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TWO-MILE ACCELERATOR PROJECT

1 July to 30 September 1970

Quarterly Status Report

STANFORD LINEAR ACCELERATOR CENTER
STANFORD UNIVERSITY
Stanford, California 94305

PREPARED FOR THE U. S. ATOMIC ENERGY COMMISSION
UNDER CONTRACT NO. AT(04-3)-400 AND CONTRACT NO. AT(04-3)-515

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ABSTRACT

A status report on the Stanford Linear Accelerator Project covering the period July 1, 1970 to September 30, 1970 is presented. Topics included are accelerator and research area operations, accelerator and research area equipment development, and physics research equipment development.

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INTRODUCTION

This is the thirty-third Quarterly Status Report of work under AEC Contract AT(04-3)-400 and the twenty-seventh Quarterly Status Report of work under AEC Contract AT(04-3)-515, both held by Stanford University. The period covered by this report is from July 1, 1970 to September 30, 1970. Contract AT(04-3)-400 provides for the construction of the Stanford Linear Accelerator Center (SLAC), a laboratory that has as its chief instrument a two-mile-long electron accelerator. Construction of the Center began in July 1962. The principal beam parameters of the accelerator in its initial operating phase are a maximum beam energy of 20 GeV, and an average beam current of 30 microamperes (at 10% beam loading). The electron beam was first activated in May 1966. In August, 1970, a beam energy of 22.1 GeV was achieved. Beam currents up to 70 milliamperes peak have been obtained.

The terms of Contract AT(04-3)-400 provide for a fully operable accelerator and for sufficient equipment to measure and control the principal parameters of the electron beam; in addition, provision is made for an initial complement of general-use research equipment with which it is possible to perform certain exploratory studies, such as measurement of the intensity and energy distribution of various secondary-particle beams.

Contract AT(04-3)-515, which went into effect January 1, 1964, provided support for the various activities at SLAC that were necessary in order to prepare for the research program which is being carried out with the two-mile accelerator, and also provides for the continuing operation of the Center after completion of construction. Among the principal activities covered in the scope of Contract AT(04-3)-515 are theoretical physics studies, experiments performed by the SLAC staff at other accelerators, research-equipment development programs (such as particle separators, specialized magnets, bubble chambers, etc.), and research into advanced accelerator technology.

1. ACCELERATOR OPERATIONS

A. Operating Hours

Manned Hours	July	August	September	Quarter
Physics Beam Hours[1]				
Machine Physics	10	22	27	59
Particle Physics	340	261	279	880
Total Physics Beam Hours	350	283	306	939
Nonphysics Hours				
Scheduled Downtime (Maintenance, Startup)	24	24	16	64
Unscheduled Downtime (Equipment Failure, Tuneup, etc.)	42	19	78	139
Total Nonphysics Hours	66	43	94	203
TOTAL MANNED HOURS	416	326	400	1,142

B. Experimental Hours[2]

1. Particle Physics

(3) Beam Line	Sched. Hrs. Electronic Experiments (a)	Electronic Experimental Hrs. Actual Hours (b)	Electronic Experimental Hrs. (4) Charged Hours	% $\left(\frac{b}{a}\right)$	Actual Bubble Chamber Hours	Test and Checkout Hours Act. Hrs.	Test and Checkout Hours Chg. Hrs.	Total Experimental Hours Actual Hours	Total Experimental Hours Charged Hours
A	964	717	756	74.4	---	15	15	732	771
B_N	---	---	---	---	---	103	103	103	103
B_C	---	---	---	---	---	4	4	4	4
B_S	638	575	442	90.1	---	300	300	875	742
C	965	646	284	66.9	316	238	156	1,200	756
Total	2,567	1,938	1,482	75.5	316	660	578	2,914	2,376
2. Machine Physics								71	71
TOTAL EXPERIMENTAL HOURS								2,985	2,447

(1) Number of hours accelerator is run with one or more beams excluding accelerator beam tuneup and other nonphysics beam time.

(2) Number of hours an experiment is run including actual beam hours and beam downtime "normal to the experiment."

(3) Refer to Fig. 1 for beam line location.

(4) Charged hours are represented by the formula $T_c = T_0\left(\frac{R+20}{200}\right)$ where T_c = charged hours, T_0 = total hours beam was available to the experimenter for both checkout and data taking, and R = the average pulse repetition rate. Maximum for $\left(\frac{R+20}{200}\right)$ is 1.5 even if the calculated amount exceeds this value.

C. Overall Experimental Program Status

1. Electronic Experiments

Approved research hours at beginning of quarter	3,686
Hours charged during the quarter	1,482
New hours approved during the quarter	1,175
Approved hours remaining at end of quarter	3,379

2. Bubble Chamber Experiments

	40" BC	82" BC
Approved pictures at beginning of quarter	797 K	2,783 K
Pictures taken during the quarter	---	866 K
New pictures approved during the quarter	2,325 K	2,331 K
Approved pictures remaining at end of quarter	3,122 K	4,248 K

	JULY	AUGUST	SEPTEMBER	QUARTER
D. Beam Intensity				
Peak	47 mA	30 mA	62.5 mA	62.5 mA
Average	4.3 μA	1.9 μA	7.6 μA	4.6 μA
E. Klystron Experience				
Total Klystron Hours	106,991	60,904	91,442	259,337
Number of Klystron Failures	6	6	6	6
F. Data Analysis				
Spark Chamber Events Measured	14,289	10,973	10,793	36,055
Bubble Chamber Events Measured	29,370	34,787	15,111	79,268
G. Computer Operations				
Manned Hours				
Computation Hours				
SLAC Facility Group	90	123	113	326
Users Groups	458	438	447	1,343
Total Computation Hours	548	561	560	1,669
Noncomputation Hours				
Scheduled Maintenance	82	98	87	267
Scheduled Modifications	--	12	28	40
Unscheduled Downtime and Reruns	41	27	11	79
Idle Time	3	1	1	5
Utility Failure	9	--	3	12
Total Noncomputation Hours	135	138	130	403
TOTAL MANNED HOURS	683	699	690	2,072

H. Special Operating Features

1. Beam Knockout

The beam knockout was used for 21 hours of checkout and 820 hours of experimental time for a total of 841 hours during the quarter.

2. Power Supplies

The 3.4 MW power supply was run for 425 hours with the 82" bubble chamber and for 7 hours of magnet testing, a total of 432 hours during the quarter.

The 5.0 MW power supply was run for 68 hours with the 54" spark chamber, for 78 hours with the analyzer magnet in beam line 11, and for 14 hours of magnet testing, a total of 160 hours during the quarter.

The 5.8 MW power supply was run for 930 hours during the quarter with the two-meter spark chamber.

The motor generator facility was run for 27 hours of checkout and magnet testing during the quarter.

3. Record Energy Attained

During the month of August a new energy record of 22.1 GeV was attained.

4. Record Power Attained

During September a new record of 750 kW average beam power was attained.

II. EXPERIMENTAL ACTIVITY DURING THE QUARTER

Figure 1 is a research area plan drawing showing the location of the various experiments. Table 1 is a list of presently approved high energy physics experiments. The right-hand column of Table 1 gives the status and activity of each experiment during the period.* Figure 2 is a tentative long-range schedule.

