into a condition of departing from straightness within this period, areas involved should be so reported, indicating their lengths, positions and long-range predicted movements.

It is strongly desired that departures from straightness of the aligned accelerator tube in the overall 10,000-foot length shall not exceed $\frac{1}{4}$ inch in a 90-day period, even though rates of curvature be minute.

The task of meeting these criteria fell upon the firm of Dames and Moore, consulting engineers in applied earth sciences, as consultants to ABA. The October 1965 time-point was chosen because it was anticipated that alignment of the accelerator would be proceeding at that time.

To keep soil movements to a minimum, two areas of least foundation competence were preloaded with earth fills for about a year prior to start of accelerator housing construction. Along the accelerator's length, a couple of locations (not preloaded) departed sharply from the general straightness of the constructed housing, but despite this, the October 1965 tolerances were met.

Maximum recorded fill settlement was $5\frac{1}{2}$ in. measured at the base of an 80-ft fill. Average settlement during earthwork construction (early 1963 to early 1964) was $\frac{3}{4}$ in./10 ft of fill, in fills ranging from 30 to 80 ft deep. Subsequent fill settlements have been very slight and have proved that replacement of alluvia with engineered fills and preloading of weaker areas have been highly effective in reducing or eliminating consolidations.

Scientific use of soil mechanics was made throughout all construction phases of the project. A well-equipped and -staffed soils laboratory was maintained by ABA on site for this purpose.

Further details on the soil mechanics program are described in References 1 and 2.

Roads, yards, and parking (RSG)

Predominant considerations in planning the $8\frac{1}{2}$ miles of site roads were the movement of heavy equipment and materials incident to physics research plus the fact that the ratio of personnel to private cars on site during the working day is almost 1 : 1. Roads between the Heavy Assembly Building and the research yard are of relatively heavy construction with 10 in. of aggregate base and 4 in. of asphalt concrete surfacing. The ratio of parking areas to building areas is large, but costs were kept fairly low by use of asphalt curbs and a light paving consisting of a 6 in. base and of oil and rock-chip seal coat surfacing. Both have stood up well for passenger car parking.

Main roads consist of the main entrance drive, the "Loop Road" circling the main "campus" area, one road on each side of the klystron gallery for the full length of the accelerator, a 2-mile bypass road paralleling the accelerator at a distance of from 200 to 500 ft, and the north and south target area roads.

Maximum grade on these roads is limited to 6% excepting the bypass road paralleling the accelerator. Where wide and heavy loads were anticipated, the inside radii of curves are not less than 40 ft. Because of the need to move buildings occasionally, generous side clearance has been provided. Roads having considerable traffic are 30 ft wide, allowing two lanes of traffic to be maintained when a vehicle is parked.

Yards surrounding buildings are paved with 2 in. of asphalt concrete on aggregate bases varying from 6 to 10 in., depending on the functions of the buildings served. The research yard, having a large percentage of concrete paving, departs somewhat from this standard. It is described later in this chapter.

There are relatively few walks on the site and these are confined to the campus area. One is formed by the top of the concrete utility tunnel serving the campus buildings; others are of asphalt concrete; and some are merely of compacted, graded rock.

Storm drainage system (RSG)

SLAC's underground drainage system consists almost entirely of corrugated metal pipe. Experience has indicated that for those pipes draining shop areas where corrosive liquids could enter the system, a bituminous inner coating would have been advisable.

The use of corrugated metal pipe extends to the culverts under the accelerator. These were sized generously, as marginal hydrologic design could prove to be false economy, considering the total cost of the machine.

Erosion control (RSG)

The side slopes of embankments along the accelerator's length were treated for soil erosion by adding a 6-in. layer of native topsoil and kneading straw into it with compacting rollers equipped with knife-type feet. Seed was added, but the seed contained in the straw predominated and the slopes yielded a lush growth of barley, wheat, and rye. Despite the growth, a heavy rainfall in the winter of the second year of construction caused extensive sloughing of the topsoil layer from the densely compacted fills. Because of this, it was decided to omit the topsoil treatment from the banks of the large beam switchyard fill, and a substitute method was used consisting of a spray application of a mixture of cellulose fiber mulch, seed, and fertilizer. Unfavorable weather conditions following the treatment resulted in a crop failure and the beam switchyard fill entered the winter of 1966–67 with bare banks. A severe storm

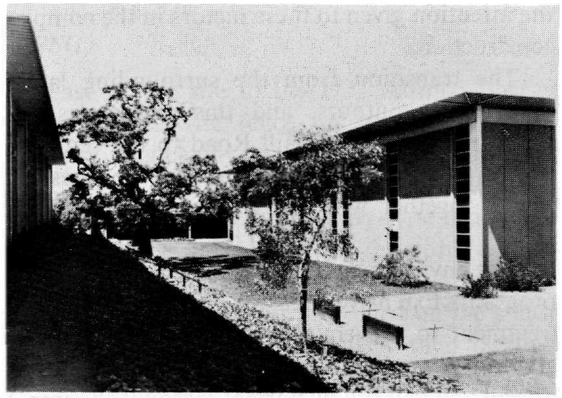


Figure 27-9 Landscaping between shop buildings.

caused the bank surfaces to turn to liquid mud following 36 hours of steady rain. Mud slides developed around the cableway structure on a bench of the slope and behind the Data Assembly Building, necessitating a large cleanup operation, fortunately without serious damage to structures or equipment.

Landscaping (JWC)

Having decided to establish SLAC in the Sand Hill Road area, it was essential, for esthetic, environmental, and political reasons, not to diminish unduly the native beauty, to site the buildings in such a way that their large scale would not dominate the landscape, to restore inevitable construction scars, and to provide landscaping to enhance the buildings. Figures 27-9 and 27-10 show

Figure 27-10 Typical landscaping—looking north of test laboratory.

the attention given to these factors in the completed landscaping and building construction.

The transition from the surrounding land was made without abrupt changes in contours, and this effort was particularly successful in the transition from Sand Hill Road to the central campus area. The retention of the rolling contours permitted the preservation of existing oak trees which, together with native grasses, provide the essential character of the area.

The environmental aspect was, however, only one part of the landscaping program. Extensive areas of cut, fill, and other construction scars required treatment to prevent soil erosion. This has been accomplished with native grasses, ivy, and prostrate shrubs. In the peripheral areas, the native grasses prevail and will follow normal seasonal changes. In the central area, irrigation is used to promote growth, present a fresh, dust-free zone, and serve as a fire-stop to possible grass fires.

In areas around and between the principal buildings, trees provide shade on building walls and foot paths, and occasionally flowering trees are included as accents.

Some of the parking areas and most of the yards are screened by means of earth mounds and dense plantings of trees and shrubs.

The largest building at SLAC, the 2-mile long klystron gallery, is expressed rather than concealed by the landscaping and is flanked by rows of eucalyptus trees which will, in a few years, complement the linear character of the accelerator.

The following categories of plants were used:

GROUND COVER AND VINES—native grasses, turf, *Hedera canariensis*, *Hypericum calycinum*, *Gazania splendens*, *Fiscus repens*

SHRUBS—*Callistemon lanceolatus*, *Ceanothus griseus horizontalis*, *Nerium oleander*, *Prenus laurocerasus*, *Pyracantha crenata*, toyon (*Heteromeles arbutifolia*)

TREES—*Fraxinus uhdei*, *Ginkgo biloba*, *Ligustrum texanum*, *Olea caropea*, *Crataegus phaenopyrum*, *Sequoia sempervirens*, *Pinus muricata*, *Quercus agrifolia*, *Quercus suber*, *Eucalyptus leucoxylon*, *Eucalyptus globulus* (normal and dwarf), *Podocarpus macrophylla*, *Magnolia grandiflora*, *Magnolia soulangeana*.

Irrigation was provided to give the turf, ivy, and *Hypericum* ground cover areas a fresh appearance throughout the year and to promote growth of the trees and shrubs. With few exceptions, plant material was of either 1- or 5-gal size.

In the peripheral areas of pines and eucalyptus, irrigation was provided by means of above-ground piping and quick couplers for hand hose connection to prevent plant loss in the first few summers and to promote growth. In these areas, the irrigation will be discontinued after satisfactory establishment.

Fencing and main entryway (RSG)

Shortly after the University's lease of the site to the U.S. Atomic Energy Commission became effective, a barbed-wire fence on steel pickets was erected along the boundaries, functioning chiefly as a barricade against cattle grazing on adjacent lands.

Near the conclusion of construction, in 1966, a security-type chain-link fence was constructed around the research area and along the north side of the klystron gallery. It was thought that by keeping all south wall doors along the klystron gallery normally locked, no fence would be needed on the south side. However, because access to areas south of the gallery then became difficult for SLAC personnel, in fact far more difficult than for trespassers, it was decided to fence the south side in 1967.

It is project policy to follow the University's precedence of keeping the campus open to the public at most times. SLAC's land areas that are clear of radiation sources are so maintained. The fence location and the main entrance reflect this, the latter being an open road intersecting Sand Hill Road, a city of Menlo Park street. Full-scale development of the entrance has been curtailed by the perpetual imminence of road-widening programs. It is the project's desire that eventually city, state, county, and SLAC road developments will be completed to the mutual advantage of all involved.

27-3 Buildings

The master plan (JWC, FFH)

The decision to build an extensive research establishment in an area of the San Francisco Peninsula associated with Stanford University, large residential estates, and high-priced subdivisions, required esthetic and structural approaches radically different from precedents in more remote and less attractive geographical situations.

From the beginning, Stanford University had assured the neighboring communities that the physical development of the Sand Hill Road site would be executed in a manner sympathetic to the environment. Accordingly, in the Stanford–AEC lease, the University retained architectural control of the development, including landscaping and site planning beyond the limits of the functional needs of the accelerator and target areas.

The basic form of the accelerator and research areas is a "Y" with an elongated tail having an overall length of approximately 12,000 ft. This, together with the required lateral clearance of 500 ft on each side of the accelerator, establishes the land area satisfying accelerator and research area requirements.

In addition to this basic ribbon of land, sufficient additional land was required for several major buildings accommodating light and heavy laboratories, shops, offices for physicists, engineers, and administrators, an auditorium and cafeteria, and several minor buildings for utility systems. Other land needs included parking for employees and visitors and yards for outdoor storage and assembly of equipment.

After numerous site studies, the decision was made to place the entrance to the project on the north side (connecting to Sand Hill Road) and to provide land on the north side of the accelerator for the support facilities. With this basic land use plan, detailed zoning developed quite naturally with the more public-type buildings for administration and engineering and the auditorium closest to Sand Hill Road. Laboratories for physicists are farther back toward the research area, and the machine shops and electronic laboratories are also farther back but along the north side of the accelerator.

A physics laboratory is by nature dynamic, and provision must be made in the planning for change and growth. For these reasons, the buildings are quite spaciously sited; thus, it will be possible to extend existing buildings and to provide new major buildings in some of the present open spaces.

In 1966, when the existing development was almost completed, an analysis of current building use and anticipated future space needs of the laboratory was made so that growth could proceed in a manner compatible with the established standards of site layout, architecture, and landscaping. This study indicates that the site could accommodate additional buildings, allowing the laboratory population to increase from the current 1200 to approximately 3500 without lowering the quality of the environment.

This study also indicated that the original master plan developed by ABA is still being followed. The current land use plan for the SLAC physical plant is shown in Fig. 5-3.

Space requirements (TEM)

BASIC PLAN. When construction started at SLAC, the laboratory staff program provided for 723 people and these were to be housed in laboratories, offices, and shops with a gross area of 196,800 ft^2, excluding the cafeteria and auditorium and the uninhabited structures such as end stations and accelerator buildings.

As plans for the scope and organization of the laboratory developed, it became evident that the laboratory staff at beam turn-on would be approximately 1100 people and that the extent of the permanent habitable buildings, including those to be constructed in 1967–1968, would be approximately 318,000 ft^2. Table 27-7 summarizes the current building space requirements.

The population density varies considerably with building function. The guide lines for density for offices were established by the AEC general design criteria.[6] These standards allow 200 net ft^2 for each division director, 100–150 ft^2 for each scientist or engineer, 60–75 ft^2 for each secretary, and 75 ft^2 for each draftsman. For office-type occupancy, these standards limit the gross building area per occupant to 200 ft^2 and, with a normal efficiency

Table 27–7 Summary of building space requirements

Building No.	*Facility*	*Gross area (ft^2)*	*Net area (ft^2)*
001	Accelerator housing	154,355	124,355
002	Klystron gallery	361,483	355,913
003	Central control building	13,842	5,925
005	Beam switchyard	50,256	47,256
	Data assembly building	8,000	7,390
	Beam switchyard substation	2,275	2,175
	Research area substation	3,280	3,080
006	Cryogenic laboratory	8,000	6,700
023	Central utility building	3,600	3,534
024	Electronic building	26,500	24,900
025	Fabrication building	32,250	30,950
	Fabrication building substation	475	430
026	Heavy assembly building	34,850	30,856
	Heavy assembly building substation	650	600
027	Shops dining room	1,000	860
035	Craft shops	15,000	13,350
040	Central laboratory	60,275	43,100
	Central laboratory substation	615	565
041	Administration & engineering building	44,023	35,630
042	Cafeteria	3,875	3,450
043	Auditorium	7,550	6,650
044	Test laboratory	41,500	37,900
	Test laboratory substation	3,550	3,120
061	End station A	30,360	28,321
062	End station B	17,000	13,000

ratio of 60 to 70%, this provides approximately 130 ft^2 of net usable space per occupant.

The space requirements for individual laboratories and shops vary with function and equipment and cannot be analyzed on an occupancy basis.

The initial staff was first housed in University buildings on the Stanford campus and moved to the site as beneficial occupancy of the structures was obtained from ABA.

INITIAL SPACE REQUIREMENTS. In the early stages of planning, it became obvious that it was necessary to increase manpower for the design and development effort more rapidly than the construction effort could complete permanent facilities to house this manpower. In order to sustain the major research activities as fully as possible, office, laboratory, and shop space was given construction priority over certain support functions. These support functions were housed in "temporary" buildings until such time as permanent facilities for crafts shop, receiving and stores, transportation, and salvage function could be completed.

As a first step, temporary quarters were obtained on the Stanford campus proper, where 55,000 ft^2 of shop and warehouse-type buildings were provided by Stanford University to house SLAC during its embryonic period.

The second step consisted of leasing approximately 10,000 ft^2 of office-trailers for approximately 2 yr and purchasing another 8000 ft^2 of light shop buildings to meet SLAC's temporary needs until permanent facilities could be completed. It was planned that these shop buildings would later be moved into the research area as support buildings.

As a third step, a future crafts shop building was hastened to completion at the SLAC site for initial, temporary use by ABA as a construction office building.

TEMPORARY BUILDINGS. At the start of the move into the first completed permanent construction, it was found that it would not be feasible to wait approximately 3 yr until final construction was complete to provide maintenance and repair shops and salvage and transportation facilities. Three temporary buildings of steel frame and metal siding, totaling approximately 20,000 ft^2, were procured for temporary housing of these facilities, subject to later transfer to the research yard area as research support buildings. To date, 17,000 ft^2 of these light shop-type buildings have been moved into the research area and are utilized as planned.

A second problem was to provide adequate engineering, drafting, and physics office space to house the increased staff requirements during the construction period. Such space was provided using relocatable classroom-type buildings as developed for the California Public School System. These were used for this purpose during the peak design period and later became available for use as field offices, control rooms, and field shops in the research area. Approximately 10,000 ft^2 of this type of structure were purchased to fill this need. To date, 6500 ft^2 have been transferred to the research area as planned.

Initial plans for computer support for research anticipated a remote tie-in with the Stanford Computation Center. Between the time of initial planning and approval of SLAC as a project, computer technology and computer service to the University and local industry increased so rapidly that the Stanford Computation Center indicated they would exceed their capacity before SLAC research could be activated. SLAC took steps to order a computer and to add a new Computation Building as a line item for future expansion. Simultaneously, steps were taken to procure 8000 ft^2 of relocatable classroom-type space suitably equipped as a temporary computation facility. It is anticipated that these buildings will be relocated and used as research support buildings when the permanent computation facility becomes available.

Architectural considerations (JWC)

The architectural expression at SLAC is an endeavor to achieve structures appropriate for a laboratory of international stature by using attractive economical materials, and to recall, in color, form, and texture, some of the character of the nearby Stanford main campus.

The architectural detail which unifies the buildings and site includes seven basic elements: exposed structure, fluted metal siding, glass in aluminum sash, sight screens for roof-mounted mechanical equipment, roof overhang, tinted concrete masonry, and, finally, a coordinated color scheme.

Maximum use has been made of consistent details and methods of construction in order to achieve economy and harmony of appearance. In order to maintain scale, the spacing of columns and widths of doors and windows were generally similar everywhere.

The coordinated color scheme is centered around an earthy color for exterior walls, aptly named "homespun brown." This predominating color resembles the tone of the Stanford sandstones and blends well with the seasonal landscape colors. Other colors in the palette include charcoal for handrailings and window panels, a beige tone for spandrels and exposed columns, and a lighter shade for fascia. Sight screens and roof gravel are both rich terra cotta.

The design of the buildings falls into three categories, each incorporating appropriate elements of the architectural concept. First, the Central Laboratory, and Administration and Engineering Building, which house administrative, engineering, and research activities, include textured columns, roof overhangs, and sight screens.

Second, those buildings such as the Heavy Assembly Building, Fabrication Building, Electronics Building, craft shops, and Central Control Building are similar in expression to the first group but lack the textured masonry veneer on columns.

Third, buildings housing general service facilities, such as substations, and the Central Utility Building are without roof overhangs and sight screens.

Exceptions to these rules include the Cryogenic Laboratory which lacks roof overhangs and sight screens at the high bay, the Cafeteria–Auditorium Building and Fire Station which utilize load-bearing concrete masonry walls and exposed wood framing, and the klystron gallery which has no roof overhang or sight screen.