The prime users of the accelerator during the period were:

E-42 — Photon-Proton Scattering at Forward Angles

E-48 — Measurement of the ξ Parameter in the Decay $K_L^o \rightarrow \pi\mu\nu$

E-49b — Inelastic Scattering from D_2 and Other Nuclei

E-50b — Asymmetry in the Photoproduction of π^o Mesons by Polarized Photons

E-56a — A Search for Short-Lived Sources of Neutrino-Like Particles

CE-67 — Study of $\pi\bar{N} \rightarrow N\bar{N}N$ at 15 GeV/c

E-69 — Improvement of the Statistical Accuracy of the Measurement of the Form Factors for K_L^o Decay

E-70 — Measurement of the Asymmetry in Compton Scattering on the Proton with Linearly Polarized Photons

N-63 — Experiment Feasibility Tests for E-63

T-52 — Final Equipment Calibration for E-52

T-65 — Experiment to Study Electroproduced Hadrons

D-9 — Study of High Energy Magnetic Bremsstrahlung in Pulsed Megagauss Fields

D-11 — Shielding Tests

D-14 — Charpak Chamber Tests

D-15 — Λp Interactions with Λ's Produced in a Dense Target by 9 GeV/c Protons

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* E-Approved counter experiments
CE-Checkout of equipment associated with counter experiments
BC-Approved bubble chamber experiments
P-Accelerator physics
R-Research area runs
N-Parasite runs
T-General research equipment tests
D-Special short particle physics runs
Y-Beam switchyard tests
S-Survey (usually Health Physics) runs

Y-4 — Heat Transfer Test of Slit Modules in C-Beam

BC-5 — Study of Many Particle Final States Produced by 12 GeV/c π^-

BC-26 — Determination of Quantum Numbers for Resonances in the R, S, T, and U Region Using π^+d Interactions at 11 GeV/c

BC-30 — Λp Interactions in the Momentum Interval 1-5 GeV/c

BC-33 — Study of $\pi\pi$ Scattering, Extrapolation Procedures and Production in π^-p Collisions

A. Status of Running Experiments

E-42 — Photon-Proton Scattering at Forward Angles - SLAC- Spokesman: A. Boyarski

The small angle $\gamma p \rightarrow \gamma p$ scattering (proton Compton) experiment was completed during the July accelerator cycle. Approximately sixteen days of running time were used. A pair spectrometer (0.044 X_0 converter, 10^{-5} ster., 35% $\Delta P/P$ per arm) was used to measure the energy of scattered photons at the bremsstrahlung end point, for photon end point energies of 8 and 16 GeV, and momentum transfers -t from 0.01 to 0.17 GeV^2. The data show a clear Compton step with a linear term from photons produced from the single π^0 production process. The pair spectrometer was also calibrated by measuring the end point of the bremsstrahlung spectrum itself. This required running the accelerator with the gun off to get ~ 10 equivalent quanta per pulse. The energy resolution of the spectrometer not including effects of straggling in the converter, was measured to be $\pm$ 0.7% as expected. (A. Boyarski, SLAC)

E-48 — Measurement of the ξ Parameter in the Decay $K_L^0 \rightarrow \pi\mu\nu$ - BNL-SLAC - Spokesman: M. Sakitt

After six days devoted to continued background studies and timing and plateauing of counters, data taking started on July 21. A beam knockout beam structure with 200 nanosecond spacing was used for time-of-flight measurement.

About 380,000 pictures were taken by the end of the running period on August 2. About 1 in 4.5 pictures contains a K_L^0 candidate. During the next running period from August 12 to 22, the rate was increased by the excellent performance of a new accelerator gun and by beam sharing with E-69 (in the B target area). In such beam sharing operation, pulses are switched to the alternate beam during the dead time of the streamer chamber, allowing approximately zero dead time operation.

During the September running period the average rate was further increased by the use of a shorter beam knockout (100 nanosecond), which resulted in a slightly increased background, and by reduced streamer chamber dead time from 1/2 second to 1/4 second. Beam sharing was done with E-49b (in the A target area).

A total of about 1.5 million pictures was obtained in the three running periods. This will lead to about 500,000 K_L^o candidates. About 1/3 to 1/2 of these K_L^o candidates will probably survive fiducial volume, energy, and other cuts.

It is expected that data taking will be completed during the next running period. (R. Mozley, SLAC)

E-49b — Inelastic Electron Scattering from Deuterium - MIT-SLAC - Spokesman: J. I. Friedman

The object of the experiment is to obtain a comparison of the structure functions for the neutron with those of the proton by measuring the inelastic scattering from hydrogen and deuterium at intermediate angles. The experiment uses the 8 GeV/c spectrometer to detect the inelastically scattered electrons at laboratory angles of 18^o, 26^o and 34^o. The inelastic scattering cross sections are being measured from hydrogen as well as deuterium in order to remove some potential systematic errors and to check the hydrogen data obtained in a previous experiment by the SLAC-MIT collaboration.

During August, the experimenters completed about 90% of the checkout and alignment of the hodoscope and electronics of the 8 GeV/c spectrometer. This was done while running parasitically and employed the SDS 930 computer. This was the first time that the SDS 930 has been used in a real-time operation. A new hodoscope and Cerenkov counter were tested. The modified liquid hydrogen-deuterium target system for this experiment was tested at a new test facility next to the Cryogenics Building.

Data were taken in September at primary electron energies of 7.9, 8.6, 8.7, 10.4, 11.9, and 13.3 GeV. For each primary energy, data were taken at secondary momenta between that for elastic scattering and 1.5 GeV/c. The remaining portion of the experimental data should be obtained during the October cycle. (D. Coward, SLAC - M. Breidenbach, MIT)

E-50b — Asymmetry in the Photoproduction of π^o Mesons from Hydrogen by Polarized Photons - Harvard-Northeastern-SLAC - Spokesman: D. Ritson

This experiment is designed to measure the asymmetry in the reaction $\gamma + p \rightarrow \pi^o + p$ using the SLAC polarized beam facility. The process is identified by detecting the recoil proton in coincidence with one of the photons from the π^0-decay.

In July, using the SLAC pair spectrometer at 0° the photon spectrum from a 30 mil-thick diamond crystal oriented with the 001 face normal to the beam was measured. The energy of the incident electron beam was 12 GeV, and the 022 $(02\bar{2})$ plane was used to produce a coherent spike at 6 GeV.

During the August cycle about 20 shifts at 120 pps were used to align and check out the equipment for E-50b which will be run in November. The run was very successful, and the rates achieved are somewhat better than those listed in the proposal. The asymmetry was measured at a photon energy of 6 GeV for eight t-values between $t=-.4\ (\mathrm{GeV/c})^2$ and $-1.1\ (\mathrm{GeV/c})^2$ and a single point at $t=-.9\ (\mathrm{GeV/c})^2$ for 4 GeV photons. If the asymmetry A is defined as

$$A = \frac{\sigma_{\perp} - \sigma_{\parallel}}{\sigma_{\perp} + \sigma_{\parallel}}$$

and $\sigma_{\perp}(\sigma_{\parallel})$ is the cross section for the photons polarized normal (parallel) to the reaction plane, then the measured asymmetry is large and positive throughout this entire t-region. (B. Wiik, SLAC)

E-56a — Search for Short-Lived Sources of Neutrino-Like Particles - U. Pennsylvania, U.C. Santa Cruz, SLAC - Spokesman: M. Schwartz

Experiment 56a is located in a hole directly behind Beam Dump East. This hole is 16 feet in diameter and about 35 feet deep. There are four large optical spark chambers located at the bottom of the hole in a direct line with the dump. Each one of these chambers is 8' × 8' × 15" and has ten functioning gaps. The chamber walls are made of thick aluminum sheets and each chamber weighs five tons. There are two scintillation counter banks for triggering located on the two faces of the last chamber.

During the months of July and August the hole was dug and the equipment was installed. Although not all of the contracted work was completed as of the start of the September machine cycle we did start to run the apparatus. The logic was set up and timed in, and the chambers were made operational. Approximately 1000 pictures were taken with beam energy between 5 and 17 GeV. By the time the cycle ended we were fairly confident of the apparatus. We had observed many cosmic rays, some definite neutrino events, and a lot of blank film.

For the next cycle we hope to make several improvements. We should be able to get sharper, brighter sparks by shifting to a helium/neon gas mixture in the chambers instead of pure helium. This also means installing a recirculating gas system. We will also try to solve the noise problem so that the scalers and the latch lights which tell which counters fired will be more reliable.
(A. Rothenberg, SLAC)

CE-67 — Study of $\pi N \rightarrow N\bar{N}N$ at 15 GeV/c - SLAC - Spokesmen: D. Leith, H. Lynch

The 16 GeV/c π^- beam was set up and the detailed beam optics checked out. The wire spark chambers, counters and general electronics were checked out and set up for the experiment. Some studies of the Cerenkov counter and how well the apparatus worked as a function of incident flux were completed. A final checkout of some of the fast electronics and a detailed study of the Cerenkov counters remains to be done before data taking can commence in October.
(D.W.G.S. Leith, SLAC)

E-69 — Improvement of Statistical Accuracy of the Measurement of the Form Factors for K_L^o Decay - Johns-Hopkins, UCLA, SLAC - Spokesman: R. Zdanis

During the July running period data were taken on the decays $K_L^o \rightarrow \pi e \nu$, $K_L^o \rightarrow \pi \mu \nu$ and $K_L^o \rightarrow \pi^+ \pi^- \pi^o$. The early part of the cycle was used to confirm the operation of the trigger logic and particle identifiers and to reduce accidentals. 1.4 million triggers were taken on the decay modes in addition to frequent calibrations with a copper regenerator. Data were taken with the magnetic field in both orientations for use in our study of possible systematic effects.

Data taking was completed during the August cycle. In all, 3×10^6 triggers were recorded. Events identified consisted of the momentum analysis on each charged particle plus lepton identifiers (shower counter for electrons and range for muons). Time-of-flight information was also available. We anticipate obtaining 500,000 properly identifiable K_L^o decays, reflecting equal division into the major charge modes of $\pi\mu\nu$, $\pi e \nu$, and $\pi^+\pi^-\pi^o$.

This experiment should provide sensitive measurements of the scalar and tensor contributions in the weak interaction and of the form-factor parameters $\lambda_+(0)$, and λ_-. (C. Buchanan, UCLA)

E-70 — Measurement of the Asymmetry in Compton Scattering on the Proton with Linearly Polarized Photons - Cornell, Northeastern, Harvard, SLAC - Spokesman: B. Wiik

A few shifts in August were used to align the counter system for E-70. This experiment measures the asymmetry in Compton scattering on the proton with a polarized beam. These test runs were also successful, with the rates as expected, and the results at 6 GeV for $t=-.4\ (\mathrm{GeV/c})^2$ and $-.5\ (\mathrm{GeV/c})^2$ were consistent with no asymmetry within an error of about $\pm .04$.

N-63 — Experiment Feasibility Tests for E-63, Measurement of K_L^o and Neutron Total Cross Sections on Nuclear Targets - Stanford - Spokesman: E. B. Hughes

Measurements were made of the probability of small (less than 100 MeV) energy losses at small momentum transfer in a live (plastic scintillator) target by neutral K mesons and neutrons. These data give information on the nature of the hadron-nucleus collision and relate to possible applications of live targets to the study of coherent nuclear reactions.

The experiments also made an unsuccessful attempt to detect, in a sodium iodide crystal, gamma rays from excited states of the carbon nucleus.

(J. Crawford, Stanford)

T-52 — Final Equipment Calibration for E-52 - Northeastern, SLAC - Spokesman: B. Wiik

Approximately four shifts were used in August for E-52 (γ+D $\rightarrow \rho^o$+D) to determine counter efficiencies and to do various other cross checks on the data taken earlier. With these measurements this experiment is now completed.

T-65 — Shower Counter Tests for E-65 - Study of Electroproduced Hadrons - SLAC - Spokesman: W. Toner

A prototype lead-lucite shower counter for the E-65 trigger array was tested successfully. The counter has an active area 25" $\times$ 18" and is made of 16 sheets of a new type of lucite which is doped in order to convert Cerenkov radiation in the ultraviolet into isotropic light in the visible blue. Pulse heights from this material are typically 2.4 times higher than from UVT lucite in small counters with good efficiency for Cerenkov light collection. Five two-inch phototubes were sufficient to give $\sim 17\%$ FWHM resolution at 15 GeV with good uniformity of response to within one inch of the edges. Eleven such counters will be used in the E-65 trigger system.

D-9 — Study of High Energy Magnetic Bremsstrahlung in Pulsed Megagauss Fields - Illinois Institute of Technology - Spokesman: T. Erber

The megagauss bremsstrahlung experiment — including beam tuneup and background checks — ran seven times in the interval 14 August - 25 September. The field (~ 1 MG) is generated in a single turn brass coil by a 20-kV, 60-kJ fast bank (2.5 μsec quarter period). The electron pulse and field maximum are synchronized to within 0.1 μsec. The beam is ~ 1.2 mm in diameter at the magnetic target, and is aimed through 2 mm holes in the brass coil; overall alignment is better than 0.3 mm. At 19 GeV incident energy, the magnetic bremsstrahlung amounts to 38.5 MeV or 4.9 photons per electron. This corresponds to an average of 8 MeV/photon. The radiation is of course linearly polarized. The deflected beam and the magnetic bremsstrahlung are recorded on X-ray film (enclosed by intensifying screens), 1" × 3" × 25 μ test emulsions and a set of 4" × 8" × 600 μ G-5 emulsions. Oscilloscope records, as well as results from the X-rays and test emulsions, indicate that the experiment functioned as planned. The large G-5 plates are now being processed by the Heckman Group, LRL, Berkeley. (T. Erber, IIT)

D-11 — Shielding Test - SLAC - Spokesmen: T. Jenkins, J. Harris

Collimators are often employed to act as shields for equipment. They also may be used to protect personnel. When used for these purposes, the assumption may be made that the beam either targets in a thick wall (hits the collimator) or misses the collimator entirely. However, what may occur is that the beam strikes the edge of the collimator at some small angle, with a large fraction of the energy escaping. To determine the efficacy of a collimator in protecting something downstream, the intensity and angular distribution of the scattered radiation should be known.

An experiment was performed to measure the angular distribution of radiation emerging from a thick target struck by a 2 GeV electron beam at small angles. The target was a 3' long iron plate, 5" thick which was pivoted about a line 1 foot from one end. The plate was inclined to the beam center line at angles of 1-1/2, 3, 6, 9, and 12°, and the scattered radiation measured from 0° to 90°.

In another part of the experiment the beam struck a 1/4" thick Al plate inclined at an angle of 4° from the beam, with the scattered beam measured out to 90°. Ion chambers and LiF powder in small polyethylene capsules were used as the detectors (in some cases inside absorbers to learn something of the energy).

The results of these tests will be used in designing collimators and shielding for SPEAR. They should also be quite useful to anyone wishing to use a collimator as a shield, either for personnel or for components.

D-14 — Charpak Chamber Tests - SLAC - Spokesman: E. Bloom

The July cycle was spent debugging a new PDP-8 and interfacing it to the experimental apparatus.

The August cycle was very productive. The chamber design was finalized for running in the 20 GeV spectrometer this December. The chamber has 2 mm wire spacing, gold plated tungsten .8 mil wire, .4 cm from H. V. plane (wire mesh) to active wires (at ground). The size of the chamber is 20 cm × 20 cm. About 100 wires per chamber will be used in the spectrometer application. The gas used is 20% Isobutane, 80% Argon, pre-mixed. The chambers are > 98% efficient into a 28 nsec gate with H.V. of 2700 V. At present three of these chambers have been built with a fourth soon to be finished. The run in the 20 GeV spectrometer will need four chambers.

Some initial tests on the electronics supplied by Ray Larsen's group in EFD have been done. These appear satisfactory with some minor modifications. Finally, a large 2 mm chamber 37 cm × 55 cm has been tested with some success: > 98% efficiency into a 40 nsec gate. This device may be used in E-71.

In the September cycle, we succeeded in getting a complete wire chamber operational. This included 64 wires and CAMAC electronics built by EFD. The system appears to work satisfactorily. Next cycle we will attempt to run two chambers and do ray tracing of beam particles.

D-15 — Λp Interactions, with Λ's Produced in a Dense Target by 9 GeV/c Protons - University of Colorado - Spokesman: T. H. Tan

In July, a short test exposure of 19, 380 pictures was taken of 9.1 GeV/c protons into the same platinum target used by BC-30 (82" bubble chamber). The film format was the 3-strip 35 mm. Λ production was found to be lower than calculated.

Y-4 — Heat Transfer Test of Slit Modules in C-Beam - SLAC - Spokesman: D. Walz

Two slit modules as used for the new B-beam slit SL-30 were tested in the central beam area of the BSY on 9-10-70. The modules contain water-cooled aluminum spheres as the power-absorption medium. The modules were installed in series, just like the SL-30 application, and they were followed by a portable beam dump for complete absorption of the residual cascade shower. Thermocouples were used to measure the axial temperature distribution along the collimating face of the modules and the lateral temperature distribution at the shower maximum of the electromagnetic cascade.