The end stations, because of function and size, do not fit into any of these categories but, because of their importance and mass, deserved special consideration and understanding. Functionally, both buildings required concrete envelopes with a minimum thickness of 2 ft for radiation purposes. Both required extensive wall openings to permit flexibility in placing beam transport structures. The architectural appearance is a direct expression of structural needs and consists of massive corner piers and horizontal beam elements with ribbed panel infilling. Both buildings have parapets vigorously expressed, and these serve as sight screens for present and future roof-mounted equipment and as protection for maintenance workers. Concrete surfaces are exposed throughout with the granite aggregate heavily exposed on major columns and beam elements and a finer sandblast finish on other exterior surfaces.

Structural design (WPS)

The choice of structural materials and systems was based on occupancy needs, structural requirements, economy, esthetics, and, in some instances, on the provision of flexibility for future modifications.

The materials used are reinforced concrete, reinforced concrete masonry, structural steel, and timber. These materials are often left exposed and become architectural features.

Generally, structural steel frames are used wherever large open spaces are required as in shops and heavy and light laboratories. Framing systems of reinforced concrete are used in office-type buildings where there are no requirements for large spans.

Heavy timber roof framing is used in the cafeteria and shops dining room in conjunction with load-bearing walls of reinforced concrete masonry.

Generally, lateral forces are resisted by exposed reinforced concrete shear walls. The principal exception to this system is the Test Laboratory where the structure is a steel rigid-frame system without shear walls or cross-bracing.

Suspended floors are of concrete, formed with pan joists, ribbed steel decking, and wood formwork.

Roof decks are of either ribbed steel decking or conventional reinforced concrete. Roof decks and suspended floors are used as diaphragms for the transfer of lateral forces to shear walls.

Building foundations are generally spread-type reinforced concrete with grade beams, bearing on undisturbed ground or engineered fills.

Considerable attention was given to the quality of concrete to assure minimum shrinkage by the use of select granite aggregate, water-reducing admixtures, and water curing.

Because of the close proximity of the San Andreas fault, earthquake-induced forces were given serious design consideration. It should be noted, however, that generally wind and not earthquake forces controlled the design of the steel-framed, high bay shop buildings.

Laboratories and office buildings (JWC, DB)

The site plan recognizes the importance of the Central Laboratory as the "headquarters" of the research effort, and places this building and its occupants at the center of gravity of the other principal buildings at SLAC.

Most of the theoretical and experimental physicists have offices and laboratories in the Central Laboratory, and their principal outside areas of interest are the research area, including end stations, associated facilities, and the computers presently in temporary structures. A permanent computation facility will be erected on a site southeast of the Central Laboratory. The Central Laboratory and research areas have direct cable connections with the computers.

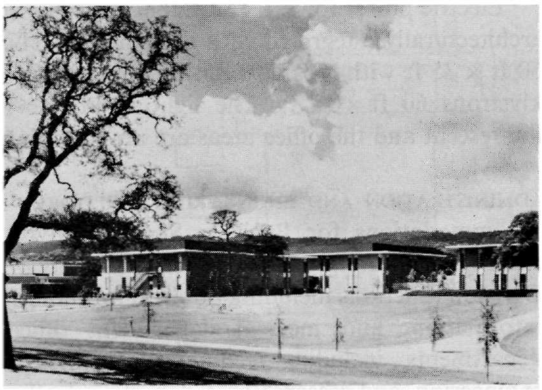
The Cryogenic Laboratory Building contains another important research facility. It is placed in the research area but because of its heavy laboratories and yard requirements, it is located near the end stations rather than near the central campus.

The Administration and Engineering Building, Central Laboratory, and Test Laboratory are physically oriented so as to provide convenient pedestrian communications. Together with the cafeteria and auditorium, these buildings create an informal quadrangle in academic tradition. They have the highest degree of architectural finish and landscaping of all SLAC buildings. The computation facility, when constructed, will conform to this architectural quality.

TEST LABORATORY. The design and construction of the accelerator required considerable development and testing of klystrons and modulators. To enable this work to be expedited, the Test Laboratory was the first building to be designed and constructed at SLAC. As a research facility, the building is sited near the Central Laboratory and incorporates similar architectural features, viz., roof overhang, concrete tile veneer on columns, and a roof sight screen. Figure 27-11 shows a view of the Test Laboratory from the center of the quadrangle. It is flanked on the left by the Central Laboratory and on the right by the Administration and Engineering Building.

As shown in Fig. 27-12, the Test Laboratory plan consists of a high bay wing, 90 ft × 250 ft × 30 ft high, and a two-story wing, 75 ft × 125 ft × 27 ft high, connected by a one-story link 25 ft × 50 ft. One longitudinal bay of the

Figure 27-11 Test laboratory—view from central quadrangle.



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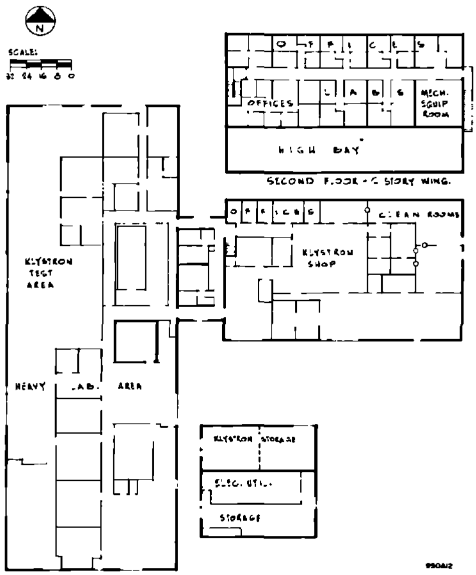


Figure 27-12 Floor plan of test laboratory.

two-story wing, 25 ft × 125 ft, reaches the full height of the building and is equipped with a 3-ton overhead crane. This area has been used as a machine and assembly shop for klystrons. The remainder of this wing is occupied by offices and light laboratories.

The main high bay wing is provided with two 10-ton overhead traveling cranes. During development and construction of the accelerator, this area was principally used for klystron and modulator development and testing. During the operational phase, some of this space has been assigned to accelerator physics, electronics, and research activities, but the development, testing, and maintenance of klystrons continues to occupy a large part of the building.

Electric power for the Test Laboratory is provided from a substation area architecturally integrated with the building. This wing includes a utility area 60 ft × 35 ft with a cable vault of similar dimensions and a storage area for klystrons 60 ft × 25 ft. The lighting in the Test Laboratory is generally fluorescent and the office areas are air-conditioned.

ADMINISTRATION AND ENGINEERING BUILDING. This building provides office accommodations for Business Services Division functions including purchasing, accounting, plant, budget, and safety offices; Administrative Services Division functions including public information, personnel, reports, technical information, and medical department offices; and Technical Division departments, including technical planning, plant engineering, mechanical engineering, and research area department offices.

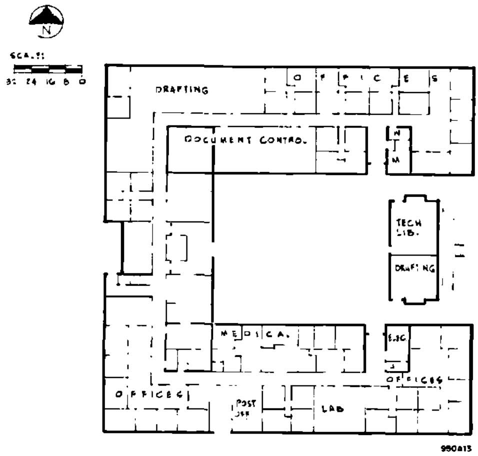
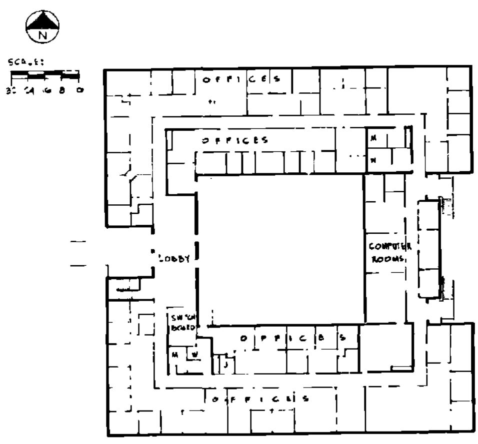


Figure 27-13 First-floor plan of administration and engineering building.

Figures 27-13 and 27-14 are floor plans of this building. The building is in the form of a hollow square with an interior court 70 ft × 70 ft and external dimensions 175 ft × 175 ft. There are two stories, both with direct access to ground level. The reception area for visitors is at the upper level, but the entrance towards the quadrangle, cafeteria, auditorium, and Central Laboratory is at the lower level, supplemented by a portico having an exposed double staircase ascending to the upper level. This staircase and view of the building as seen from the center of the quadrangle is shown in Fig. 27-15.

Figure 27-14 Second-floor plan of administration and engineering building.



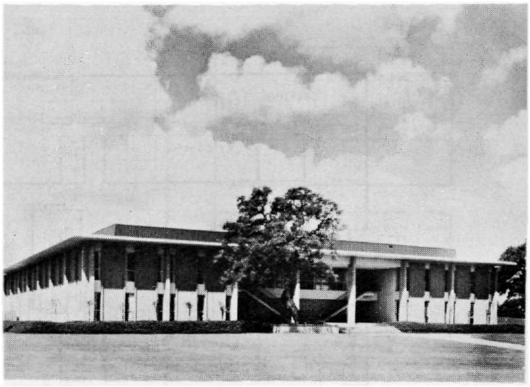


Figure 27-15 Administration and engineering building.

The structure is a reinforced concrete frame with precast concrete tile veneer on exterior columns, wall panels of insulated ribbed metal siding and aluminum windows. Lateral forces are resisted by reinforced concrete, shear walls at toilets and stair wells. The roof and wall slabs are of reinforced concrete and the roof overhangs the walls approximately 4 ft. Interior wall surfaces and partitions are of gypsum wallboard with glazed areas to permit light to enter interior offices.

The lighting and air-conditioning system is integrated with a modular suspended T-bar and glass fiber ceiling, permitting relocation of office partitions. This arrangement has presented many acoustic problems due to noise transfer between offices. In later buildings, particularly the Central Laboratory, some improvement has been accomplished by using ceiling board of higher density.

AUDITORIUM AND CAFETERIA. In early studies of the site planning, these two buildings were separately located on the north and east sides, respectively, of the central quadrangle. They were subsequently combined to provide an integrated center for seminars, to leave the north side of the quadrangle open for a possible future major building, and to commit this desirable site to a use other than offices or laboratories. The site is an oak-covered knoll with a view of the central campus, glimpses of the research area, and commanding views of the surrounding countryside. Figure 27-16 shows a view of this building across the quadrangle from the steps of the Administration and Engineering Building.

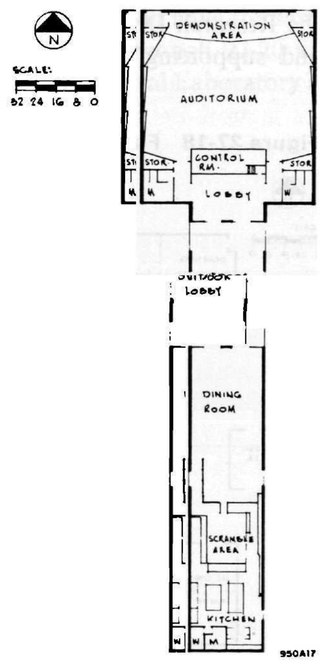
The program included an auditorium with 300 seats, lobby, toilets, control room for audio–visual equipment, dining room, kitchen, and "scramble"-type self-service cafeteria area. As shown in Fig. 27-17, the two functions, auditorium and cafeteria, are joined by a partially enclosed lobby used

Figure 27-16 Auditorium and cafeteria.

for occasional assemblies and exhibitions. An area east of the building has informal paving and is used for outdoor eating when weather permits.

The buildings are constructed with reinforced concrete foundations, load-bearing concrete masonry walls, steel roof girders over the auditorium, glued laminated wood girders elsewhere, 3-in. × 6-in. tongue and groove wood

Figure 27-17 Floor plan of auditorium and cafeteria.



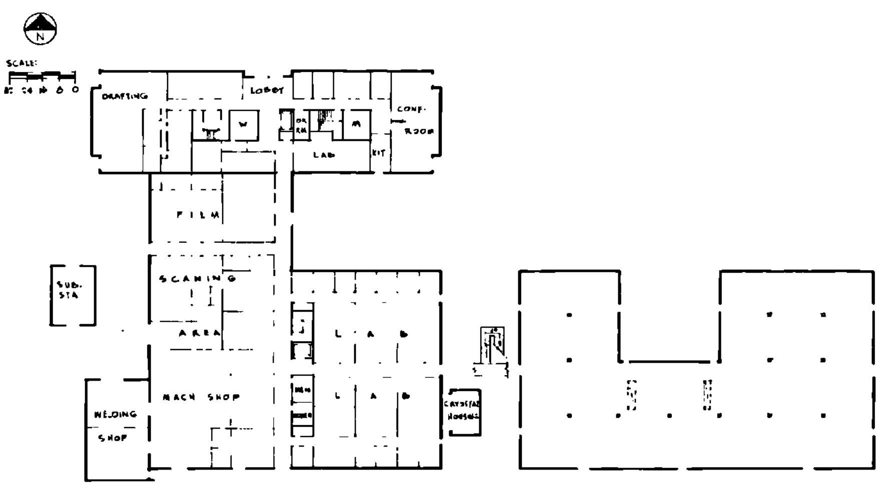
decking throughout with suspended ceiling in the auditorium and toilets and exposed wood decking elesewhere. Windows and exterior doors are of aluminum. Lighting in the cafeteria is fluorescent. In the auditorium, fluorescent tubes in 4-ft diameter flush-mounted ceiling fixtures provide lighting for lectures and seminars. Supplemental incandescent lighting is provided for blackboards and aisles.

Considerable attention has been given to auditorium seating arrangements to ensure good sight lines, comfort, and ease of access. The floor is stepped with ten risers, the lower five, $10\frac{1}{2}$ in., and the upper five, 15 in. The seat platforms are 3 ft, 8 in. wide. A continuous table 2 ft, 5 in. high on pipe legs is placed along the front edge of the platforms. The seats pivot on pipe supports and also have a few inches slide action. Fabric upholstery is used over polyurethane foam on a moulded glass fiber shell. The continuous table is provided with 24-V lamps for note-taking at each seat position and these are individually switched. The table surface is white linoleum..The auditorium is equipped with double-hung blackboards providing 320 ft^2 of visible surface, and a motor-operated projection screen. The acoustics of the auditorium provide good audibility of a normal human voice with reinforcement.

The cafeteria service is operated by a private subcontractor, using kitchen equipment provided by SLAC. The dining room has an area of 1900 ft^2, a scramble area of 550 ft^2, and kitchen area including storage and dishwashing of 1000 ft^2.

CENTRAL LABORATORY. The Central Laboratory serves as headquarters for the Research Division and includes the director's office, offices for physicists and supporting engineers and clerical staff, the main SLAC library, light

Figure 27-18 First-floor plan of central laboratory.



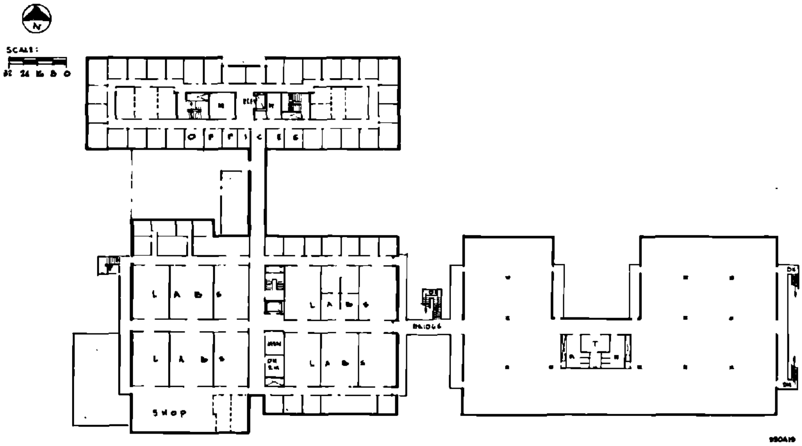


Figure 27-19 Second-floor plan of central laboratory.

laboratories, and machine shops. Offices and the library are placed in a three-story office-type structure, 49 ft × 171 ft × 38 ft high. Laboratories, related offices, and machine shops occupy a two-story wing, 96 ft × 143 ft × 25 ft high. The two wings are linked by a one-story area 48 ft × 70 ft, on the roof of which is an enclosed corridor joining the second floors.

A two-story addition, 96 ft × 175 ft, scheduled for completion in late 1968, will be constructed adjacent to the existing two-story wing. The addition will have a small basement area for storage but otherwise will have the same heights as the existing two-story portion. Figures 27-18 through 27-20 are floor plans of the above described areas. A view of the Central Laboratory as

Figure 27-20 Third-floor plan of central laboratory.