The nominal incident electron beam energy was 18 GeV, the peak current was about 70 mA, and the pulse width was about 1.6×10^{-6} sec. Useful data were obtained for pulse repetition rates varying in increments of 60 pps from 60 to 300 pps. At 300 pps the average beam power incident on the modules was approximately 600 kW. At this proper level the temperatures in the modules were stable, even though several thermocouples indicated that the boiling temperature of water at the local pressure was reached. The new B-beam slit SL-30 should thus perform well at the design power level of 500 kW.

After completion of the experiment the test apparatus was used as a power absorber to establish a figure for the maximum average power currently available from the accelerator. At a pulse repetition rate of 360 pps the accelerator delivered between 730 and 750 kW, depending on whether average or peak current readings are used. At this power level the modules failed due to melting of the collimating face.

Bubble Chamber Experiments (R. Gearhart)

BC-5 — Study of Many Particle Final States Produced by 12 GeV/c π - University of Hawaii - Spokesman: M. Peters

The University of Hawaii group continued their experiment with an exposure of 300,738 pictures (82" bubble chamber - 46 mm single strip film format). The group is studying 6 and 8 prong events in a search for 4 and 5 body decays of meson resonances and for many body decays of baryon resonances.

BC-26 — Determination of Quantum Numbers for Resonances in the R, S, T, and U Region Using π^+d Interactions at 11 GeV/c - Duke University - Spokesman: L. Fortney

An exposure of some 230,865 pictures in the 82" bubble chamber using the 46 mm single strip film format was taken. The rf separated beam was used to produce a positive pion beam at 11 GeV/c. The flux was ~ 12 tracks/picture.

BC-30 — Λp Interactions in the Momentum Interval 1-5 GeV/c - Spokesmen: J. Kadyk, G. Trilling

The experiment is a study of Λp elastic scattering and the reactions $\Lambda p \rightarrow \Lambda p \pi^+ \pi^-$ and $\Lambda p \rightarrow \Sigma^{\pm} \pi^{\mp} p$ in the momentum interval of about 1-5 GeV/c.

The experiment should give total and differential cross sections for these reactions, as well as polarization information. The Λ particles are produced by directing a K^- beam into a platinum target placed inside the 82" bubble chamber.

Prior to cooling down, the platinum target (10" × 3" × 3/4") was mounted in the 82" bubble chamber near the entrance window and 3/4" below the mid-plane. The 3" dimension is along the beam direction.

Lambdas are produced in the platinum by interactions with K^-'s at 12 GeV/c from the rf separated beam. A few inches of the incoming tracks are visible, permitting determination of the line along which the origin of the lambda will lie. Some 49,570 pictures were taken in July and 133,000 in September (out of a planned exposure of 500,000). Preliminary results show that the maximum flux available in the beam ($\sim 7\ K^-$/pulse) is also the maximum desirable for efficient scanning. The film format is the single strip 46 mm.

BC-33 — Study of $\pi\pi$ Scattering, Extrapolation Procedures, and ρ Production in $\pi^- p$ Collisions - University of Pennsylvania - Spokesman: W. Selove

An exposure of 150,314 pictures was taken in the 82" bubble chamber of a 4.5 π^- beam. The 3-track 35 mm film format was used. 39,802 pictures were declared unacceptable due to camera induced errors. The typical flux was $\sim$10 tracks/picture, permitting measurement with an HPD system. The film is to be developed at BNL and no preliminary results are yet available. 254,319 pictures were taken during the October accelerator cycle. This completes the planned exposure.

B. New Experiments

During the August 14-15, 1970 meeting of the SLAC Program Advisory Committee, Experiments E-70, E-71, BC-34, BC-37, BC-38, BC-39, BC-40, BC-42, BC-43, and BC-44 were approved.

The next scheduled meeting of the SLAC Program Advisory Committee will be held on November 13 and 14, 1970. The next meeting after that will be in February 1971.

Call for Bubble Chamber Proposals

Bubble chamber proposals will be considered at the February 1971 meeting of SLAC's Program Advisory Committee. The deadline for receipt of new BC proposals at SLAC is January 1, 1971.

Summaries of Newly Approved Experiments

E-70 — Measurement of the Asymmetry in Compton Scattering on the Proton with Linearly Polarized Photons - Cornell, Harvard, Northeastern, SLAC - Spokesman: B. H. Wiik

This is an experiment to measure the asymmetry in proton-Compton scattering with linearly polarized photons at 6 and 10 GeV and for values of the four momentum transfer $-t$ between .1 to .7 $(\mathrm{GeV}/c)^2$. A well collimated linearly polarized photon beam from a diamond will strike a hydrogen target and the scattered photon will be detected by a shower counter in coincidence with the recoil proton as detected by the 1.6 (GeV/c) spectrometer. This technique has been used successfully to measure the differential cross section for Compton scattering (E-50a). The results will give direct information on the size of the s-channel photon helicity flip amplitude.

E-71 — Vector Meson Electroproduction at High Energy - U.C. Santa Cruz, SLAC - Spokesman: R. E. Taylor

This is an experiment to investigate the reaction $ep \rightarrow ep\rho^0$ using a missing mass technique where the momentum vectors of the scattered electron and the recoil proton are measured by the 20 GeV/c spectrometer and the 1.6 GeV/c spectrometer respectively. The mass of the unobserved system is then uniquely determined by kinematics.

By measuring at small electron scattering angles, small momentum transfer to the proton, and electron energy losses of about one half the incident energy, data taking is still efficient at low incident beam currents.

The mass distribution, t-dependence (from .15 to .35 $(\mathrm{GeV}/c)^2$) and q^2-dependence (from 0 to 1.0 $(\mathrm{GeV}/c)^2$) for electroproduction of rho mesons will be measured. A separation of the production of longitudinal rho mesons from transverse rho production will be attempted at $q^2 = .1$ and .3 $(\mathrm{GeV}/c)^2$. Data of good statistical significance at the 2, 3, 4, ... pion continuum in inelastic electron scattering as well as experience in doing coincidence studies at SLAC will be obtained. Qualitative features of the data which are important in this experiment will be available on line.

BC-34 — K^-d Interactions Around 12 GeV/c - Johns Hopkins University - Spokesman: A. Pevsner

Johns-Hopkins has already analyzed a 100,000 picture 12.6 GeV/c K^-d exposure obtained in the BNL 80" chamber in 1965 and some results have been published. Four broad categories of interest have emerged from this work.

1. Diffractive Coherent Production: The most significant results of the earlier analysis regard the observation of the Q and L enhancements in the coherent channel $K^-d \rightarrow K^-\pi^+\pi^-d$. The coherent production rates for both the Q and L were found to be comparable to those on nuclear targets, at high energies, establishing spin 1/2 for both. The relative absence of background in the coherent channel permits a meaningful study of the spin and parity of the $K\pi\pi$ system. The observed decay distributions for the L suggest strongly a 2^-, or 1^+ assignment. A definitive statement on the J^P of the L system is of great importance and will be possible with increased statistics. The 2^- assignment could represent the first instance of a Regge recurrence (of the K) among bosons. This group was the first to point out the connection between the L enhancement and the threshold enhancement in the K* (1420) π system, but limited statistics do not permit a clearcut decision regarding the presence of the L in the K* (890) π and K channels, although the data suggests that such decay modes might be present. The question of $L \rightarrow K^*(890)\,\pi$ and $L \rightarrow K\rho$ modes is of great importance in establishing the L as a bona fide resonance instead of only a K* (1420) π threshold enhancement. A coherent production experiment has a distinct advantage for spin and parity determination in this case due primarily to the suppression of 1^-, 2^+, 3^- states and to the absence of the N* (1238) that overlaps the L region in the $Kp \rightarrow K\pi\pi p$ experiments.

2. Coherent Nondiffractive Production: It is planned to study further the coherent channel $K^-d \rightarrow K^*(890)\,d$. This group's small sample of data at 12.6 GeV/c supports the hypothesis of a pure ω exchange production mechanism, but it is important to study this channel with increased statistics. As a test of present theoretical models the determination of the energy dependence of the cross section and the density matrix elements of the K* (890) is of great importance.

3. Production Mechanism and Properties of the $N^*_{1/2}$ Resonances by Diffractive Process: At present this group is studying the πN and $\pi\pi N$ systems in several reactions. The study of the $N^*_{1/2}$ (1400) resonance is of interest in

view of the rather contradictory data presently available regarding its production rate, slope of the diffraction peak in production, and its decay branching ratios.

It should be emphasized that while the study of this system through $\pi\pi N$ decay modes has been extremely difficult the reaction $K^- d \rightarrow K^- \pi^- p\, p_s$ permits the study of the $N^*_{1/2}(1400)$ through a two body πN mode. A decided advantage in using a K^- beam is the absence of overlapping meson resonances. Preliminary data on this indicates a prominent structure around 1500 MeV in the πN system which is clearly not dominated by the $N^*_{1/2}(1238)$.

4. Strange Particle Systems: With increased statistics a search will be made for higher Ξ^* resonances although the cross sections are expected to be rather low. A search for possible exotic objects like the Ξ^{*--} and Ω^{--} will also be done.

BC-37 — An Investigation of K_2^0 Interactions in Deuterium with the SLAC 40-Inch Bubble Chamber - Yale University - Spokesman: H. D. Taft

The primary motivation for this experiment is to study exchange processes in high energy K-nucleon interactions in order to determine the magnitudes and phases of the t-channel amplitudes as functions of s and t. For reactions in which only the K and the exchanged particle are involved at one vertex, the exchanged particle must of course have natural parity. For reactions involving K* production, further decomposition into trajectories having natural or unnatural parity is possible using the measured density matrix elements. Given the appropriate data a nearly unambiguous determination of the amplitudes associated with certain of the exchanged trajectories is possible. Such a program will provide more reliable insight into the validity of a Regge pole model description of these reactions than may be obtained from phenomenological fits using an arbitrary choice of trajectories.

Nearly all reactions involving incident K^0 or $\overline{K}^0$ on neutrons or deuterons may be studied (assuming charge symmetry) with incident K^+ or K^- on protons or deuterons. Since the problems associated with the use of neutral beams as well as with the extraction of neutron cross sections from deuterium cross sections are considerable, such reactions will be used principally for calibration purposes. In this role they will be of value since the topologies and momentum transfer distributions will be similar to those of the reactions of physical interest. Thus a verification that this treatment of these problems is correct will be possible.

In addition to the redundant reactions there are in fact several reactions observable with K_2^o incident on deuterium which yield unique information not obtainable in any other way. These are all of the form

$$K_2^o + d \rightarrow K_1^o \text{ (or } K_1^* \text{ or } K_2^*) + d \text{ (or } n+p)$$

The coherence (in terms of eigenstates of C) of the initial and final K meson states places restrictions on the C quantum number of the exchanged objects. Alternatively, if the C behavior of the exchanged object is assumed, then conclusions may be drawn concerning the G parity of the multiplet to which the K* belongs. For experimental reasons, the only K^{*o} decay mode observable, without accurate time-of-flight information, which preserves this coherence is $K^{*o} \rightarrow K_1^o \rho^o$. With time-of-flight information one could also examine $K^{*o} \rightarrow K_1^o \pi^o$.

Finally, there are two reactions which, while also observable in K^+ and K^- beams separately, are most easily compared in a beam whose mixture of K^o and $\bar{K}^o$ is well known.

BC-38 — A Study of $\pi^+ d$ Interactions at 15 GeV/c - Florida State and University of Pennsylvania - Spokesman: V. Hagopian

The principal objectives of this experiment are as follows:

Resonances

(a) Study of S=0 resonances decaying into strange particles, e.g., $K^o\bar{K}^o$, $\Lambda^o K^o$, etc.

(b) Study of S≠0 resonances, e.g., $K\pi$, $\Lambda\pi$, etc.

(c) Study of S=0 resonances decaying into π's (special emphasis on masses 1.5 to 4.0 GeV and total charge = 0).

Dynamics

(a) Study of coherent production, $\pi^+ + d \rightarrow (\pi^+\pi^+\pi^-) + d$ (6000 events).

(b) Study of $\pi^+ + n \rightarrow B + p$ production where B is ω (~ 300 events), ρ (~ 1000 events) or A.

(c) Multiperipheral dynamics (e.g., $\pi^+ + n \rightarrow \pi^+\pi^+\pi^-\pi^- p$, 7500 events).

The experiment will use the separated π^+ beam at highest available momentum - about 15 GeV/c. An exposure of 250 K pictures with 10 to 12 beam particles per picture on 35 mm perforated film suitable for the Flying Spot Digitizer (HPD), corresponding to about 30 events/μb will be taken.

BC-39 — Study of π^+ Interactions in Hydrogen at 15 BeV/c - Columbia, State University of New York at Binghamton - Spokesmen: C. Baltay, N. Yeh

This experiment is a study of various topics in strong interactions using the interactions of high energy pions in hydrogen. The two main areas of interest are the study of mesonic and baryonic resonances, and a study of the dynamics of high energy hadron collisions.

A half dozen to a dozen mesonic states have been found and their existence and spin parity assignments have been established in the last decade. Another two dozen other states have been claimed, but either their existence is questionable or their spin parity assignments are undetermined or uncertain. The incompleteness of the experimental data makes it difficult to find the theoretical model or "pattern" that these states fit into. The search for more mesonic states and the determination of their properties is a worthwhile and exciting activity until some pattern emerges and its validity is demonstrated by the experimental data.

There has been much theoretical activity in the field of dynamical models of strong interactions. Recently many theoretical predictions have become more concrete and comparison with experimental data more meaningful. Therefore, there is a need for good high statistics data, especially at high energies where many of the theories are more likely to be valid.

It is planned to have 10 incident π^+ tracks per picture using events within a 50-in. long fiducial volume. At this flux one interaction per picture is expected, producing on the average 4 charged products. The 50-in. fiducial volume allows $\sim$ 2 ft. for measurement of the outgoing tracks on all events. This is important to obtain good resolution. These factors in the proposed 500 K picture exposure will yield a sensitivity of 20 events/μ barn for the experiment.

BC-40 — Proposal for 8.0 and 14 GeV/c, π^+ and π^- Exposures in the SLAC 82-Inch HBC - MIT - Spokesmen: B. T. Feld, I. A. Pless

A study of πp interactions leading to quasi-two body final states will be executed in order to extract the ω, B, A_1, A_2, π Regge trajectories. Vector meson exchange reactions will be studied to test absorption models, and the region of boson resonances above 1.5 GeV/c^2 will be inspected in the light of quark model predictions. This study will use 1.6 M pictures taken in the 82-inch HBC with a sufficient beam intensity to insure an average of one interaction per picture. Systematic errors which arise in the comparison of data at different energies will be reduced by eliminating the fluctuations which come from the different analysis techniques of different groups.

BC-42 — Bubble Chamber Study of Deep Inelastic Muon Scattering - U.C. Santa Cruz, SLAC - Spokesman: E. D. Bloom

This experiment will study deep inelastic muon scattering using the 40" bubble chamber in a rapid cycling, triggered mode. With a muon beam having a flux of 10^3 muons per sec into the 40" bubble chamber cycling at 20 pps, a trigger system involving scintillation counters, wire spark chambers, and a small computer, it is estimated that about 1000 events in the inelastic region with $q^2 \geq 0.5$ $(GeV/c)^2$ in 360 hours of good running.

By looking at rather general features of the data, e.g., the geometry of the events, transverse momenta distributions, longitudinal momenta distributions, pion multiplicities, peripherality, and missing mass plots as a function of q^2 in rough bins, one might answer some important questions:

1. Does "diffraction" go away as q^2 approaches the scaling region, or do diffractive processes dominate this region (D_2 in the chamber might help answer this question);

2. Is the ρ meson an important final state in the scaling region, or more generally, what reaction channels contribute to the large inelastic cross sections in this region;

3. Is the character of the scaling region similar to the low s ($=W^2$) region at $q^2=0$, i.e., do events in the scaling region show a typical nonperipheral geometry; and

4. Do new prominent enhancements emerge in particular channels for $q^2 \neq 0$.

Since the bubble chamber sees the total geometry of each event, including the vertex, the above questions have a good chance of being answered with the anticipated number of events.