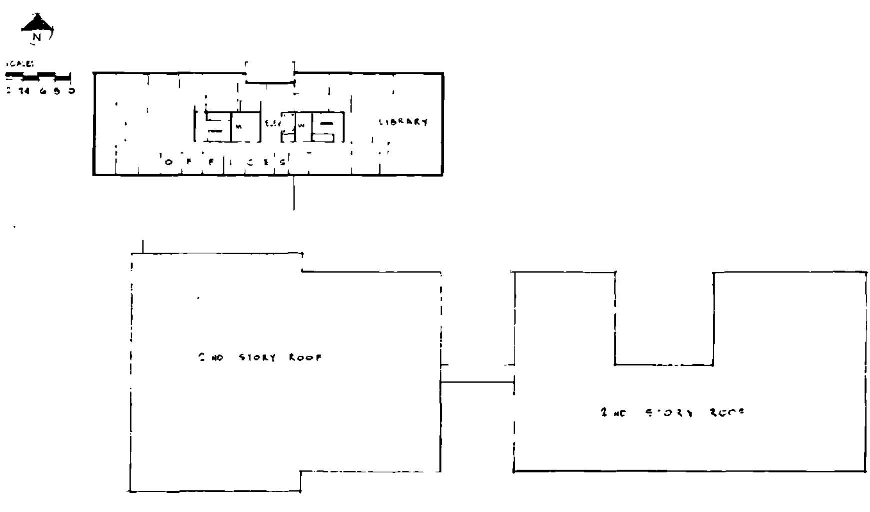


Figure 27-21 Central laboratory.

seen from the cafeteria with the Test Laboratory in the right background is shown in Fig. 27-21.

The addition mentioned above will be constructed with reinforced concrete framing and two-way ribbed slabs. Lateral forces are carried by the perimeter concrete walls formed to match the ribbed metal siding of the existing building. This structural system has been selected to provide maximum flexibility in placing interior partitions.

Services in the addition have been designed for ease of alteration and maximum flexibility. The mechanical ventilation system will provide heating and some cooling, and individual fan coil units in the offices and laboratories will provide the supplemental cooling. The fluorescent lighting fixtures will be chain-supported, plugged in a bus duct, and switched by pull cords. Similarly, laboratory equipment will be plugged into separate overhead bus ducts.

TEMPORARY COMPUTER FACILITY. The temporary computer facility serves as the computation center for the project and houses staff offices plus computers, key punches, electronic scanning equipment, service and dispatch areas. The facility is situated south of the Central Laboratory and adjacent to the planned site for the permanent computation facility.

The principal building in the facility houses the computer. It consists of sixteen prefabricated classroom-type units placed on elevated concrete perimeter footings with one permanent partition down the middle formed by the ends of the units. The building units are 10 ft, 3 in. × 32 ft each, and the complex is 82 ft × 64 ft and contains 5248 gross ft^2. The elevated footings permit underfloor access required for power distribution to the computer equipment. This Computer Building, as well as the surrounding staff offices of similar construction, are shown in plan on Fig. 27-22.

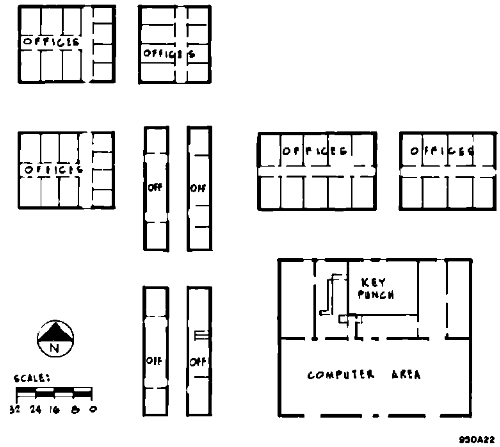


Figure 27-22 Floor plans of temporary computer facility building.

The prefabricated units have a structural steel frame augmented with wood roof joists and sidewall studding. Exterior end walls are steel framed, accommodating windows and doors. The roofing consists of metal sheathing. Floor joists of steel support a plywood floor covered with vinyl asbestos floor tile. The suspended ceiling houses recessed light fixtures and air-conditioning ducts. The $1\frac{1}{2}$-in. thick, glass fiber, ceiling panels serve as roof insulation.

Air conditioning is accomplished by roof-mounted heat pumps. In the case of the Computer Building, heat pumps air-condition the north half of the building, but the south half, containing the largest heat load, is serviced by a 45-ton air-cooled refrigerant compressor alongside the building. This unit supplies refrigerant to direct expansion coils in two roof-mounted fan-coil units. The system is automatically controlled to maintain desired temperature and humidity settings.

Power for the computer equipment is supplied by two special shielded transformers of 90 kVA each, located on pads outside the building. Conventional power requirements are serviced by a separate distribution system.

A raised computer-type floor has been installed in the south half of the Computer Building. This floor consists of 2 ft square removable metal panels supported by adjustable jacks. It provides space for interconnecting computer cabling.

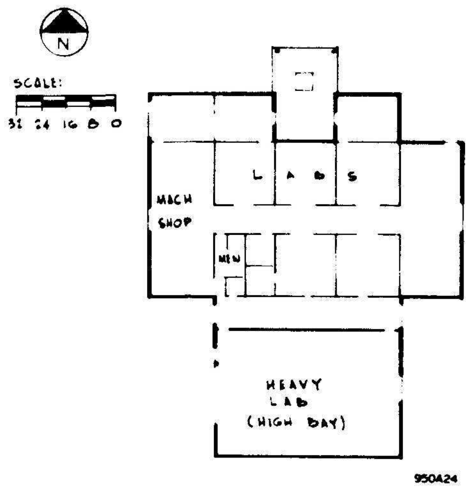
CRYOGENIC LABORATORY. The research programs at SLAC include many facilities for low-temperature development work on accelerators, magnets, bubble chambers, and other devices. This work is performed in this heavy laboratory-type building. For functional reasons, the site is related to the research area. Because of the elevation of the site and the required building height for crane purposes, this building posed architectural problems and

Figure 27-23 Cryogenic laboratory.

these were increased by the need to provide a pitched roof and roof fans for hydrogen exhaust. The solution provides a high bay roof with a one-in-ten slope, without roof overhang, thereby reducing the building profile, and a low bay area containing laboratories with typical roof overhang and sight screen around roof-mounted mechanical equipment. Figure 27-23 shows these architectural considerations.

The high bay area is 41 ft × 60 ft with an eave height of 32 ft, 6 in., and is equipped with a 20-ton overhead traveling crane, with hook height of 25 ft. The high bay is separated from the remainder of the building by a 12-in. thick reinforced concrete wall and a 7-ft wide service corridor. A floor plan of the structure is shown in Fig. 27-24. The structure of the building is of steel, with columns and spandrels exposed as architectural elements. The

Figure 27-24 Floor plan of cryogenic laboratory.



walls are of ribbed metal siding in the high bay, and gypsum wallboard on wood studs elsewhere. All walls are insulated with exposed, rigid, Styrofoam material in the high bay and insulation between wood studs. The metal siding at the high bay is attached to the structure with permanent fastenings on one entire edge for hinge action, and elsewhere with explosion-vent fasteners for immediate pressure release. Floor slabs are concrete.

As an additional safety measure, membrane roofing of polyisobutylene is used instead of a flammable type. The roof insulation applied over the steel decking is of asbestos fiber type. The finish color of the roof is terra cotta to match the other buildings.

Lighting throughout the building is fluorescent. Heating and ventilating are provided by roof-mounted equipment utilizing hot water from the central system.

Shops and support buildings (JWC)

The shops, together with the General Services Building, are situated in a strip of land approximately 400 ft × 1700 ft, immediately north of the klystron gallery. Figure 27-25 shows a photograph of the shops complex. The buildings are surrounded by paved yards of asphalt concrete with minimum widths of 50 ft. The yards are used for material storage, assembly, parking for service vehicles, and sites for temporary relocatable buildings. By the use of mounds of earth, grade changes, and dense landscaping, a considerable degree of screening has been achieved.

The architectural expression used for the shops includes exposed structural steel frames, ribbed metal siding, roof overhangs, aluminum sash, and metal sight screens around roof-mounted mechanical equipment.

The interior face of the ribbed metal siding is covered by an 8-ft high wainscot of hardboard. This provides a clean working surface, protection against mechanical damage, and a measure of thermal insulation at work level.

Figure 27-25 Shops complex.

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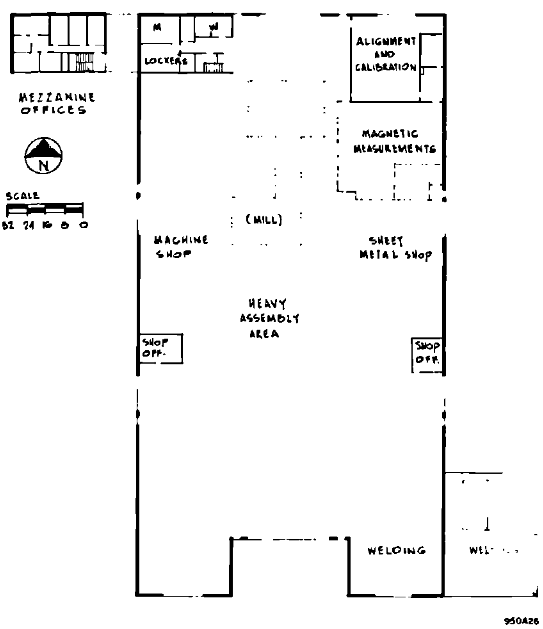
Lighting in the shops is by fluorescent fixtures, generally mounted just below the roof to provide maximum head room for traveling cranes. In some areas, such as the Electronics Building, lights are mounted at approximately 10 ft above the floor together with plug-in bus ducts for assembly testing and calibration of electronic devices. Heating and ventilation of the shops is by hot water unit heaters using hot water piped from the Central Utility Building. Services including compressed air, low conductivity water, cooling tower water, and domestic water from central sources are distributed in the buildings according to specific needs.

HEAVY ASSEMBLY BUILDING. This building houses machine shop, welding, and assembly functions of greater capacity than the other shop buildings. The effort in this building is principally in direct support of the experimental physics program.

During construction of the accelerator, approximately one-third of the building was used for magnet assembly, alignment, and testing. This work took place in the east bay of this facility and required the use of a temperature-controlled room with an area of about 1500 ft^2 and power supplies and test manifolds, all served by a 20-ton overhead electric crane. The remainder of the building is occupied by heavy machine tools served by a second 20-ton crane and a precision erection floor, served by a 50-ton bridge crane with two 25-ton trolleys with hook heights of 32 ft.

Figure 27-26 Floor plan of heavy assembly building.



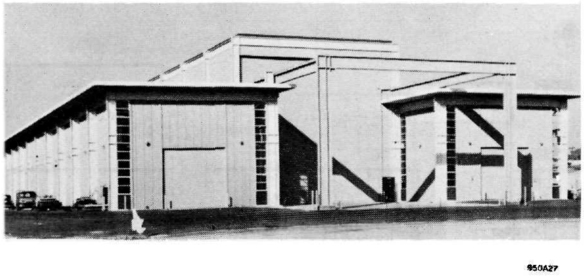


Figure 27-27 Heavy assembly building.

The building consists of a center bay 50 ft × 225 ft and two side bays each 40 ft × 250 ft (see Fig. 27-26). The crane supports in the center bay are extended 50 ft through a large 40-ft × 40-ft rollup door to the exterior to handle large loads, as shown on Fig. 27-27. The gross area of the building is 34,850 ft^2 including 1000-ft^2 office mezzanine and 1000 ft^2 for toilet and locker facilities. The clear interior height of the center bay is 43 ft and 25 ft, 3 in., in the side bays.

The heavy-duty floor is of reinforced concrete, 9 in. thick, over 6-in. thick aggregate base and was designed to provide for uniform floor loading of 5000 lb/ft^2 on a 5-ft square crib. The major machine tools are placed on massive concrete bases isolated from the structure by means of cork insulation.

The building is provided with electric power from a detached substation building. Heating and ventilation are by means of hot water unit heaters and low-profile gravity roof ventilators augmented by operable sash. Welding and other shop gases are piped to the building from a gas storage facility in the building yard.

FABRICATION BUILDING. The Fabrication Building accommodates a medium machine shop, horizontal and vertical brazing furnaces, assembly space, metal-cleaning and plating facilities, and installations for testing and tuning waveguides. All the components of the accelerator proper were manufactured, tested, and/or assembled in this building. Basic materials and components, such as high-purity copper stock, extruded aluminum support girders, vacuum pipes, and cooling-water pipes were processed, machined, and assembled, finally emerging as a 40-ft long accelerator segment ready for installation.

The main building (see Figs. 27-28 and 27-29) consists of three bays, each 40 and 120 ft with a clear height of 22 ft, 6 in. There are four minor external additions—the furnace building, cleaning building, and saw shop. The cleaning building is 42 ft × 75 ft × 12 ft high and accommodates tanks for metal cleaning. This area, together with an area 40 ft × 60 ft in the Fabrication Building, provides an integrated metal-cleaning and plating activity. The furnace building is 20 ft × 20 ft × 20 ft high, over a pit 18 ft deep. It

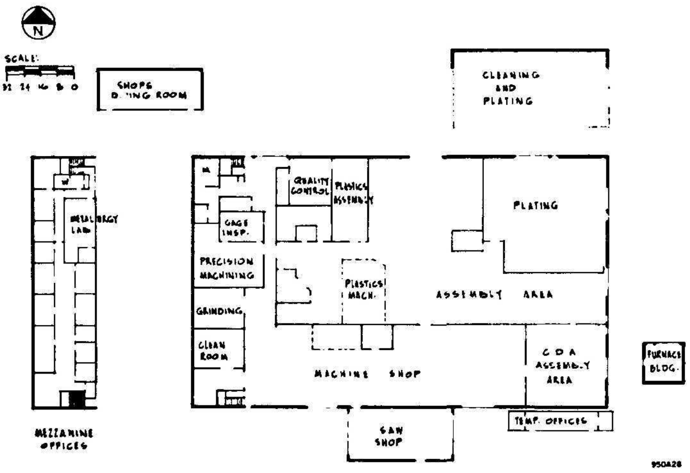


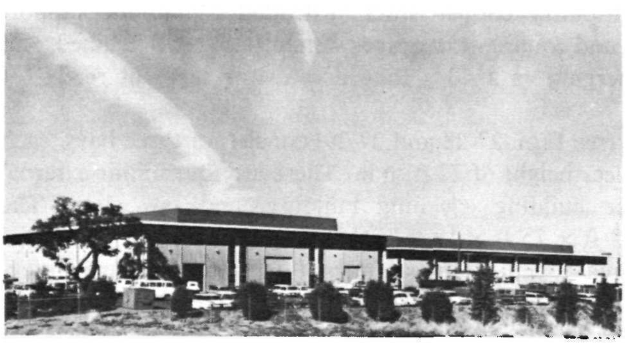
Figure 27-28 Floor plan of fabrication building.

houses an electric pit furnace which was used for brazing subassemblies of the accelerator. The saw shop, 20 ft × 50 ft × 12 ft high, houses saws for cutting metal stock. The Fabrication Building is equipped with two 5-ton electric overhead traveling cranes.

During construction of the accelerator, large quantities of hydrogen were used as fuel for brazing. Other gases, such as oxygen and nitrogen, were used in large quantities for welding and inert environments. To support these activities, an outdoor gas storage area was provided with underground piping to the Fabrication Building for distribution.

ELECTRONICS BUILDING. The Electronics Building has the same overall dimensions and structural form as the Fabrication Building. In the original SLAC space layout, one-half of this building was to be devoted to stores, and it was known as the Electronics and Stores Building. However, as the

Figure 27-29 Fabrication and electronics buildings.



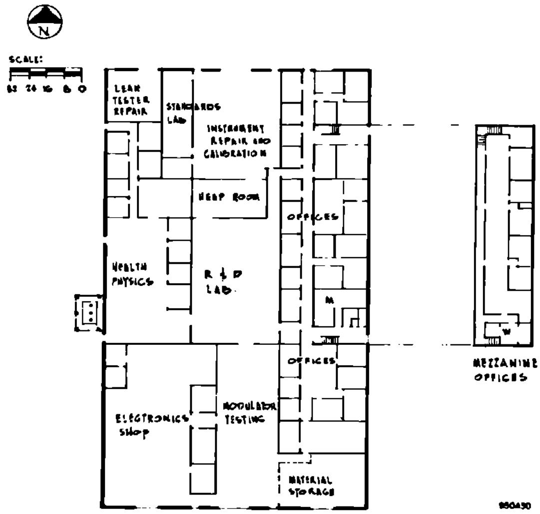


Figure 27-30 Floor plan of electronics building.

space requirements of electronics became larger, general stores were moved on an interim basis to a temporary metal building. Most of the Electronics Building was occupied by electronics and health physics personnel, including physicists, engineers, and technicians. Figure 27-29 shows a photograph of this building and the Fabrication Building, and Fig. 27-30 shows the floor plan to accommodate these activities.

SHOPS DINING ROOM. This small building provides lunch room facilities in a landscaped court between the electronics and fabrication buildings. To provide a change of environment from the working areas, the lunch room is constructed of concrete masonry and heavy timber, similar to the cafeteria.

The dimensions of the shops dining room are 20 ft × 50 ft × 11 ft high, with a covered terrace 14 ft × 43 ft for outdoor eating. The room is equipped with tables and chairs and several vending machines.

CRAFTS SHOP. This building occupied by crafts shop is 100 ft × 150 ft × 13 ft high (see Fig. 27-31). During construction of the accelerator, this building was occupied by ABA, the architect–engineer–manager for construction of the conventional facilities, and it was called the Construction Office Building. Initially, the 1961 SLAC space plan indicated that a portion of the machine shop area in the Fabrication Building would be available for crafts after completion of the accelerator; however, the machine shop and assembly requirements of the research program have shown that all the existing shops are required for future programs. Consequently, the former Construction Office Building was converted to shops for carpenters, electricians, plumbers, painters, vacuum equipment maintenance, and for the associated office staff.