BC-43 — A Study of π^+d Interactions at 15 GeV/c - Washington, U.C. Berkeley - Spokesmen: H. J. Lubatti, W. B. Fretter

This experiment is a study of π^+d interactions at 15 GeV/c. It is planned to study in detail the coherent production of 3 and 5 pion states and perform a systematic study of boson resonances in the region above 1.2 GeV/c^2 (S, T, U region). 250 K pictures are approved with a beam intensity sufficient to yield 6 tracks/pickup for PEPR analysis.

BC-44 — Proposal for a Measurement of the Total Hadronic γp Cross Section at Photon Energies Between 0.5 and 1.2 GeV - DESY - Spokesman: G. Wolf

This is an experiment to measure directly the total hadronic γp cross section, $\sigma_{\gamma p}^{tot}$, at photon energies, E_γ, between 0.5 and 1.2 GeV in steps of 50 MeV in the total c.m.s. energy. The measurement will be done with a 10^5 exposures in the

82" LRL-SLAC hydrogen bubble chamber with the Compton backscattered laser beam. The expected uncertainty in each cross section point is < 5%. At energies below 1 GeV (and above the 2π threshold) $\sigma_{\gamma p}^{tot}$ has not yet been measured directly. The only data available come from the extrapolation of inelastic ep data, a procedure which for $E\gamma$ > 1 GeV resulted in values for $\sigma_{\gamma p}^{tot}$ systematically larger than those measured directly by 10%.

Precise data on $\sigma_{\gamma p}^{tot}$ will allow more accurate calculations of the real part of the forward Compton-scattering amplitude, Re f(0), with the help of dispersion relations. Conversely, when measurements of Re f(0) are available, a check of the dispersion relations will be possible. Accurate measurements of $\sigma_{\gamma p}^{tot}$ are required to determine whether there exists an energy independent contribution, C, to the spin independent amplitude f, for forward Compton scattering.

The values of $\sigma_{\gamma p}^{tot}$ obtained from extrapolating the ep data indicate a peculiarity of $\sigma_{\gamma p}^{tot}$ near the "second resonance" ($E\gamma \simeq 0.75$ GeV, total c.m.s. energy $\sqrt{s} \simeq 1.5$ GeV) when compared to the average of the total π^+p and π^-p cross sections. There, this ratio is larger by ~ 30%. Hence in this energy region one (or possibly several) nucleon isobar (called N* (1500)) couples more strongly to photons. Applying vector dominance one expects the N* (1500) to decay into nucleon + vector meson, and in this case specifically into nucleon + ρ. This experiment will allow a study of several γp reactions separately and a test of the N* (1500) $\rightarrow$ Nρ conjecture.

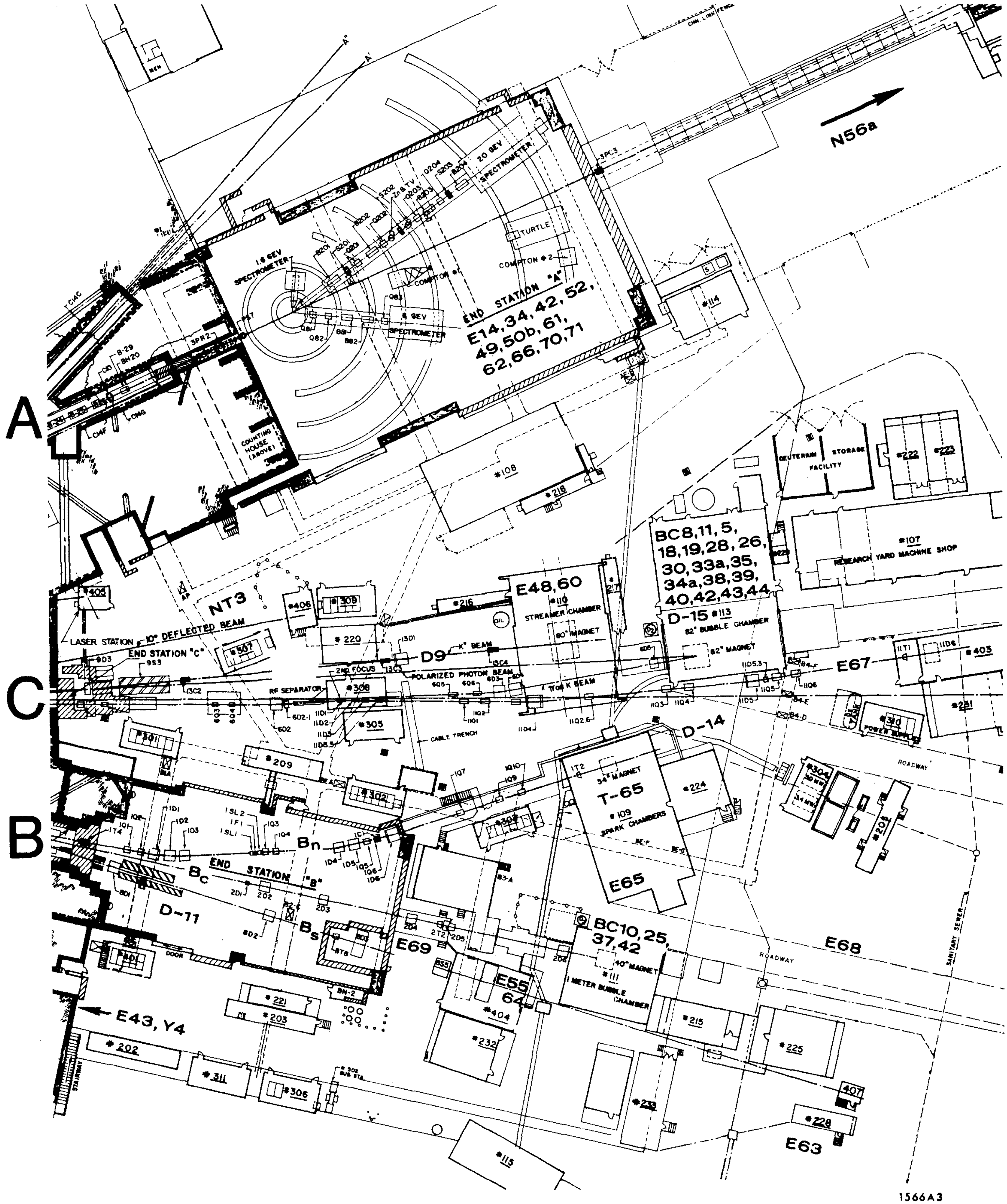

FIG. 1--Experiment locations.

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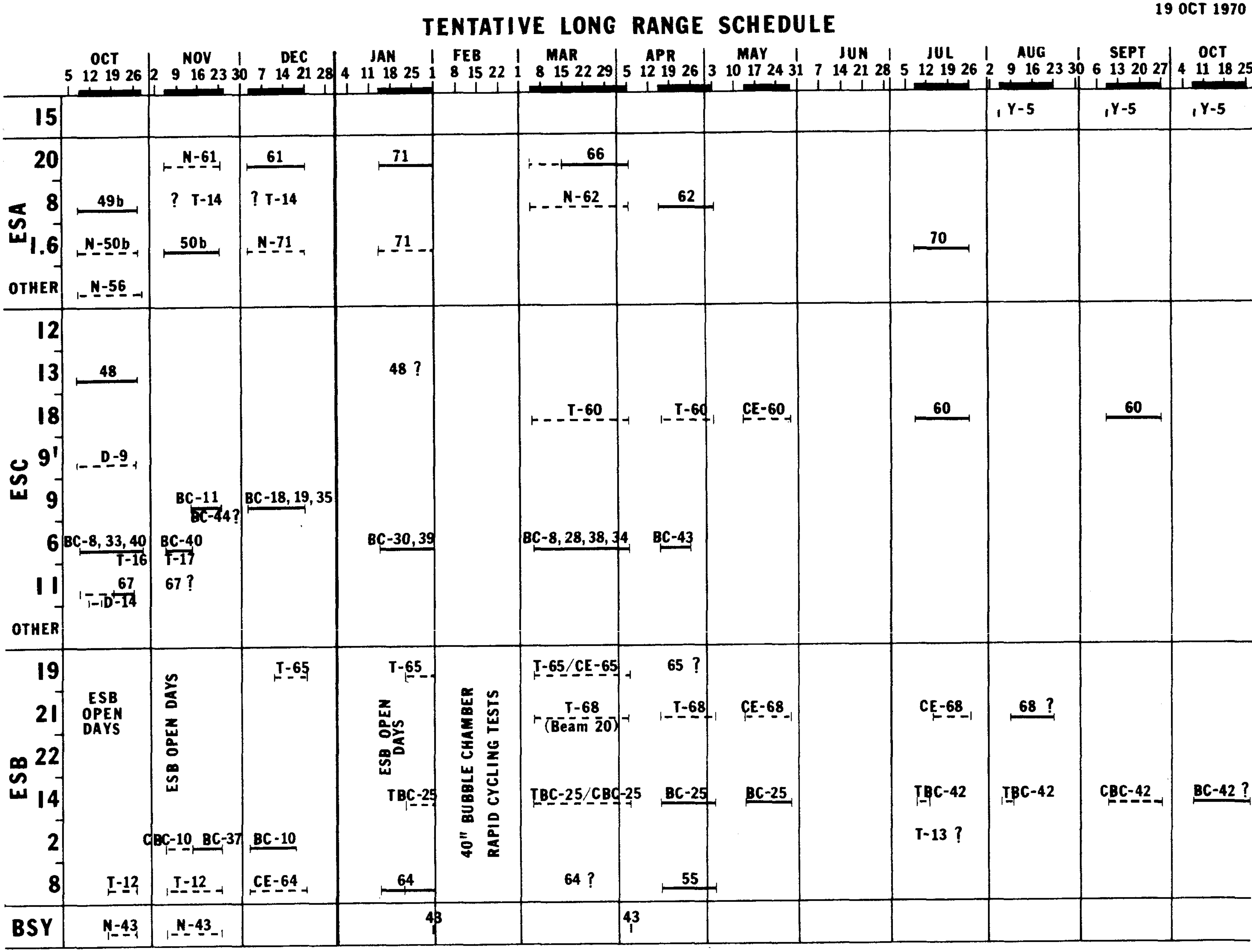

FIG. 2--Tentative long-range schedule.

TABLE 1

TABLE OF PROGRAMMED EXPERIMENTS

Number	Title	Authors	Date Approved	Status
E-14	Test of Quantum Electrodynamics by Photoproduction of Asymmetric Muon Pairs	STANFORD (Group A) W. Panofsky, D. H. Coward, H. DeStaebler, J. Litt, A. Minten, L. W. Mo, R. E. Taylor MIT J. I. Friedman, H. W. Kendall L. VanSpeybroeck	11/18/66	Inactive
E-34	Electron-Deuteron Quasi-Elastic Scattering	STANFORD E. Bloom, D. Coward, H. DeStaebler, J. Drees, J. Litt, R. E. Taylor MIT J. Friedman, G. C. Hartmann, H. W. Kendall CAL TECH B. C. Barish	7/2/68	Inactive
E-42	Photon-Proton Scattering at Forward Angles	SLAC A. Boyarski, F. Bulos, W. Busza, R. Diebold, S. Ecklund, G. Fischer, H. Lynch, B. Richter	3/22/69	Running/ Complete
E-43	Velocity of Light Experiment	UCSD G. Masek	12/14/68	Inactive
E-48	Proposal to Measure the ξ Parameter in the Decay $K^o_L \to \pi\mu\nu$	BNL D. Hill, R. Palmer, M. Sakitt, N. Samios SLAC D. Fries, F. Liu, R. Mozley, A. Odian, J. Park, W. Swanson, F. Villa	2/8/69	Running
E-49b	Inelastic Scattering From D_2 and Other Nuclei: Large Angles	SLAC D. Coward MIT J. Elias, J. I. Friedman, H. W. Kendall, M. Sogard, K. Tsipis, M. Breidenbach, R. Verdier	8/6/69	Setup/ Running

Table of Programmed Experiments (cont'd) - 2

Number	Title	Authors	Date Approved	Status
E-50a	Compton Scattering at High Energies From Hydrogen	SLAC R. Anderson, D. Gustavson, J. Johnson, I. Overman, D. Ritson, B. Wiik HARVARD UNIV. J. Walker NORTHEASTERN UNIV. R. Weinstein	3/22/69	Complete
E-50b	Asymmetry in the Photoproduction of π^0 Mesons by Polarized Photons.	SLAC R. Anderson, D. Gustavson, J. Johnson, I. Overman, D. Ritson, B. Wiik HARVARD UNIV. J. Walker NORTHEASTERN UNIV. R. Weinstein	3/21/70	Checkout/ Running/ Special Test
E-52	Determination of γ_ρ^2 and the Total ρN Cross Section From Coherent ρ-Photo-productions on Deuterium	SLAC R. Anderson, D. Gustavson, J. Johnson, I. Overman, B. H. Wiik NORTHEASTERN UNIV. R. Weinstein	8/6/69	Special Test/ Complete
E-55	Study of Dalitz Plot for the Decay $K_L^0 \longrightarrow \pi^+\pi^-\pi^0$	SLAC H. Saal U. C. SANTA CRUZ D. Dorfan UNIV. COLORADO U. Nauenberg	5/23/70	Setup
E-56a	A Search for Short-Lived Sources of Neutrino-Like Particles	SLAC D. Fryberger, A. Rothenberg, M. Schwartz, T. Zipf UNIV. OF PENNNSYLVANIA E. Beier, A. Mann, E. Rybaczewski U. C. SANTA CRUZ D. Dorfan	3/21/70†	Parasiting
E-60	Hyperon Production in K^-p Interactions	SLAC K. Bunnell, R. Mozley, A. Odian, J. Park, B. Swanson, F. Villa, L. Wang U.C. RIVERSIDE S. Fung, A. Kernan, R. Poe, T. Schalk, B. Shen LRL BERKELEY M. Alston-Garnjost, R. Bangerter, A. Barbaro-Galtieri, F. Lynch, F. Solmitz	12/12/69	Inactive

Table of Programmed Experiments (cont'd) - 3

Number	Title	Authors	Date Approved	Status
E-61	Forward Electron Scattering	SLAC E. Bloom, R. Cottrell, H. DeStaebler, C. Jordan, M. Mestayer, H. Piel, R.E. Taylor	2/21/70	Inactive
E-62	Particle Spectra at High Energies	CAL TECH B.C. Barish, A. Dzierba, W. Ford, R. Gomez, Y. Nagashima, P. Oddone, C. Peck, J. Pine, F. Sciulli, A.V. Tollestrup	3/21/70	Inactive
E-63	Measurement of K_L^0 and Neutron Total Cross Sections on Nuclear Targets	STANFORD UNIV. J. Crawford, R. Ford, E.B. Hughes, L. Middleman, L.H. O'Neill, J. Otis	3/21/70*	Parasiting
E-64	Study of the Decay $K_L^0 \to \pi^\pm \mu^\mp \nu$	SLAC D. Fryberger, D. Hitlin, J. Liu, M. Schwartz, S. Wojcicki U.C. SANTA CRUZ D. Dorfan	3/21/70	Setup
E-65	Study of Electroproduced Hadrons	SLAC B. Dieterle, W. Lakin, F. Martin, E. Petraske, M. Perl, J. Tenenbaum, W. Toner	3/21/70	Inactive
E-66	Inelastic Photoproduction of Charged Pi and K Mesons in the Forward Direction	SLAC A. Boyarski, S. Ecklund, B. Richter, R. Siemann	3/21/70	Inactive
E-67	Study of $\pi N \to N\bar{N}N$ at 15 GeV/c	SLAC F. Bulos, R. Carnegie, E. Kluge, D.W.G.S. Leith, H. Lynch, B. Ratcliff, S. Williams, H. Williams	3/21/70	Setup/ Checkout
E-68	Inclusive Pion-Proton Scattering	UNIV. OF WASHINGTON J.E. Rothberg, R.W. Williams, K.K. Young, A. Schenck L. Sompayrac, M. Delay	5/23/70	Inactive