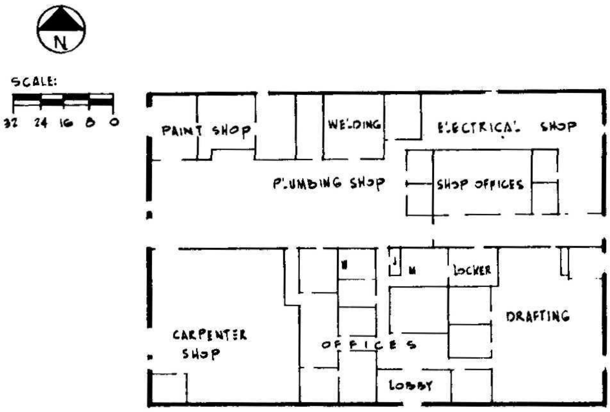


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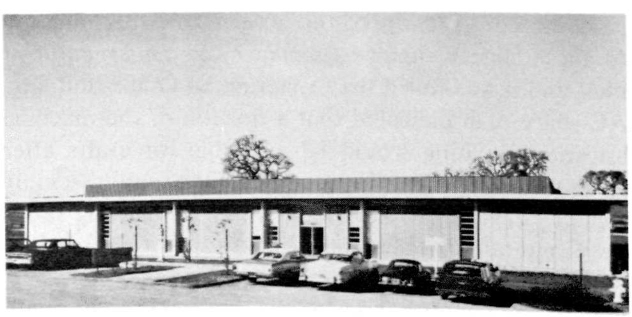
Figure 27-31 Floor plan of crafts shop building.

In land use planning, this building is ideally situated as a part of a support complex including the crafts shop sandblasting facility, the General Services Building, and a common storage yard. Its conformance to standard SLAC architectural expression can be noted (see Fig. 27-32).

GENERAL SERVICES BUILDING. This building is due to be completed in the latter half of 1968 and will provide accommodation for central stores, shipping and receiving, property control, salvage, vehicle maintenance, transportation, labor crew, gardeners, and tool storage. The site is adjacent to the crafts shop, which allows joint use of service yards and construction material storage facilities. The General Services Building, however, has the distinction of being the only Stanford University structure adjacent to a state freeway and for this reason, considerable care was necessary in its planning and design.

Figure 27-32 Crafts shop building.



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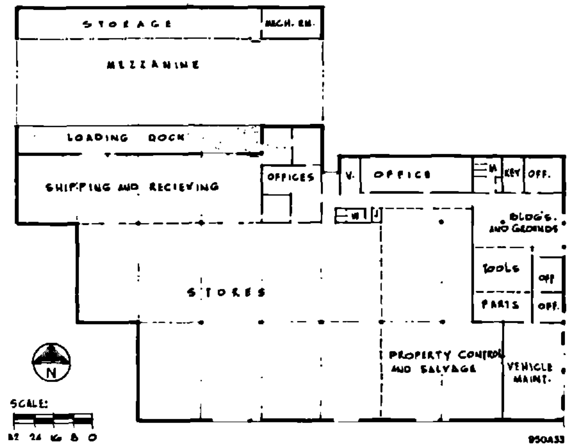


Figure 27-33 Floor plan of general services building.

The building plan (see Fig. 27-33) includes 24,000 ft^2 of fully enclosed building 24 ft high, 7000 ft^2 of covered but not fully enclosed sheds, and 41,000 ft^2 of fenced yard for outdoor storage. To accommodate the building program and to present a satisfactory exterior, the storage sheds and main building create a screen around the storage yards. Earth mounding and landscaping with fast-growing pines and eucalyptus supplement the screening.

Architectural details include exposed structural steel framing, ribbed metal siding, roof overhang, operable aluminum sash, and a sight screen at the roof to screen present and future roof-mounted equipment. The roofing is of builtup asphalt and gravel over an insulated ribbed steel deck. The columns and spread footings are designed to support future mezzanine loads. Interior partitions are made of wood stud and gypsum wallboard for offices and fire separations. Storage areas are defined by chain link-type fences. The loading dock is equipped with load levelers and scale, and ramps are provided for use of fork lift trucks.

The vehicle maintenance area will be principally used for servicing fork lift trucks and other special vehicles, and is provided with a fuel pump, 10,000-gal underground gasoline tank, service pit, steam cleaning, compressed air, lubrication, and battery-charging facilities. Accommodation in the sheds includes a masonry block building for storage of volatile solvents, a fenced concrete slab at yard elevation for hazardous chemicals, with sump for accidental spillage, and a raised, fenced, concrete dock for storage of gas bottles. Lighting is fluorescent throughout and heating is by gas-fired unit heaters in high bay areas and by gas-fired multizone units for offices.

CENTRAL UTILITY BUILDING. This building, located in the Test Laboratory yard, is the heart of the utility complex serving the buildings of the campus area (Test Laboratory, cafeteria–auditorium, Administration and Engineering Building, Central Laboratory, Central Control Building, computation facility, and Cryogenic Laboratory). It houses two water chillers and pumps, two hot water generators and pumps, two air compressors, and space for an extra unit of each of these.

It is a steel-framed, steel-sided building conforming with the standard SLAC architectural detail. It is 60 ft × 60 ft in plan, 16 ft high, and divided in half by a concrete block wall to form two rooms. One room is for the hot water generators and the other for mechanical equipment. The latter room is further partitioned to form an 8-ft × 12-ft shop and an 11-ft × 12-ft office. Access to the hot water generator room is through a 12-ft wide door, 8 ft high. A 7-ft × 8-ft door serves the machinery room. This building has a gravity ventilation system with two $7\frac{1}{2}$-ft × $9\frac{1}{2}$-ft roof vents and louver panels in the east and west walls.

ELECTRICAL SUBSTATION BUILDINGS. The major power substations of the project are all housed in covered steel buildings with the exception of the master substation which is enclosed in an open fenced area, but with its switchgear housed in a steel building. Buildings are provided for the Test Laboratory, beam switchyard, and research area substations, plus the master substation switch-house. They function as shelters for foul weather protection, maintenance, and architectural sight screens. To some extent, they permit somewhat lower equipment costs. All are gravity-ventilated (roof vents and wall louvers) and conform to standard SLAC architectural detail.

The buildings house forced air cooled, dry-type transformers, secondary switchgear, and related equipment as follows:

- Test Laboratory—two 2667-kVA substations
- Beam switchyard—two 2000-kVA substations; two 1333-kVA substations
- Research area—four 3333-kVA substations and one 5000/6666-kVA substation plus 12-kV switchgear
- Master switch-house—instrumentation power transformer only, plus sixteen 12-kV breakers and metering equipment.

The Test Laboratory substation is located adjacent to that building. It is a two-story building, 34 ft × 60 ft in plan. The lower floor is a concrete underground structure, $9\frac{1}{2}$ ft high, functioning as a cable vault for the underground duct banks entering it. The upper floor is a conventional SLAC steel building with a height to tops of roof beams of 12 ft, 8 in., to 13 ft. Its floor is a 9-in. reinforced concrete slab. Its equipment door is 8 ft wide by 10 ft high.

The beam switchyard substation is a single-story steel building, located near the beam switchyard's Data Assembly Building. Its interior height is 14 ft, and equipment doors are 8 ft × 9 ft.

The Research Area Substation Building is similar in construction and of equal height, but is 83 ft, 4 in. × 38 ft, 6 in. in plan. It is distinctive in being perched at the top of 40-ft high retaining walls, overlooking the research area yard. It was desired to have it somewhat centrally located with respect to research loads without having it located within the yard itself, where it would form a restriction to research activity. Cables enter and exit via a 9-ft × 9-ft pit in the floor, 8ft deep. The major research loads reach the yard through a 10-ft × 3-ft niche in the retaining wall face. Doors 8 ft × 8 ft, at either end, allow movement of equipment.

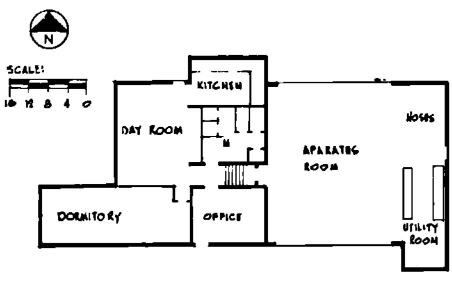
The master substation switch-house is a two-storied structure situated south of the klystron gallery and in its fill bank, with the lower floor having access to the substation yard and the upper floor opening onto the gallery level. The building is 30 ft × 50 ft with heights of 13 ft for the lower cable gallery and 15 ft for the upper switchgear room.

FIRE STATION. The fire-fighting services at SLAC are provided by the Stanford Fire Department. The SLAC Fire Station is a substation of the Stanford Fire Department.

The site is central with the final selection based on ease of access to possible disaster areas. The building program (see Fig. 27-34) required an apparatus room to house two vehicles, a 500-gal/min pumper and a 1000 gal/min triple combination pumper. It also provided living accommodations for a shift of one officer and three firemen, and a utility room for minor repairs, hose racks, and dryer. The gross building area is 2600 ft^2, and its construction has reinforced concrete spread footings, grouted exposed concrete masonry walls, laminated wood roof girders, a plywood deck, builtup roofing, wood stud and gypsum wallboard partitions, operable aluminum sash. The apparatus room doors are of translucent fiberglass and are electrically operated. Heating is by hot water unit heaters in the apparatus room and by baseboard convectors elsewhere.

The Fire Station communication systems include radio, telephone, and fire alarm. Fire alarm boxes are placed at convenient locations throughout the site. Alarms originating at SLAC are received at the main Stanford

Figure 27-34 Floor plan of fire station.



University Station and equipment at SLAC is dispatched by instruction from this station.

Fire protection at SLAC includes the services of the Stanford Fire Department, fire hydrants connected to the domestic water system, automatic wet sprinkler systems in most buildings, rate of rise heat detectors in others, and portable CO_2 extinguishers distributed throughout the buildings, all in accordance with the AEC design criteria, Uniform Building Code (Fire Zone III), and other recognized standards, such as those of the National Board of Fire Underwriters. The last-mentioned is used as a guide only because SLAC buildings are self-insured by the AEC.

The water mains used for fire protection include a 12-in. loop around the Administration and Engineering Building and Test Laboratory, a 10-in. loop along the accelerator between Sectors 7 and 30, and 8-in. loops serving the Central Laboratory, research area, Cryogenic Laboratory, and shops complex. Sectors 1 through 6 are served by a single 6-in. water main. Automatic fire sprinklers are installed in all required areas, except where their use in conjunction with electrical installations would actually increase the hazard. In these cases, rate of rise detectors are used.

Accelerator buildings (JA, RSG, FFH, CRJ)

The housing of the accelerator consists of five principal structures plus a small structure housing the alignment system laser.

1. *The accelerator housing*—a concrete tunnel of rectangular cross section, 2 miles long, enclosing the accelerator tube and its support and alignment pipe. It is situated in an earth fill directly below the klystron gallery with its ceiling 25 ft below the gallery floor.
2. *The klystron gallery*—a steel building, probably the world's longest, which houses the accelerator's klystrons, modulators, and all other associated components.
3. *The central control building*—from which the 10,000-ft accelerator is operated.
4. *The beam switchyard housing*—a large, concrete structure of complex shape under 32 ft of earth and concrete.
5. *The data assembly building*—from which the beam switchyard equipment is operated.
6. *The laser room*—a small steel underground capsule located at the level of the accelerator housing and at the east end of the accelerator.

The accelerator tube and the alignment pipe are supported by the floor of the accelerator housing. The stability of this structure is an important factor in the operation of the machine. Soil mechanics, geology, hydrology, and careful control of concrete construction were key design considerations in securing this stability.

The klystron gallery houses the electrical and electronic components supplying energy to the machine as well as vacuum, cooling, and control systems necessary to its function. Connections to the accelerator are made through vertical 27-in. diameter steel pipe service shafts located at approximately 20-ft intervals over the length of the accelerator. There are also vertical manway shafts between the two structures, located near the end of each of the thirty sectors.

The Central Control Building is located adjacent to Sector 27, one-tenth of the accelerator's length from its junction with the beam switchyard. This point was selected as an optimum point for economy of control cable lengths for the overall length of the machine from main injector to end stations.

The beam switchyard housing forms a system of large concrete ducts for the several beam runs into the research area. It houses the components controlling these research beams. Steering and collimation of these beams result in energy losses from the beams causing radiation and heat transfer problems which, in turn, complicated the design of the structure.

The functions of the beam switchyard are controlled from the Data Assembly Building which also houses the magnet power supplies. It receives signals from the equipment in the beam switchyard and the end station buildings which enable operators to provide beams refined to specifications necessary for the research experiments in progress. The Data Assembly Building also receives from and transmits to the Central Control Room appropriate control and status signals necessary for beam control and coordination. These facilities are described more fully in the following pages.

ACCELERATOR HOUSING. The functions of the accelerator housing are to provide a stable support for the accelerator, a corrosion-inhibiting environment, and, together with the superimposed earth-fill, adequate radiation shielding.

The basic criteria for the accelerator housing suggested a box culvert-type section with internal height of 10 ft and width of 11 ft. The required accuracy of alignment was to be within $\frac{1}{4}$ in. of a straight line for the entire length of the accelerator.

The environmental radiation standards adopted by SLAC required that the housing be covered by 23 ft of earth. Because of the rolling terrain of the accelerator alignment, a cut and fill technique was selected. Because of existing contours and geology, this meant that in some places cuts of up to 80 ft and compacted fills of up to 30 ft of height were necessary to obtain the correct elevation for the housing foundation. A study of the excavation and fill requirements for the entire SLAC building program, including shielding beams at the research area, indicated that economies would be possible if the accelerator housing were constructed with a 0.5% decline from west to east. The klystron gallery follows the same slope, with the structure perpendicular to the incline.

During the planning phase of the accelerator, other public agencies proposed major construction projects in the area which would affect construction at SLAC. First, construction of the Junipero Serra Freeway (Interstate Route 280) included a bridge crossing over the accelerator in the vicinity of Sectors 25 to 26. With the cooperation of the State of California Division of Highways, this bridge was completed in advance of the road construction and before completion of the accelerator.

The bridge foundations used pile-supported footings spaced sufficiently far from the accelerator housing to avoid appreciable influence on earth pressures against the housing. Vibration studies made on a similar bridge in the Bay Area indicated that traffic vibrations would not affect accelerator operation.

Second, the Corps of Engineers has proposed a 100-ft high dam on San Francisquito Creek for flood control. If the dam is constructed, its reservoir area would extend to the accelerator earthwork between Sectors 11 and 21, with a possible water elevation of 287 ft adjacent to a minimum accelerator housing floor elevation of 265 ft. It was estimated that maximum flood levels would be of short duration and that the normal water level would be below that of the housing floor. Studies of local geology and soil mechanics indicated that the stability of the housing and earthwork would not be adversely affected by the construction of this flood control dam, although if it is constructed in the future, the accelerator earthwork would probably have to be protected by rip-rapping the slopes.

The accelerator housing is alternately on cut and fill, with cut areas predominating. In areas of cut, the bedrock foundation materials provided fair-to-excellent conditions for minimum settlement. In the fill areas, however, softer soil layers were overexcavated and replaced with compacted fills of sandy materials. Special treatment in the area of Sectors 18 and 19 in particular was necessary because predicted settlements would have been excessive on account of the depth of the alluvium and open fractured claystone and the required depth of fill. To reduce settlement substantially in this area, the unsatisfactory materials were removed, and prior to construction of the housing, replaced with suitable compacted fill. A surcharged condition was then created, by placing compacted fill to the elevation of the top of the accelerator housing and uncompacted fill to a level 10 ft above the klystron gallery floor level. The surcharge remained in place for approximately 6 months to accelerate consolidation of the fill and underlying earth and rock. Similar but less extensive procedures were used in other problem areas.

The typical box section of the housing has 18-in. thick sidewalls, 24-in. roof slab, and 27-in. floor slab. The section is designed for earth loads without hydrostatic pressure because drains are provided at both sides to suppress the water table. The outfalls for this drain system are located so that the effluent can be monitored for radioactivity.

The exterior surfaces of the walls and roof are covered with a 10-mil polyvinyl membrane protected from mechanical damage by $\frac{1}{2}$-in. fiberboard.

The specifications for concrete for the housing were developed to obtain minimum cracking by reducing drying shrinkage and thermal shocks to a practical minimum. Specifications required modified Type II cement with tricalcium aluminate content limited to 6%, tricalcium silicate content between 42% and 50%, and a 28-day mortar strength test of 4500 lb/in^2. A low shrinkage aggregate, crushed granite rock from the Watsonville area, was used. The additional cost for aggregate was approximately balanced by savings in cement quantities.

Concrete temperature at the time of placement was limited to 60°F. During the summer months, this requirement involved addition of ice to the mix. Also, during the summer months, concrete was placed only in the late afternoon and at night time. All concrete was fog spray cured until just before backfilling.

Construction joints are spaced at 80- to 90-ft intervals and these, together with the few minor cracks that developed, were injected with epoxy. In order to provide a dust-free interior and to facilitate cleaning, the interior surfaces are epoxy-sealed.

To provide a conduit for accelerator waveguides, piping for vacuum, and cooling between housing and klystron gallery, 27-in. diameter steel service shafts occur at approximately 20-ft centers. These were placed in oversized holes bored in the shielding fill and welded to a sleeve cast integrally with the roof slab. The bored hole was then backfilled with granular material.

At each sector, a personnel accessway is provided in the form of a vertical steel shaft, 39 in. in diameter, containing a ladder. At less frequent intervals, a material access shaft with internal dimensions of 6 ft × 12 ft is provided. It terminates ouside the klystron gallery.

The accelerator housing is similar throughout its length except at the west end injector, at the access structures at Sectors 10 and 20, and at the east end alignment station. At the west end, the housing is terminated by an exposed portal at ground level.

Figure 27-35 shows the accelerator housing under construction at Sector 20, the two-thirds beam takeoff point. The vertical structure in the center rear of the photograph is a material accessway located at Sector 19.

Because of the radiation level, there can be no personnel in the housing during accelerator operation. Furthermore, the contained air becomes contaminated with short-lived radioactivity. Following shutdown and radiation decay, air is exhaused by fans at alternate personnel accessways. The remaining accessways serve as filtered air inlets.

At Sector 11, additional radiation shielding was required at the positron radiator. This was accomplished by placing a 7-ft thickness of salvaged naval armor plate directly over the housing in the earth fill. In the same area, boron frit (calcium borate) was added to the concrete to reduce the residual radiation in the concrete adjacent to the positron source.

Channel inserts were imbedded in the ceiling at 10-ft centers to support piping and cables. Pairs of channel inserts were imbedded in the floor

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Figure 27-35 Accelerator housing under construction at two-thirds beam takeoff point.

and one wall at 40-ft, 6-in. centers to provide anchorage for accelerator supports.

Lighting in the housing is incandescent with porcelain sockets for 150-W bulbs located on 10-ft centers. In four sectors with highest predicted radiation, mineral-insulated metal-sheathed wiring was used. Elsewhere, polyethylene-insulated wire was used in preference to other organic materials.

KLYSTRON GALLERY. The klystron gallery and end stations A and B are unique elements in the SLAC building program. The end stations are monumental in scale, but only the parapet of end station A is apparent from off-site view. The klystron gallery, 2 miles long, is quite exposed to off-site view and, therefore, was the subject of intensive architectural and structural studies. It was essential in order to minimize cost of such a large building that its elements be simplified and optimized to the best extent possible. A report "Klystron Gallery Design Criteria—Report TR-860-079" (dated June 14, 1962) was prepared by the former Systems Engineering and Installations Department and reflected the minimum requirements as established with the various SLAC occupant groups. It was subsequently furnished to ABA to be used as a guide in the preparation of their design documents. The as-built unit cost of the klystron gallery was \$10/ft^2 exclusive of outside utilities, roadways, and landscaping.

The functional requirements of the building dictated the overall dimensions, 10,081 ft long, 30 ft wide, 15 ft high. The building provides shelter for klystrons, modulators, and associated equipment. The structural frame, including rigid frame bents on 10-ft centers, was designed to support piping, conduits, and cable trays. These contribute uniformly distributed loads of 30 lb/ft^2 for a strip 8 ft wide, the full length of the klystron gallery. The remainder of the roof structure will support 5 lb/ft^2 in addition to normal live and dead loads. The longitudinal walls of the klystron gallery provide support capacity of 300 lb/linear ft for cable trays.

The spacing of the structural bents at 10 ft on center was established to satisfy piping, conduit, and cable tray spans. The construction photograph, Fig. 27-36, shows the structural bent framing. Alternate columns are 8-in. wide flange sections and 14-in. wide flange sections of approximately the same weight per foot. The larger column is exposed on the exterior and the smaller column is concealed by the ribbed metal siding. This arrangement satisfied structural considerations and at the same time provided better external scale with exposed columns at 20-ft centers. Steel purlins, at 7-ft centers, transversely span between 10-in. wide flange top members of the bent framing and support the roof deck.

The length of the klystron gallery is punctuated by alcoves on both sides and these generally occur at sector intervals. An instrumentation and control alcove, 52 ft × 11 ft, occurs at each sector on the north side, opposite a mechanical equipment alcove 41 ft × 11 ft. Electrical equipment alcoves, 50 ft × 11 ft, coupled with screened electrical equipment yards, 30 ft × 11 ft, occur on the south side of even-numbered sectors. Also at each sector, on the south side, there are smaller alcoves, 10 ft × 10 ft, to cover the vertical manway access to the accelerator housing.

The external skin of the klystron gallery consists of two types of ribbed metal. The ribbed metal used for walls on other SLAC buildings is here used for roofing and is extended down as a heavy fascia, 5 ft deep. The lower part of the wall, approximately 9½ ft high, is of ribbed metal with a smaller rib. The heavy fascia is interrupted by the various alcoves which are all enclosed with the small-ribbed metal siding to eave height.

Figure 27-36 Klystron gallery under construction.

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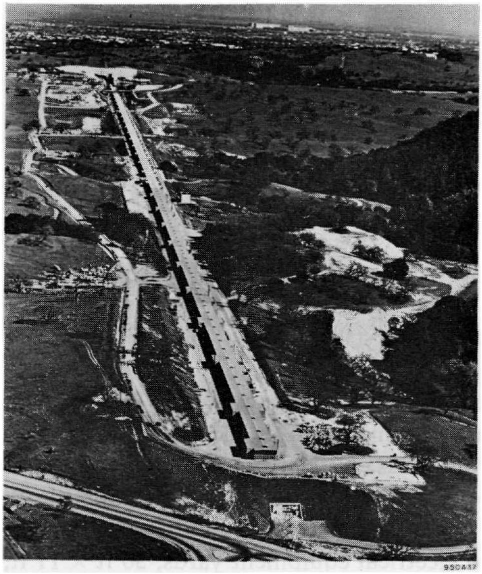


Figure 27-37 Klystron gallery completed.

A regular pattern of painted concrete shear walls occurs on both sides of the klystron gallery. These have vertical grooves at 30-in. centers.

The alcoves, fascia, shear walls, wall, and roof textures present a rhythm of architectural elements that add interest and scale and reduce the monotony of a 2-miles long structure of uniform height. The ridge line of the almost flat roof is punctuated by low-profile gravity ventilators at 70-ft centers. These elements of design are clearly visible in Fig. 27-37, which is an aerial photograph, looking east along the completed klystron gallery, with the injector station, or west end, in the foreground. Visible, also in the foreground below the klystron gallery, is the west entrance to the accelerator housing.

The floor slab is provided with expansion joints at each sector. High quality concrete was obtained by the use of low shrinkage granite aggregate and strict temperature control of concrete during mixing, placing, and curing. All lighting in the klystron gallery is incandescent to avoid interferences with sensitive control systems.

CENTRAL CONTROL BUILDING. The Central Control Building houses the central controls and instrumentation for the operation and maintenance of the accelerator including communication systems linking the Data Assembly Building, the experimental areas, and the accelerator.

The site selection was a compromise of considerations, including economy of cable length, convenience to the Electronics Building for support work, and accessibility for visitors. The contours of the site at the slope of the klystron gallery cut dictated a three-story structure with the uppermost level

Figure 27-38 Central control building.

at the level of the Electronics Building yard and the lowest at klystron gallery level. The exterior face of the third level office wing is depicted in Fig. 27-38.

The uppermost floor has an area of 7000 ft^2 and contains staff offices, toilets, and a large room 54 ft × 90 ft for consoles and electronic equipment racks. The lowest floor area is used for mechanical equipment, battery, and battery chargers. The intermediate floor area, 54 ft × 90 ft, serves as a plenum space and cable distribution gallery for the console and racks above. Floor plans for the building are shown in Fig. 27-39. Connection to the cable system in the klystron gallery is by way of a concrete tunnel, with internal dimensions of 6 ft, 6 in. × 6 ft, 6 in., under the north road alongside the klystron gallery.

The designers of the instrumentation and control systems were concerned about the possibility of RF interference from accelerator component and overhead power line sources, and since the magnitude of these interferences could not be determined accurately in advance of construction, the Central Control Building was designed so that, if necessary, an RF shielding enclosure could be constructed within the building without structural alteration. It was assumed that if this requirement should arise in the future, the rack area and cable gallery would be included within the RF shield. The Central Control Building was, therefore, designed so that the rack area floor system, slab, beams, and columns are electrically isolated from the rest of the building. This was accomplished by provision of a 6-in. gap between the rack area floor slab and the perimeter wall, and a requirement that steel column anchorage for this floor would be at least 2 in. clear of foundation reinforcement. In addition, laminated plastic sheet was placed under the column base plates and sleeves, and washers of similar material were provided at all anchor bolts. The middle floor of the building, known as the cable gallery, serves as a plenum space for the air-conditioning system and also as a work space for installation, maintenance, and modification of the cable systems.

Cable and chilled air to each rack penetrate the rack area floor slab through 6-in. diameter holes at approximately 28-in. centers under the rows of racks. The clear headroom in the cable gallery is 8 ft high, in order to

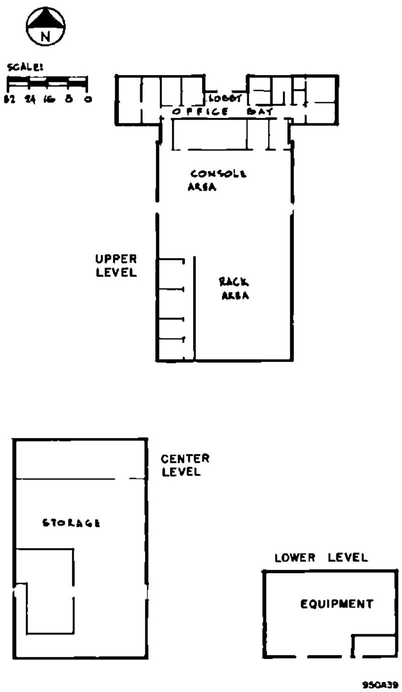


Figure 27-39 Floor plan of central control building.

provide ease of working for installation and maintenance and as a possible expansion space for future control systems.

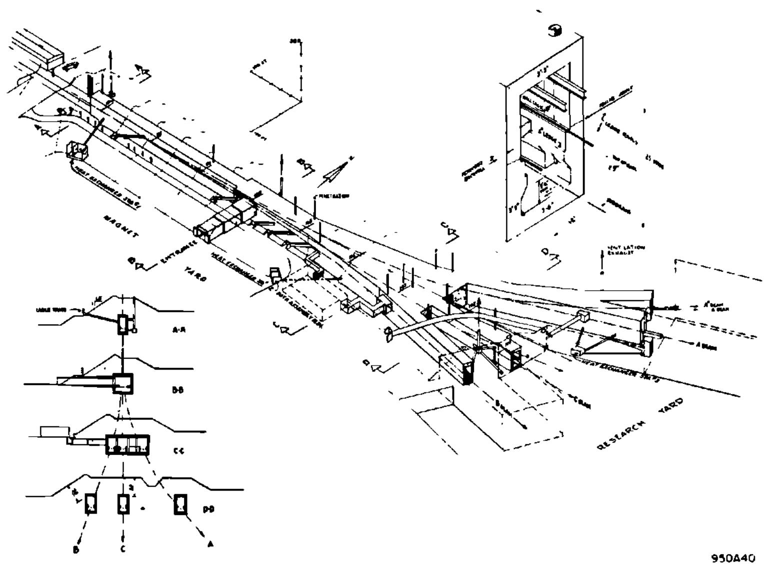
The exterior walls of the Central Control Building, below the rack area floor, are of reinforced concrete. Above this level, the structure, walls, and roof deck are of steel. The columns supporting the free-standing rack area are square steel tubes. All lighting is incandescent in order to minimize possible electrical interference. The building is air-conditioned by utilizing chilled water from a chiller in the mechanical equipment room. Cooling water for the condenser and hot water are from central sources.

LASER ROOM. During design of the machine's laser beam alignment system, it became apparent that it would be necessary to direct this light beam from a laser source at the east end of the accelerator to the injector end. The laser itself would be at beam level and offset to one side where it could be reasonably well shielded from radiation. Since by the time this decision was made the accelerator housing, klystron gallery, and beam switchyard housing were completed, some ingenuity was necessary to provide a suitable underground structure.

Thirty feet beyond the east end of the klystron gallery, an 11-ft diameter hole was drilled to clear the north wall of the accelerator housing. The depth of this hole was 3 ft below that structure's floor level and 38 ft below road level. A steel pipe casing was used to prevent cave-ins. Within this casing, a prefabricated steel housing, 8 ft in diameter and 9 ft high, was installed on a concrete base, with a connection to the accelerator housing through a drilled hole in that structure's wall. Access to the Laser Room is obtained by means of a 3-ft diameter steel pipe shaft enclosing a ladder and connecting to a concrete vault, $8\frac{1}{2}$ ft × $4\frac{1}{2}$ ft × $6\frac{1}{2}$ ft high, near the surface. A conventional manhole provides entry from the road level. The structure was backfilled with pea gravel to the accelerator housing level and with earth above that. As the excavation caused release of some of the easily flowing gravel backfill around the accelerator housing, it was necessary to use an extensive amount of fluid cement and fine aggregate grout to fill voids within the area. Alignment observation is conducted at the west end of the accelerator in a space partitioned, shielded, and air-conditioned in a conventional manner.

BEAM SWITCHYARD. The beam switchyard, an underground concrete structure, is an extension to the 10,200-ft long accelerator housing and terminates near the end stations. The structure contains 31,000 ft^2 of floor area with a total volume of 690,000 ft^3. It houses the beam bending magnets, collimators, and beam-analyzing equipment which are used to divert the beam into the proper experimental areas. This complex connecting link between the accelerator proper and the research area is shown in Fig. 27-40. Subsequent Figs. 27-41 through 27-43 show the construction progress of the beam switchyard.

Figure 27-40 Beam switchyard rendering.



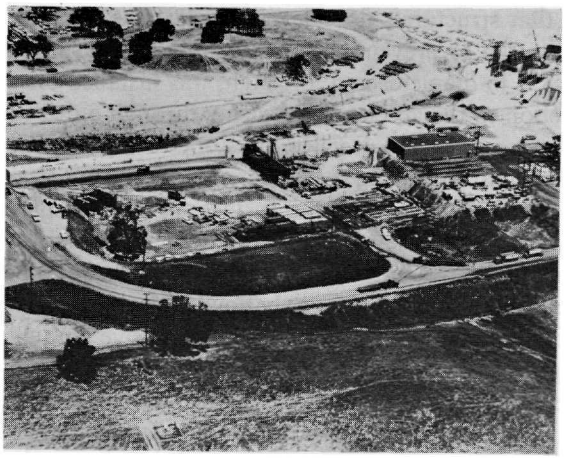


Figure 27-41 Beam switchyard backfill under construction.

The establishment of the basic housing alignment was dictated by the beam line geometry. However, the cross-sectional shape of the housing was determined by operational considerations. Primary among these was the prediction of extremely high-radiation areas and the possibility of having to do all routine maintenance and modifications by the use of remote-handling equipment. This consideration resulted in a two-story layout (see Figs. 27-44 and 27-45), with the beam line equipment below and handling equipment

Figure 27-42 Beam switchyard nearing completion.

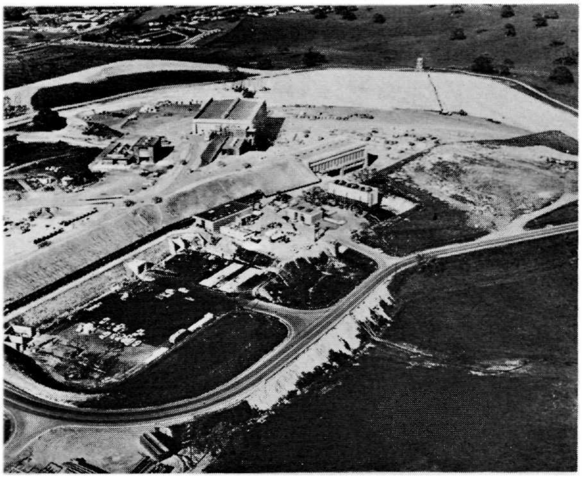
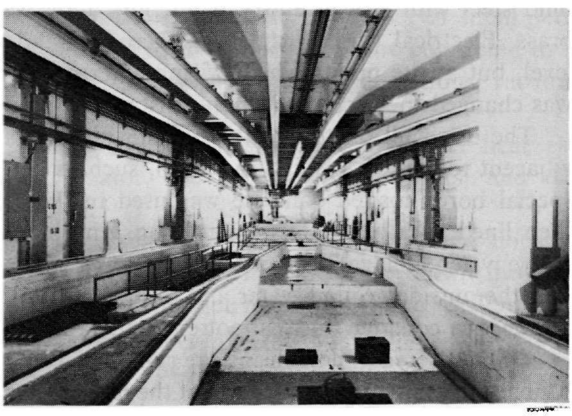


Figure 27-43 Beam switchyard completed.

above, separated by a floor of removable concrete shielding. In the upper level, there is a rail system designed for future use by a 50-ton shielded rail car to be equipped with remote-handling tools.

The height of the structure was determined by the minimum hook height requirements of the 16-ton overhead bridge cranes which traverse the lengths of all three legs of the beam switchyard. This layout resulted in a height of 25 ft from floor to ceiling. The width was determined by the size of the equipment and by the requirement that space be provided to shift the beam alignment a maximum of 9 in. in any direction. This resulted in a basic width of 12 ft.

Figure 27-44 Interior of beam switchyard diverging area, looking west.



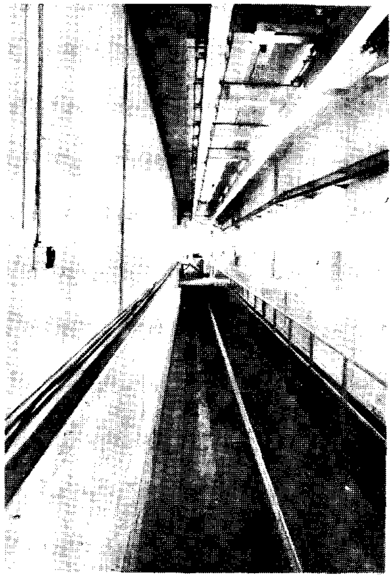


Figure 27-45 Interior of beam switchyard A channel, looking east.

The selection of materials was predicated upon the assumption of high radiation, creation of secondary radiation of air and dust particles, and generation of a nitric acid atmosphere. These considerations eliminated the use of all materials other than concrete for the structure itself. Special precautions were used to avoid concrete dusting. Special phenolic resin paint was used on floor and walls of the lower housing under the shielding floor. The upper housing was painted with a less expensive vinyl base because of the lower radiation levels expected. No galvanized metal was permitted because of the nitric acid atmosphere. All metals were either stainless steel, aluminum, mild steel with special epoxy paint, low alloy weathering steel, copper, or brass. Electrical wiring insulations were of standard materials in the upper level, but at the points where wiring entered the lower level, the insulation was changed to special radiation-resistant material.

The earth fill on top of the housing is 32 ft above the ceiling. In areas adjacent to sources of high radiation, such as slits, collimators, and dumps, special boron-loaded concrete was used in the structure. These areas were then lined with a stainless steel lining. The lining serves to prevent radioactive water spillage from entering the pores of the concrete or from escaping into the outside ground water and to prevent dusting of the concrete so that radioactive concrete dust cannot enter the atmosphere.

Utilities serving the housing are run outside along its length on a cableway bench. They enter the upper level of the housing through a series of horizontal utility ducts. Vertical wall chases are provided at periodic intervals for utility access from the upper to the lower level. All utilities are routed to avoid known radiation sources and over the shortest feasible paths between the upper and lower housing levels.

The following structural design criteria were used for the concrete housing: The foundation modulus for shale was to be 1.1×10^6 lb/ft^3 and for sandstone, 8.3×10^6 lb/ft^3. The minimum ultimate compressive strength of the concrete was to be 4000 psi at 28 days. Reinforcement was to be in accordance with American Society of Testing Materials (ASTM) Specification A-432, with a design bending stress of 20,000 psi. The earth load on the roof was to be between 1.0 and 1.6 times the nominal vertical overburden pressure depending upon the width of the section under consideration. The earth load on the walls was to be either 0.5 or 0.6 times the nominal vertical overburden pressure, the lesser value applied to the bottom of the wall and the greater value to the top of the wall.

Housing ventilation is provided by four strategically placed exhaust ducts which extend vertically through the 32 ft of shielding fill above the housing ceiling. The main entrance way is equipped with a filter bank which filters the intake air. The exhaust ducts are equipped with fans sized to provide six air changes per hour. The housing is sealed during actual beam operation to prevent the escape of radioactive air into the outside atmosphere. After a beam run is completed, the air is monitored and when a safe level is reached, it is exhausted into the atmosphere.

The crane system in the beam switchyard is complicated by the diverging beam lines. Three 16-ton cab-operated bridge cranes are used, one for each beam line. A transfer system is available to move the cranes from one set of rails to another. All of the cranes are capable of running on any rail system within the switchyard. Two cranes can be used on one set of tracks and can be used in tandem to lift 32 tons.

BEAM SWITCHYARD APPURTENANT STRUCTURES. To avoid the radiation atmosphere within the beam switchyard housing and to provide access to critical items of equipment during beam operation, a number of small peripheral structures are located external to the housing and are connected to it by duct systems. These structures consist of heat exchanger stations, vacuum pumping stations, and utility alcoves.

There are four heat exchanger stations, serving the magnet heat exchangers, the high-power collimator, the A- and B-beam slits, and the A-beam dump.

There are seven vacuum pumping stations located above the housing on top of the shielding fill. Vertical vacuum fingers extend down into the housing through vertical shafts to provide the beam line vacuum. In addition, there are a number of utility alcoves along the cable bench to provide areas for instruments to monitor utility services entering the housing.

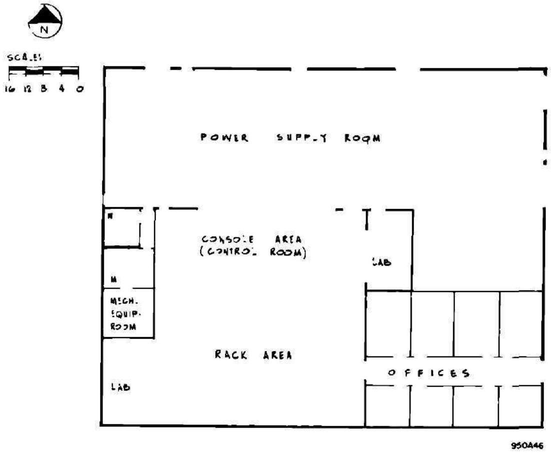


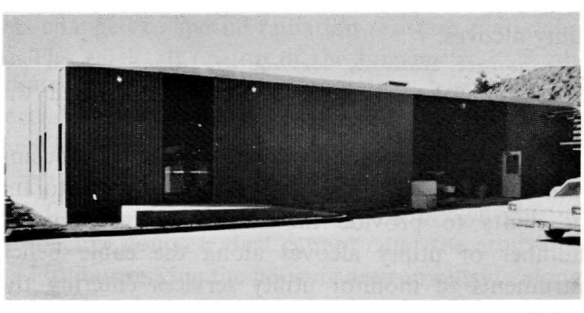
Figure 27-46 Floor plan of data assembly building.

DATA ASSEMBLY BUILDING. The Data Assembly Building serves as the control center for the beam switchyard. The building is 80 ft × 100 × 15 ft high, and is situated on the south side of the beam switchyard shielding fill. The site selection was based on the economics of cable and utility costs related to the function of the building.

As shown on Fig. 27-46, the building provides 2300 ft^2 of control room, 1200 ft^2 of offices, and 3750 ft^2 of power supply space. The balance of the building includes toilets and a light laboratory.

The architectural form is the same as the utility buildings without roof overhang or roof sight screen (see Fig. 27-47). The power supply area (see Fig. 27-48) required maximum wall space for cable racks and for electrical control panels. The control room is equipped with a luminous ceiling for controlled illumination and a raised computer-type floor to provide space for interconnecting cables. Windows are provided only in the office area.

Figure 27-47 Data assembly building.



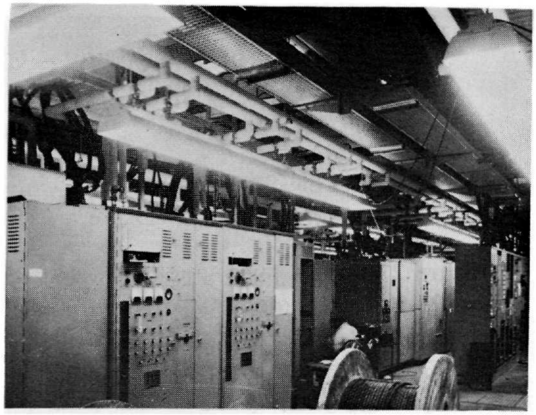


Figure 27-48 Data assembly building interior —power supply room.

The construction is made of a structural steel frame with diagonal bracing, ribbed metal siding and roof deck, and builtup asphalt and gravel roofing. A considerable quantity of conduits, cables, and piping is suspended from the roof girders and, because of the uniqueness of the beam switchyard control problems, complete data on suspended loads were not available for the initial structural design. Some reinforcement of the roof structure was required later.

The control room and office area are air-conditioned by means of local equipment. Gravity roof ventilators are provided for the unheated power supply room.

Research area buildings (RSG, GIR, WPS)

The diverging beam lines, starting at the beam switchyard, continue on into the research area creating a fan-shaped yard area of approximately 10 acres of concrete and asphalt. This research yard was scooped out of the gently rolling hillside to form a flat-bottomed bowl-shaped excavation completely surrounded by either native or artificially created earthen embankments approximately 40 ft high. Within this fan-shaped bowl are located the two large end station buildings and roughly a dozen smaller research and support-type buildings and facilities. The principal buildings are located along the beam paths. As of July 1967, the following major units are in service:

A-beam line
- Counting house
- End station A
- 2-Meter streamer chamber enclosure
- Beam dump east

C-beam line
82-In. bubble chamber enclosure
Bubble chamber offices and shop
B-beam line
End station B
40-In. bubble chamber enclosure
54-In. spark chamber enclosure

Figure 27-49 is a photograph of the research area yard looking north. Figure 27-50 is a photograph of the research area yard looking west with end station A at the right and end station B at the left. Buried underneath the research area yard is a network of approximately 1700 linear ft of utility tunnels providing utility service to the end station buildings and other experimental areas within the yard. The research area yard thereby fulfills its function of providing adequate work space where high-energy physics experiments can be conducted in an area shielded from the surrounding community and capable of adequate personnel access controls.

Because of the constantly changing nature of the research activities within the research area yard, all the special project buildings had to be designed for maximum flexibility as to their present and future use. They had to be capable of being relocated. They had to be inexpensive. Many of them house heavy magnets. Provision had to be made for crane access. Because of these requirements and the fact that the research yard is shielded from view from the neighboring community, the project architectural standards have been relaxed for research yard buildings under 35 ft in height. This has permitted

Figure 27-49 Research yard.

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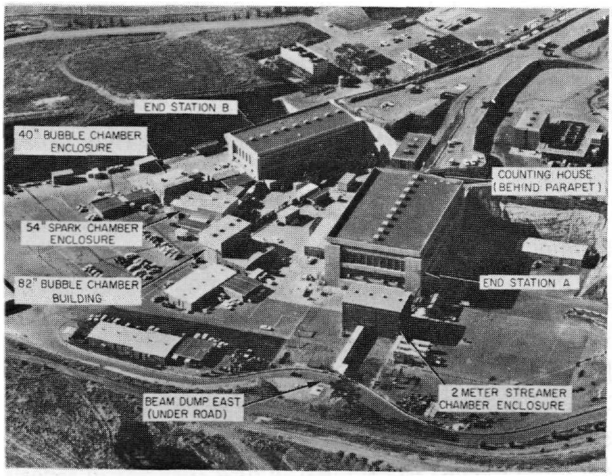


Figure 27-50 End stations.

the use of "pre-engineered" steel buildings with rigid steel structural framing and galvanized sheet steel roof decks and siding.

YARD AREA. The substratum of the research yard is Miocene sandstone with recommended design bearing values as shown in Fig. 27-51. Approximately 1.1 million yd^3 of this material (maximum excavated depth of 70 ft) were removed. Most of this was used to form the compacted radiation shielding fill over the beam switchyard. The shielding dikes on the north and south rims of the research yard and between the experimental area and the outside community are constructed in accordance with the project requirement of 400 ft of embankment in the forward (easterly) direction at the height of the electron beam (approximately 7 ft above yard surface).

A surface area of approximately 10 acres is covered with concrete and asphalt pavement. The area nearest the end stations has a 6-in. nonreinforced concrete slab on an untreated base of 6 in. of compacted rock material. This area lies between the end stations and extends approximately 50 ft beyond the end stations at the remaining two open sides. A midportion of the yard adjacent to the concrete slab is paved with 3 in. of hot-mixed asphaltic concrete on 9 in. of base rock. The remainder of the yard, a strip nearest the eastern earthen bank, is treated with an asphalt seal coat over a similar base material as for the asphaltic concrete.

The yard is underlaid with a storm drain system connected to inlet structures placed on a uniform grid. This surface is sloped to each drain inlet in a grid or waffle pattern except for a level area adjacent to the two end stations (approximately 50 ft). The inlets are spaced at 100-ft intervals. The asphalt surface has a 6-in. vertical variation from high to low. This slope is twice as

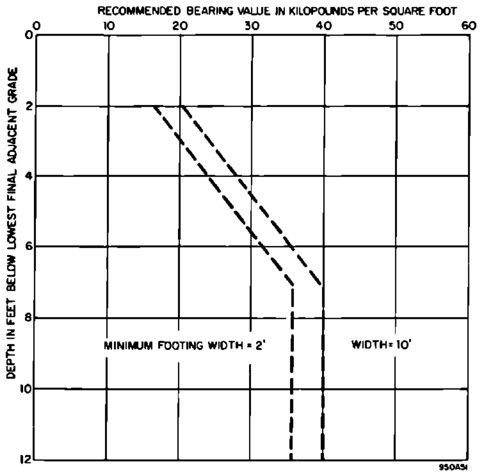


Figure 27-51 Research yard recommended design bearing values (dead loads) for footings founded in poorly cemented, fine-grain, Miocene sandstone. (These bearing pressures are based on Miocene sandstone extending below the footing at least one footing width.)

steep as the concrete paved area. The storm drain system is sized to handle the runoff from the maximum rainstorm expected to occur within a 10-yr span of time. Pipe sizes range from 12 to 42 in. in diameter. The material is galvanized corrugated steel. Catch basins are cast-in-place reinforced concrete boxes with lift-out subway-type heavy-duty grating.

Underground utility housings extend under both end station buildings. They project at right angles from longitudinal housings located alongside the exterior of each building. The housings are constructed of reinforced concrete and are rectangular in cross section. They vary in height from 7 to 10 ft and are 7 ft wide. There are approximately 4 ft of compacted select backfill between housing roofs and the floors of the end station buildings. Housing roofs can withstand a uniform live loading of 3000 lb/ft^2. The housings have underfloor drains sloping to a common sump pump. The longitudinal housings are interconnected by two corrugated metal utility housings, oval-shaped in cross section, buried under the yard area between the two buildings. The intersections of the metal housings with the concrete housings occur in vaults which are essentially a widening-out of the housings. The vault roofs are part of the experimental pad area and are structurally supported by steel columns. Access to the underground utilities is obtained through 3-ft × 6-ft manhole openings. The manholes within the two buildings also serve as floor drains. A recessed lip around the perimeter of the manhole serves as a gutter. This gutter is connected to a drain pipe which spills waste water at the floor level of the utility housings.

Provision has been made for the future extension of the utility housings into the eastern part of the research yard by means of knockout end walls.

COUNTING HOUSE. The counting house serves as the control center for the spectrometers located within end station A and as the point of experimental data accumulation and computer analysis. It is located on top of the beam switchyard fill, 45 ft above the floor of the end station. The upper portion of the end station A west wall acts as a common wall between the two buildings. The building is a steel frame structure with 1900 ft^2 of main floor area and 1600 ft^2 of mezzanine floor. The main floor consists largely of removable panels over a 2-ft deep space for cabling. Cables can enter the counting house through sleeves in the west wall at the level of this underfloor space. Cabling also enters the underfloor cavity at the south wall by means of cable trays attached to the outside face of the retaining wall.

Viewing ports in the common wall allow experiments in progress in the end station to be viewed from the counting house level.

An industrial freight elevator, 5 ft × 7 ft × 10 ft high, is used for transporting pieces of experimental apparatus from end station floor level to the counting house level. The elevator is of a hydraulic, piston-type with a 3500-lb capacity and an up-and-down speed of 50 ft/min. A steel stairway is also provided for personnel use. The counting house is fully air-conditioned to accommodate temperature-sensitive electronic equipment.

END STATION A. End Station A is located in the north part of the research yard straddling the A-beam as it emerges from the beam switchyard. It is a large concrete building used to house the spectrometers and provide crane, utilities, radiation shielding, and personnel access controls to the experimental area within the building.

The building is rectangular in plan with its west wall abutting the end of the beam switchyard. This wall also acts as a retaining wall for the earth shielding fill over the beam switchyard. The long axis of the building is parallel with and offset 17.5 ft to the south of the A-beam. The direction of the A-beam through the end station is at an angle of 24°29′30″ north of the C-beam. The inside dimensions of the building are 200 ft × 125 ft. As shown by the building cross section (see Fig. 27-52), the clear height from the floor to the highest position of the crane hook is 50 ft. Large openings through the north and south walls, 32 ft high by 40 ft wide, are designed for bringing in equipment. The opening on the south side has a motorized 2-ft thick, concrete door weighing approximately 450,000 lb. The door is mounted on wheeled trucks which roll on a single crane rail. A compressed air tank and motor are provided for auxiliary, emergency power operation of this door.

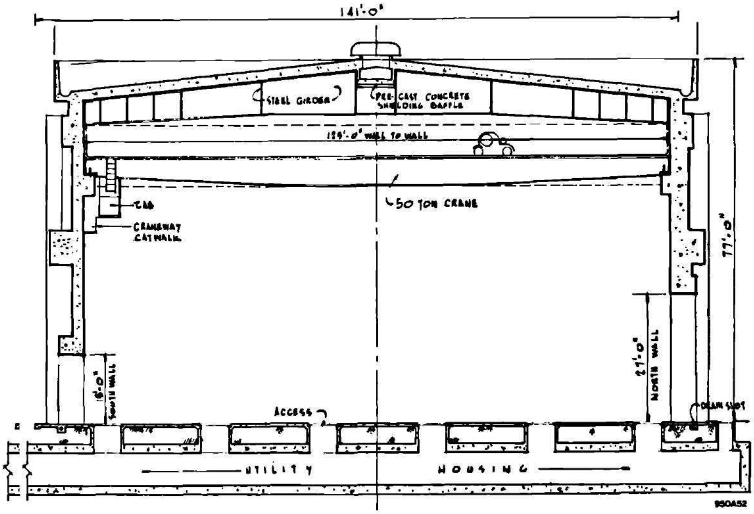
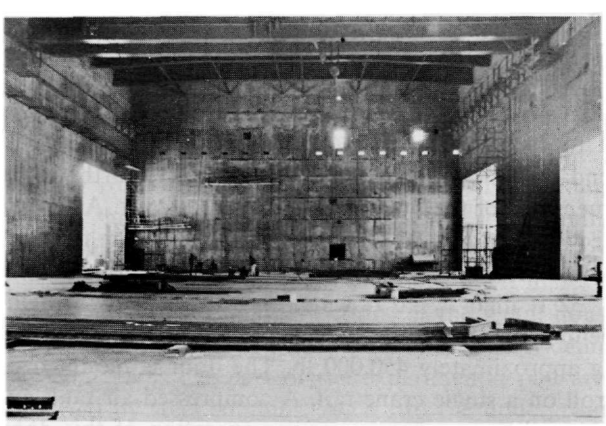


Figure 27-52 Cross section of end station A.

The corresponding opening on the north wall is covered by 2-ft thick, portable concrete blocks. Another opening in the north walls, 27 ft high by 105 ft long, is provided to accommodate the 20-GeV spectrometer. This opening is covered by 3-ft thick, portable concrete blocks. Other openings in the east and south walls are, respectively, 14 ft high × approximately 95 ft wide, with 5-ft thick, portable concrete blocks and 15-ft high × 105-ft wide with 3-ft thick, portable concrete blocks. Many of the features described in this paragraph can be seen in Fig. 27-53.

Figure 27-53 End station A interior.



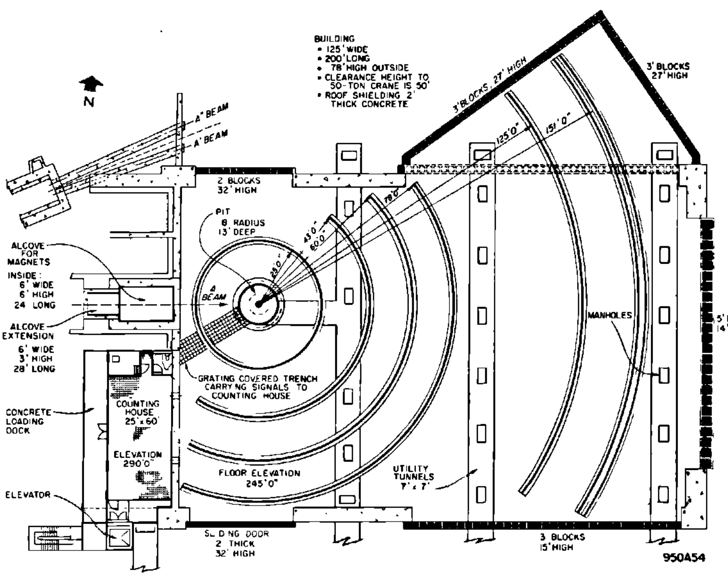
Specific features are constructed in the floor of the end station to accommodate the three spectrometers and these are noted on the floor plan (see Fig. 27-54). A central pivot, about which the spectrometers rotate, is a 28-ft long muzzle section of a 16-in. naval rifle. Eleven and one-half feet of this barrel extends above the floor of a circular utilities pit, 16 ft in radius × 13 ft deep. Radiating outward from this pivot, in concentric circular segments, are crane rails on reinforced concrete grade beams for supporting heavy spectrometer and shielding loads. Several of the concrete grade beams are deepened or are supported on 30-in. diameter × 30-ft deep, drilled-in concrete caissons to carry heavy loads without affecting the adjacent underfloor utility housings.

The structural design of the building was influenced to a large extent by the radiation criteria for the walls and roof. A minimum of 300 lb/ft^2 of mass was required to maintain safe radiation levels outside the building. As a result, all walls and roofs are of concrete, having a minimum thickness of 2 ft.

Wall thickness varies above the minimum as required by structural considerations. Granite rock aggregate was used extensively because of its proven, economic property of reducing shrinkage cracking. Generally, concrete surfaces are not painted. Large equipment and the necessity for unobstructed beam lines dictated the column-free interior.

The floor slab is made of 6-in. thick, unreinforced concrete on a 6-in. untreated base of coarse graded aggregate. It is structurally independent from the walls. The thickness is a compromise between requirements for the expected high floor loading and the ease in removing sections of the floor as required for future utilities. Undisturbed soil (Miocene sandstone) beneath

Figure 27-54 Floor plan of end station A.



the floor has an exceedingly high load bearing value and care was exercised in the design and construction to minimize disturbance. Where it was necessary to disturb natural soil to install utility ducts and housings, compacted, select, imported backfill of high quality was used.

The building is a large single-story concrete structure designed as a rigid frame. There are large sections of uninterrupted walls carrying large earthquake-induced shear forces into the sandstone foundation. One of these walls is over 5 ft thick, 47 ft wide, and extends 18 ft into the ground. The unusually firm foundation material in this area allowed a maximum design loading of 40,000 lb/ft^2. Because of the large mass of building walls and roof and the proximity of the San Andreas fault, the possible lateral forces induced by an earthquake served as a controlling design factor. The building is designed for a ground acceleration of 0.5 g which corresponds to an earthquake of magnitude 8.0 on the Richter scale. A computer analysis of the structures indicated they were quite stiff regardless of the large wall openings. End station A has a vibration period of 0.06 sec in the transverse direction and 0.14 sec longitudinally. Project-accepted seismic design criteria, based on the foregoing factors, established a coefficient for base shear of 0.2 g.

Roof slabs are supported on steel girders. These girders are designed for composite action with the concrete roof slab. The roof slab was cast in place on top of 8-in. thick, precast concrete planks. The steel girders were shored up temporarily by intermediate posts or shores to support the weight of the roof until the concrete had gained sufficient strength. The shores consisted of groups of four wooden telephone poles lashed together. The shores were systematically removed by jacking the roof down in small uniform increments.

End station A is equipped with a top-riding, 50-ton, overhead electric bridge crane. This crane has a 15-ton auxiliary hoist mounted on the same trolley with the main 50-ton hoist. Main and auxiliary hoists are controlled by a stepless General Electric silicon-controlled rectifiers (SCR) system. Extremely low speeds of 2 in./min on the main hoist can be maintained indefinitely regardless of the load on the hook. The maximum speeds are 10 and 20 ft/min for the main and auxiliary hoists, respectively. Maximum bridge speed is 100 ft/min through a 5-step, wound-rotor motor. Maximum trolley speed is 50 ft/min in 5 steps. Inching speed of $1\frac{1}{2}$ ft/min is obtained through pony motors on both bridge and trolley drives. The crane is operated from either a fixed cab or a movable pendant push-button control station suspended from a separate motorized trolley. The maximum height of the main hook above floor is 50 ft.

End station A is heated by four electric heating units, one in each corner of the building. The electric heating elements have low surface temperatures to reduce the possibility of igniting hydrogen in case of an accidental spill. Heater units discharge forced air picked up near the roof at a height of approximately 13 ft above the floor. Each heater is divided into three separate subunits (one air-handling fan). The heating capacity of each heater unit is 75 kW and the air-handling capacity is 7000 ft^3/min. It is necessary to heat this building to reduce the distortion and consequent misalignment of the spectrometers due to temperature changes.

Ventilation is provided by ten roof-mounted, 25,000 ft^3/min, belt-driven, exhaust fans located along the length of the building. The fans draw air from the highest point of the building through shielded openings in the 2-ft thick, roof slab and exhaust it through automatic back-draft dampers. The fan motors are totally enclosed, explosion-proof, belt-drive type. The roof has a 10% slope toward the fans for positive movement of light gas. Air movement is based on a 2-min air change of the upper 20 ft of the building. The exhaust fans are manually controlled with controls located in the counting house as well as at the house power panel. A relay in the control circuit provides automatic override control for full capacity operation when activated by the hydrogen detection system. Normal ventilation requirements are met by drawing air supplied from the utility housings through the grate-covered floor openings. Interchangeable solid coverings are available when required for equipment and shielding support. A few manholes into the exterior utility housings are fitted with portable air intake structures.

Local ventilation over hydrogen targets is provided by the use of portable exhaust ducting, hood, and fan. The fan is actuated by a local hydrogen-detecting device. The ducts pass through a system of shielded exhaust ports through the walls of the end station above the portable shielding blocks. All ventilation fans contain backdraft dampers to prevent natural chimney action when the fans are not operating.

2-METER STREAMER CHAMBER ENCLOSURE. This building is used to house the 2-meter streamer chamber. It is a rigid frame building with sheet metal roof and siding, has a floor area of 4000 ft^2 and an eave height of 45 ft. Because of the height of this building, it was subject to architectural review. This resulted in special fluted siding and roofing, special roof ventilators, and exterior paint. The 2-meter streamer chamber is mounted on tracks and rollers and can be towed out of the building through a large door, thus eliminating the need for special heavy crane handling facilities within the building.

This building is equipped with a top-riding 5-ton overhead electric bridge crane. The crane has ac induction motors driving through variable-speed electric clutches for all three motions (hoist, trolley, and bridge). This system gives accurate speed variations, regardless of load, through SCR controls in conjunction with signals from a feedback generator connected to the load side of the clutches. The crane is controlled through pendant-mounted push buttons. Clutch current is controlled through push buttons connected to a resistor with taps for five speeds. A selector switch gives an inching range to all motions. Comfort heat in this building is provided by portable heat lamps.

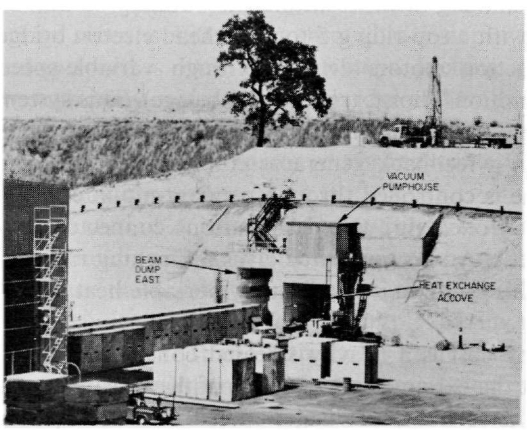
BEAM DUMP EAST. Beam dump east is a heavily shielded concrete structure located on the A-beam line at the extreme easterly edge of the research yard. The purpose of the structure is to house the water-cooled beam dump that absorbs the residual A-beam. Shielding is provided to reduce the radiation from the dump to the external areas. A stainless steel lined sump is provided to hold dump water in case of accidental leakage. Other features include rails for handling the dump vessel, a crane for handling equipment and shielding blocks, and a secondary heat exchanger system to water-cool the closed primary cooling system.

The structure is similar in cross section to the beam switchyard. It has a corbelled ledge on which concrete shielding blocks rest, giving it a two-story configuration. It measures 96 ft long × 10 ft wide by approximately 18 ft high (plus sump). The concrete walls, roof, and floor have an average thickness of about 3 ft. The structure is nestled into a sandstone bank and is completely covered by shielding fill. Figure 27-55 shows these features plus the concrete shield blocks defining the A-beam path to beam dump east. To increase the density of the top fill (because of a paved access roadway), two layers of concrete filled and encased gun barrels are placed between the roof and the compacted rock fill. Approximately sixty-five 105-mm World War II "Long Toms" are so used. The approximate depth of fill between the top of concrete housing and the roadway subgrade is 6 ft.

The interior surfaces are painted by means of the same scheme used for the beam switchyard, as follows: the lower portion (below layer of concrete shielding) is painted with special phenolic resin paint; the upper portion (lower radiation exposure above concrete shielding blocks) is painted with vinyl paint. The exterior surface is covered with a 20-mil thickness of polyvinyl chloride membrane to prevent entry of ground water.

Beam dump east is equipped with a top riding, 10-ton, overhead electric bridge crane. Speed regulation of bridge and hoist is obtained through wound-rotor main motors for normal speeds and inching motors are used to provide a speed of $1\frac{1}{2}$ ft/min. The hoist trolley is driven with a two-speed

Figure 27-55 Beam dump east.



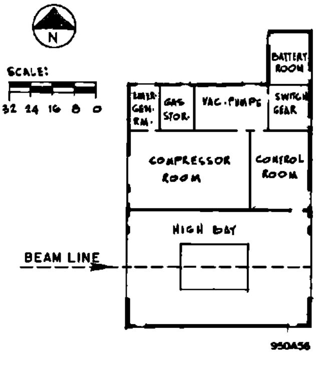
motor. The hook height above floor is approximately 15 ft; the length of the craneway is approximately 96 ft. The crane is controlled from a pendant-mounted push-button station. Because it contains no temperature-sensitive equipment, beam dump east has not been provided with any source of heat.

Beam dump east has a manually operated, exhaust fan to purge its atmosphere before personnel entry. The discharge end of the ventilator duct has a pneumatically controlled lid to prevent unwanted air circulation when the fan is off. The fan is a 5-hp, belt-drive, vane-axial type.

END STATION A POWER SUPPLY SHELTER. This building is used to house the electrical power supply equipment that powers the electromagnets associated with the spectrometers inside end station A. It is a rigid frame building with painted, galvanized sheet metal, roof siding. There are 3300 ft^2 of floor area and an eave height of 16 ft. The roof slopes from the ridge at 1 in. in 12 in. Translucent plastic panels occupy the upper 5 ft of the side walls, which allows natural daylight to enter without windows. This building is unheated and the walls are not insulated. The siding and framing are bolted to the flat level concrete yard area, using it as a floor slab. There are two roof-mounted 2500 ft^3/min powered exhaust fans.

82-IN. BUBBLE CHAMBER ENCLOSURE. The Lawrence Radiation Laboratory's 72-in. bubble chamber was modified and enlarged to an 82-in. unit. It was then disassembled and transported to SLAC. In preparation for this move, the 82-in. bubble chamber building was erected to house the chamber and associated equipment. The building is a rigid frame-type with a gross area of approximately 5600 ft^2. A 40-ft high bay with a floor area of 2500 ft^2 is used to house the bubble chamber. The remaining areas, shown in Fig. 27-56, have ceiling heights of approximately 15 and 9 ft high. These areas house the chamber ancillary equipment and the control room.

Figure 27-56 Floor plan of 82-in. hydrogen bubble chamber building.

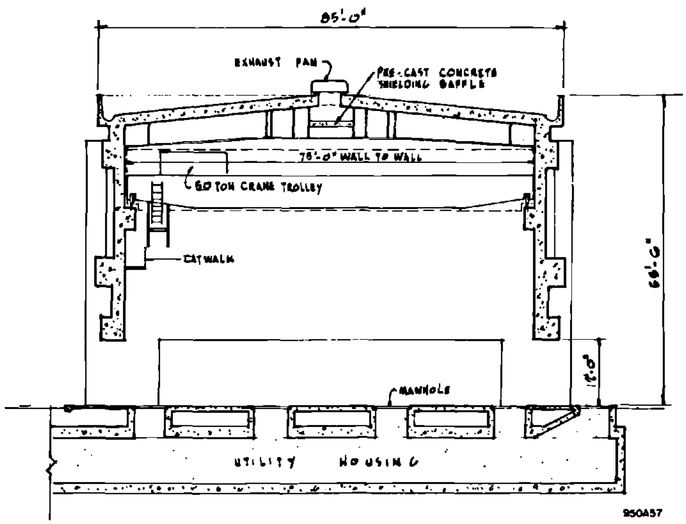


Adjacent to the north side of the building is an outdoor storage area for liquid nitrogen, Dewar, compressor and oil processing facilities. One 720-ft^2 concrete assembly pad is provided east of the high bay of the building. The pad was used to assemble the heavy components of the chamber prior to its move into the building. A 15-ton crane is provided in the high bay for the assembly of the remaining components and for the future maintenance of the chamber.

The high bay area of the building is provided with plastic blowout panels on the top 16 ft. Roll-up doors are provided at each end of the high bay section to facilitate moving the bubble chamber in and out of the building for future experiments. The interior wall between the high bay area and the compressor and control rooms is designed for 216 lb/ft^2 static loading to afford blast protection to the personnel in the compressor and control rooms. The electrical equipment and installation in the high bay and compressor room conform to the requirements of the National Electrical Code for Class 1, Division 2, Group B, to meet the hydrogen safety requirements.

END STATION B. End station B is located in the south part of the research area yard with its west wall abutting the beam switchyard. It is located almost south of end station A. The building is rectangular in plan with inside dimensions of 150 ft × 75 ft at the floor and 183 ft × 75 ft at a mezzanine level formed by the beam port funnel. The long axis of the building is oriented with and centered on the B-beam. The direction of the B-beam through the end station is at an angle of 12°29′32″ south of the C-beam. The north and south walls of the end station B (similar to end station A) are provided with large openings for bringing in equipment. These large openings and the

Figure 27-57 Cross section of end station B.



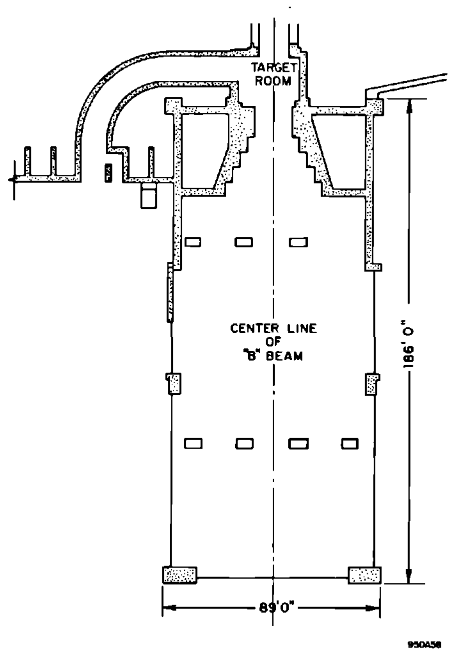


Figure 27-58 Floor plan of end station B.

funnel-shaped beam port can be noted on Figs. 27-57 and 27-58. A portion of the south opening, 20 ft × 20 ft, has a motorized 2-ft thick, concrete door. The door has auxiliary emergency power operation. Other openings in the north, south, and east walls, 12 ft × 70 ft, 12 ft × 70 ft, and 12 ft × 62 ft, respectively, are covered with 2-ft thick portable concrete blocks.

The structural design features of this building are similar to end station A with a 2-ft minimum wall and roof thickness. Earthquake structural design parameters and type of floor slab and rigid frame construction are all identical to those used in end station A except for the bridge crane span. This span was scaled down to fit the smaller building. The maximum height of the hook above the floor is $35\frac{1}{2}$ ft. The crane and the massive concrete blocks which it is required to handle are shown on Fig. 27-59.

Unlike end station A, there is no heat-sensitive equipment located in end station B; therefore, there is no provision for heat in this building. Ventilation consists of nine roof-mounted 25,000 ft^3/min, belt-driven, exhaust fans (compared to ten fans in end station A). Air-handling design and controls are similar to those used in end station A. Local ventilation over hydrogen targets is also provided in this building.

The beam port funnel is located at the upstream end of the building and is shaped as a stepped funnel in plan, open at the top. The narrow opening through the upstream wall has dimensions of 15 ft wide by approximately $26\frac{1}{2}$ ft high. The funnel opens in uniform 3-ft × 6-ft steps until the width of

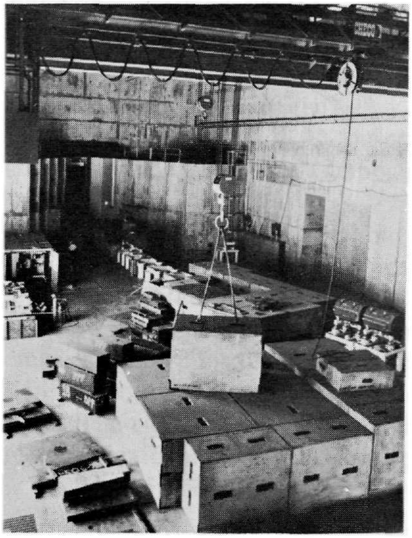


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Figure 27-59 End station B, interior photograph, looking west toward target room funnel.

39 ft is attained at the downstream end. The space under the mezzanine, behind the stepped funnel wall, is filled solidly with compacted rock of approximately 150 lb/ft^3 density. The mezzanine surface is 25 ft above the floor of the end station.

The beam port funnel is preceded by the B-beam target room, which is 25 ft wide × 20 ft long × $26\frac{1}{2}$ ft high. This room is covered by a shielding fill of compacted rock having the same high density as that behind the beam port funnel sides.

The target room is served by two 24-in. diameter steel penetrations in the roof and through the dense rock shielding fill. The penetrations will carry cabling necessary for controlling experimentation into the room. The south wall of the target room opens into a forward-curving access structure which is 10 ft wide × 12 ft high. The exterior opening of this access structure is shielded with portable concrete blocks. A personnel door is provided at the main opening. The target room end of end station B is equipped with a 15-ton, underslung, overhead electric bridge crane. Speeds of hoists, bridge, and trolley are controlled through two-speed motors at $4\frac{1}{2}$ and $1\frac{1}{2}$ ft/min. All motions are controlled from a wall-mounted push-button station. The maximum hook height above the floor is 21 ft.

The target room and the access tunnel are equipped with a 12,000 ft^3/min electrical fan. The fan is operated manually for purging prior to personnel entry. Controls are located at the exterior of the mazed man-door. A backdraft damper located over the man-door allows the fan to draw in fresh air. There are no provisions for heating this area.

54-IN. SPARK CHAMBER BUILDING. This building is used to house the μ-beam spark chamber. It is a rigid frame building with sheet metal roof and siding, it has a floor area of 4200 ft^2 and eave heights of 22 and 28 ft. Special attention was paid in this building to make the structure as light-proof as possible. This was necessary to accommodate the light-sensitive nature of the photographic film associated with the spark chamber. To provide access for a mobile crane, a portion of the siding and subframing was made removable. This building is not equipped with a bridge crane. It does not have a source of building heat.

40-IN. BUBBLE CHAMBER BUILDING. This building is used to house the 40-in. bubble chamber. It is made out of a rigid frame with sheet metal roof and siding, has a floor area of 2000 ft^2 and an eave height of 27 ft. It is mounted on rubber-tired casters which allow the entire building to be rolled away from the bubble chamber in the event that crane access is required to the heavy magnets. This arrangement also permits the building to be relocated anywhere within the yard. The building is windowless; but daylight is allowed to enter through a band of translucent corrugated plastic placed along the upper few feet of the siding. The walls and ceiling incorporate a system of blow-off panels designed to swing open at an internal pressure of 30 lb/ft^2. This safety precaution is taken because of the large volume of liquid hydrogen used by the bubble chamber.

The building is equipped with a $7\frac{1}{2}$-ton top riding overhead electric bridge crane. The crane has ac induction motors driving through variable-speed electric clutches which control the hoist, trolley, and bridge motions. This system gives accurate speed variations, regardless of load, through SCR controls in conjunction with signals from a feedback generator connected to the load side of the clutches. The crane is controlled through pendant-mounted push buttons. Clutch current is controlled through push buttons connected to a resistor with taps for five speeds. A selector switch gives an inching range to all motions. Building heat is provided by four 12-kW space heaters.

PORTABLE EQUIPMENT SHELTERS. These shelters are multipurpose units used as shelters for any system that can fit inside them, including power supplies, magnets, instruments, etc. They are small (16-ft × 32-ft) units with an eave height of 12 ft. They have no floor and hence can be lifted by a crane and set down over any object requiring protection from the weather. There are approximately one dozen of these units in use in the research area yard. They are constructed of self-framing interlocking panels on both roof and walls. The units are prewired for both lights and utility outlets. There is no source of heat. Ventilation is provided by wall louvers.

Table 27-8 Small, temporary buildings

Building No.	*Area (ft^2)*	*Purpose*
101	3920	Spectrometer staging area
102	5370	Research area shops and test area
104	3840	General storage
107	4000	Bubble chamber crew quarters and shop

OTHER SUPPORT BUILDINGS As noted previously, a number of small buildings used for temporary purposes during construction have since been relocated to the research area yard in support of experimental activities (see Table 27-8).

27-4 Utilities (FFH, GIR)

Cooling-water systems

Closed-loop, low-conductivity cooling-water systems and cooling tower water systems are described separately in Chapter 24.

Electric power system

The electric power system is described separately in Chapter 25.

Fire alarm system

The criteria established for the fire alarm system provide for an automatic detection system to protect personnel and to minimize the possibility of loss of equipment. The fire detection system is provided with detection devices at specific points. Master coded boxes are tied into a series-parallel, supervised circuit. The master control, located in the Fire Station Building, has four, coded, master box circuits—the klystron gallery loop, the campus loop, the research area loop, and the tie line to Stanford University Fire Station.

Pulse-coded alarm signals from the master fire alarm boxes are audibly indicated and permanently recorded at the master control panel and, through the tie line, at the Stanford University Fire Station. The coded signal directs the Fire Department to the particular box originating the alarm and the annunciator used in conjunction with the master box gives further instructions for the exact location. Noncoded stations and automatic devices are installed throughout the buildings for actuating the master boxes.

In conjunction with the automatic fire detection system, a water sprinkler system was installed in all buildings except in areas where water could cause severe damage to electronic equipment. In these areas, portable fire-extinguishing equipment suitable for electronic equipment is provided. Automatic water flow switches are included to actuate the fire alarm system.

There are twenty-nine street-type fire alarm boxes strategically located throughout the site. Every one of the boxes is connected to one of the four fire-monitoring circuits which originate in the Fire Station. Associated with each fire alarm box is a fire alarm subsystem which covers a specific area or building which, in turn, is normally subdivided into several fire zones. The subsystems are provided with local audible alarms and ventilation fan interlocks where needed.

Each zone is equipped with either a heat detector, a smoke detector, a sprinkler flow switch, a manual switch, or combination thereof. All fire systems are equipped with emergency standby power. In addition, all alarm circuits are continually monitored for circuit faults.

Domestic water

Domestic water is obtained from the city of Menlo Park system. In 1963, a 2-million-gal reservoir was constructed about 2 miles north of the main injector end of the machine. One million gallons capacity in the reservoir is reserved for SLAC use and provides for 2 days of normal domestic usage at 140,000 gal/day plus 3000 gal/min for fire-fighting for 4 hours.

Domestic water is supplied to the project through two supply pipes. The main supply is a 16-in. pipe connecting to the project meter box located adjacent to the main SLAC entryway off Sand Hill Road. The second supply is normally valve-closed and is a 10-in. pipe connecting to the domestic water main serving the 2-mile long Klystron Gallery Building at the beginning of Sector 7, or about 2000 ft east of the main injector.

Fire protection requirements were established as 1500 gal/min at 60 psig minimum pressure for hose streams and 1500 gal/min at 20 psig residual pressure for sprinkler systems. These requirements were the controlling factor in sizing the distribution system piping.

All water lines in the fire protection system were looped for added reliability except for the main serving the klystron gallery, which can be supplied from either end. Within the site, mains are 12, 10, 8, or 6 in. All pipes larger than 3 in. in size are Class 150 asbestos cement. Branch lines to buildings or other loads, 3 in. and smaller, are Schedule 40 galvanized steel.

The principal demands for domestic water are domestic use, fire protection, cooling tower makeup, a small amount for diffusion vacuum pump cooling, and irrigation. Water usage at SLAC averages 267,000 gal/day in dry weather when irrigation systems are in use and 167,000 gal/day during wet weather.

The annual average consumption has been about 90 million gal of which 15 million leave via the sanitary sewer and 75 million are used for irrigation or evaporated at the cooling towers. The cooling tower makeup demand is estimated at 45 million gal/yr and is the principal load served.

Sanitary sewer system

Sanitary sewage from the site is disposed of by the Menlo Park sanitary district. An annexation fee was charged for this service, plus a unit rate for any excess over 15,000 gal/day. The average flow rate is 41,000 gal/day. The flow is metered at the point of entry into the sanitary district's sewage lines.

A minimum of 8-in. diameter for the outfall and 6-in. diameter for all other mains was established and in most cases was the controlling factor in sizing the pipes.

The entire collection system, with the exception of three small areas, has gravity flow to the outfall. The three areas that require lift stations are small and serve individual comfort stations. The Data Assembly Building is one such instance. It is served by a pneumatic ejector station housed in a reinforced concrete vault below grade with a capacity of 50 gal/min at 50 ft of dynamic head. It also serves as an intermediate lift station for the pneumatic ejector serving the south side of the research area yard. This ejector is a factory-built packaged unit with a capacity of 30 gal/min at 33 ft of dynamic head. It serves one comfort station and a photographic dark room. The third unit is located in the north side of the research area yard. It is identical to the packaged unit described above. It also has very nominal use.

The majority of the gravity-type sewers are of asbestos cement, Class 1500. The force mains are asbestos cement, Class 150.

Central heating water

A central hot water heating system serves all of the permanent buildings in the "campus area." Located in the Central Utility Building are two natural gas, fire tube, hot water generators, each rated at 10,050 MBtu/hour, which supply 400 gal/min of 235°F hot water. Three hot water pumps are used to maintain a supply pressure of 65 psig. The return pressure is 33 psig. The hot water generators are designed for pressure of 60 psig, but because of the safety requirements for unattended, fully automatic units, the pressure relief valves are set at 30 psig. Ten thousand gallons of Diesel fuel are provided for standby use. This amount is adequate for 3 days' supply, based on estimated January requirements. Provision was made for one additional unit.

The distribution system is made of black iron pipe with molded glass fiber insulation. Exposed piping and piping in the concrete utility tunnels have canvas-jacketed insulation. Buried insulated pipe is protected from water damage by a $\frac{3}{16}$-in., glass fiber reinforced resin coating. All main headers are oversized at least 50% above foreseeable requirements. All high points in the distribution system are provided with vent valves. Drains are provided at low points. In addition to providing the general building heating requirements, the hot water is used at the water distillation facility and at the cleaning and plating shop for heating the various cleaning tanks.

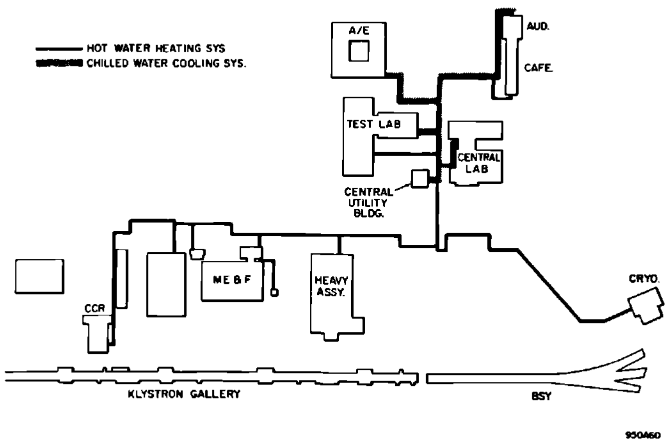

Figure 27-60 Central heating and chilled water distribution systems.

Figure 27-60 shows the layout of distribution piping for this utility service.

Central chilled water

The air-conditioning requirements of the campus buildings contained within the loop road are supplied by a central chilled water system located in the Central Utility Building. Two 200-ton centrifugal compressor water chillers provide 400 gal/min of 40°F chilled water. Condenser water for the system is provided from the central two-cell cooling tower. Two pumps rated at 450 gal/min each provide 66 psig for the supply side of the distribution system. The return pressure is 33 psig. The air-conditioning units are designed for a 10°F rise in water temperature. Provision was made for one additional chiller and pump.

The distribution system is made of black iron pipe with molded glass fiber insulation. Exposed piping in the concrete utility tunnel has canvas-jacketed insulation. Buried insulated pipe is protected from water damage by a $\frac{3}{16}$-in., glass fiber reinforced resin coating. Under paving and roadways, a metal shield covers the glass fiber reinforced resin coating.

Figure 27-60 shows the layout of the distribution piping for this utility service.

Natural gas

Natural gas is supplied to the site by the Pacific Gas & Electric Company. A 3- and a 6-in. line extend onto the site from the main along Sand Hill Road. The 3-in. line is for future firm gas connections to laboratories. It is presently capped off at its point of entry into the utility tunnel east of the Administration and Engineering Building. The 6-in. line is for interruptible gas and serves the Central Utility Building, the Test Laboratory, and other buildings on the site.

The pipe is of black iron and is wrapped for direct burial.

Compressed air

The compressed air used on the site is generated and distributed by two rather distinct systems with cross-ties for emergency backup.

The larger of the two systems supplies the "campus area" and klystron gallery. Two 300-SCFM compressors, located in the Central Utility Building, supply air at 100 psig. The compressors are of oil-free construction with Teflon rings. The after-cooler uses 40°F chilled water to dry the air. The result is an oil- and water-free air which approaches instrument air quality. Provision was made for the future addition of one more 300-SCFM compressor.

The distribution piping ranges in size up to 6 in. in diameter and serves the General Services Building, craft shops, and the electronics, fabrication, and heavy assembly buildings. A $1\frac{1}{2}$-in. line connects to the klystron gallery and master substation switch house.

The second and smaller system supplies the research area yard. One 300-SCFM compressor is located in the Beam Switchyard Substation Building. It is practically identical to the two units described above. This air is supplied to the beam switchyard, Data Assembly Building, end stations A and B, counting house, and research area yard. This system is tied into the Central Utility Building system at the klystron gallery. Air quality is comparable to that produced at the Central Utility Building.

Telephones and radio

VOICE COMMUNICATIONS. Three main methods of voice intercommunication have been provided for general use by project personnel: the telephone, the service channel system, and the paging system. They cover the klystron gallery, accelerator housing, beam switchyard, and research areas. In addition, there are systems not employed for general usage, such as local paging and several specialized radio networks.

TELEPHONE SYSTEM. Telephones in the areas noted above are owned, installed, and maintained by SLAC. Service is extended to all locations from the Central Control Building on SLAC cables as part of the instrumentation and control system. All telephones in these areas are connected to the telephone company's project central switchboard and are identical in function and operation to all other telephones on the project. They are located approximately 100 ft apart along the full length of the klystron gallery.

There are four telephones in each sector: (1) beside each access door to the accelerator housing, (2) in every instrumentation and control alcove, (3) on the north wall near column 5, and (4) in the accelerator housing in each manway access alcove. Telephones in the beam switchyard are located outside all accessways where personnel may enter and at various locations inside. Telephones are also placed at convenient locations on both the inside and outside walls of the end stations and in all other buildings in the experimental areas.

SERVICE CHANNEL SYSTEM. As the name implies, service channels are used for servicing and maintenance work. They allow maintenance and test personnel to communicate among themselves and with the control rooms for extended periods of time and to coordinate their efforts without loading other communication facilities or being subject to interruption by other traffic. Each channel consists merely of a telephone line with common battery applied and a multiplicity of access points.

There are six channels available. Access to them is at jack panels on each fiat and trigger rack in the klystron gallery and at boxes spaced every 40 ft along the south wall of the accelerator housing. Three channels of the available six (channels 4, 5, and 6) appear at the boxes in the accelerator housing.

Service channel boxes in the beam switchyard contain six channels and are located at 40-ft intervals along the upper housing. The six channels in the beam switchyard and experimental areas are separate and distinct from the klystron gallery and accelerator housing service channels.

Users of the service channels are issued a headset assembly consisting of an operator-type headset, a 25-ft retractile cord, and a small belt-clipped box. The box also contains a slide switch to disable the microphone for monitoring purposes and push buttons marked "CNTL" and "SWBD" for signaling the control room and the telephone switchboard operator, respectively. Extension cords of various lengths are available when required.

There are several ways in which communications may be established on service channels. Someone may be "met" by prearrangement on a specified channel. It is then just necessary to plug in and talk. The switchboard operator may be signaled and instructed to page a desired party to plug into the channel in use. The control operators can also operate the paging system to call certain personnel to a service channel.

The service channels are not used as a substitute for the telephone system; however, there are occasions when it is necessary for maintenance people to converse with someone on the project from the location of the equipment on which they are working. The telephone operator can dial a call for them within the project while they are on a service channel. The operator, however, cannot extend a call outside the project.

PAGING SYSTEM. A single paging system covers the accelerator, beam switchyard, and research areas. These areas may be paged individually as required.

The system is used for locating personnel and for routine or emergency announcements. Access to the system is restricted to three locations: the project telephone switchboard and the central and beam switchyard control rooms. All paging equipment operates from the existing 24-V battery sources and is independent of ac power.

RADIO SYSTEM. There are at present four radio networks in operation on separate frequencies. The utility network is used for dispatching the SLAC taxi service, maintenance forces, surveillance guards, and other administrative services. The fire protection network is part of the Stanford University Fire Department system. Health physics personnel and groups concerned with the operation of the accelerator employ the operations network for radiation safety, personnel search, and other business involving machine operation. The experimenters have a low-power network to coordinate setup and alignment of test apparatus. Individual, electronic, pocket-size, paging devices are used by several of the using groups to increase the effectiveness of radio communication at SLAC.

Temporary communications

When a voice communication link is needed for short-term use, a pool of equipment, consisting of sound-powered telephones, military field telephones, citizens' band portable radios, wireless intercom units, paging amplifiers, speakers, and microphones, is available.

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