Table of Programmed Experiments (cont'd) - 4

Number	Title	Authors	Date Approved	Status
E-69	Improvement of the Statistical Accuracy of the Measurement of the Form Factors for K^o_L Decay	JOHNS-HOPKINS UNIV. B.Cox, C.Chien, L.Ettlinger, L.Madansky, A.Pevsner, L.Resvanis, V.Shreedhar, R.Zdanis SLAC E.Dally, E.Seppi UCLA C.Buchanan, D.Drickey, F.Rudnick, P.Shepard, D.Stork, H.Ticho	5/23/70	Checkout/ Running/ Complete
E-70	Measurement of the Asymmetry in Compton Scattering on the Proton with Linearly Polarized Photons	SLAC R.Anderson, D.Gustavson J.Johnson, I.Overman, D.Ritson, B.Wiik CORNELL R.Talman NORTHEASTERN UNIV. R.Weinstein HARVARD D.Worcester	8/15/70	Inactive
E-71	Vector Meson Electroproduction at High Energy	SLAC E.Bloom, R.Cottrell, H.DeStaebler, C.Jordan, M.Mestayer, G.Miller, H.Piel, R.E.Taylor UCSC C.Prescott	8/15/70	Inactive
BC-5	A Proposal to Study Many Particle Final States Produced by 12 GeV/c π^- Mesons at SLAC	UNIV. OF HAWAII A.Kohya, M.W.Peters, V.Peterson, V.Stenger, A.Johnson, N.Rogers, P.Wohlmut	12/16/67	Running/ Complete
BC-6	Proposal to SLAC for Study of the One Pion Exchange Contribution to γ-Nucleon Scattering (in 82 Inch Deuterium Bubble Chamber)	OAK RIDGE H.O.Chon, R.D.McCulloch UNIV. OF TENNESSEE G.T.Condo, W.M.Bugg	9/28/68	Complete
BC-8	Exposure of the 82 Inch Hydrogen Chamber to a Beam of π^+ Mesons at 7.0, 11.0 and 14.0 GeV/c	PURDUE D.D.Carmony	Ext. 3/21/70	Inactive
BC-10	A Proposal to Investigate K^o_2p Interactions with the 40-Inch HBC	STANFORD B.C.Shen, D.W.G.S.Leith, A.D.Brody, W.B.Johnson, R.R.Larsen, G.A.Loew, R.Miller, W.M.Smart	5/11/68	Setup

Table of Programmed Experiments (cont'd) - 5

Number	Title	Authors	Date Approved	Status
BC-11	A Bubble Chamber Experiment with the Polarized Laser Induced Photon Beam (Extended 10/3/69)	SLAC J. Ballam, G. Chadwick, Z. Guiragossián, P. Klein, A. Levy, M. Menke, J. Murray, G. Wolf TUFTS UNIV. C. Sinclair U.C. BERKELEY H. Bingham, B. Equer, K. Moffeit UCLRL M. Rabin, W. Podolsky, A. Rosenfeld	5/11/68	Inactive
BC-18	A 4.25 GeV γ-Deuterium Experiment in the SLAC 40" Bubble Chamber and with Polarized Photons in the 82 inch Bubble Chamber	WEIZMANN INSTITUTE Y. Eisenberg, B. Haber, U. Karshon, L. Lyons, E. E. Ronat, A. Shapira, G. Yekutieli	9/28/68	Inactive
BC-19	γ-d Experiment with AnAnnihilation Beam of 7.5 GeV in SLAC 40" Bubble Chamber and with Polarized Photons in the 82 inch Bubble Chamber	TEL-AVIV UNIV. G. Alexander, I. Bar-Nir, A. Brandstetter, S. Degan, J. Grunhaus, A. Levy, Y. Oren	Ext. 3/21/70	Inactive
BC-25	Study of Pomeranchon, Meson and Baryon Exchanges by Triggering the SLAC 40" Bubble Chamber on Fast Forward Particles	CAL TECH B. Barish, W. Ford, R. Gomez, C. Peck, J. Pine, F. Sciulli, B. Sherwood, A. Tollestrup, G. Zweig	6/18/69	Inactive
BC-26	Determination of Quantum Numbers for Resonances in the R, S, T, and U Region Using π^+ - d Interactions at 12 BeV	DUKE UNIV. M. Binkley, D. Carpenter, L. Fortney, C. Rose, E. Fowler, J. Elliot, J. Golson, V. Joshi, J. Kronenfeld, T. Snow, W. Yeager	6/11/69	Running/ Complete
BC-28	A 5 GeV/c π^+p Experiment in the SLAC 82-Inch HBC	WEIZMANN INSTITUTE Y. Eisenberg, B. Haber, U. Karshon, E. Ronat, A. Shapira, G. Yekutieli	8/6/69	Inactive
BC-30	Λp Interactions in the Momentum Interval 1-5 GeV/c	LRL BERKELEY G. Trilling, J. Kadyk, G. Goldhaber, J. Hauptman	12/12/69	Special Test/ Running
BC-33a	300,000 Pictures, 4.5 GeV/c π^- in H_2 82-Inch Bubble Chamber	UNIV. OF PENNSYLVANIA S. Barish, J. Bensinger, E. Bogart, P. Jacques, W. Selove	3/21/70	Running/ Complete

Table of Programmed Experiments (cont'd) - 6

Number	Title	Authors	Date Approved	Status
BC-34a	K^-d Interactions Around 12 GeV/c	JOHNS-HOPKINS UNIV. C. Chien, B. Cox, D. Denegri, L. Ettlinger, G. Goodman, R. Mercer, A. Pevsner, R. Sekulin, R. Zdanis	8/15/70	Inactive
BC-35	γ-d Interactions at 3.5 and 5.5 GeV with Polarized Photon Beam	U. C. RIVERSIDE S. Fung, A. Kernan, R. Poe, T. Schalk, B. Shen U. C. BERKELEY R. Birge, R. Ely, G. Gidal, D. Grether, G. Kalmus, W. Michael	3/21/70	Inactive
BC-37	An Investigation of K_2^0 Interactions in Deuterium with the SLAC 40 Inch Bubble Chamber	YALE UNIV. V. D. Bogert, T. Ludlam, H. D. Taft	8/15/70	Inactive
BC-38	A Study of π^+d Interactions at 15 GeV/c	FLORIDA STATE UNIV. J. Albright, A. Colleraine, S. Hagopian, V. Hagopian, J. Lannutti, G. Yost UNIV. OF PENN. J. Bensinger	8/15/70	Inactive
BC-39	Study of π^+ Interactions in Hydrogen at 15 BeV/c	COLUMBIA C. Baltay, L. Gerschwin, W. Cooper, S. Csorna, M. Habibi, M. Kalelkar STATE UNIV. of NEW YORK N. Yeh, A. Gaigalas	8/15/70	Inactive
BC-40	8.0 and 14 GeV/c, π^+ and π^- Exposures in the SLAC 82 Inch HBC	MIT Z. Carmel, F. Dao, B. Feld, R. Hulsizer, V. Kistiakowsky, I. Pless, V. Simac, F. Triantis, T. Watts, J. Wolfson, R. Yamamoto, D. Ballantyne, M. Hodous, A. Nakkasyan, A. Napier, R. Singer, P. Trepagnier	8/15/70	Inactive
BC-42	Bubble Chamber Study of Deep Inelastic Muon Scattering	SLAC E. Bloom, R. Cottrell, H. DeStaebler, C. Jordan, M. Mestayer, H. Piel, R. E. Taylor, J. Ballam, G. Chadwick, P. Seyboth, I. Skillicorn, H. Spitzer UCSC C. Prescott	8/15/70	Inactive

Table of Programmed Experiments (cont'd) - 7

Number	Title	Authors	Date Approved	Status
BC-43	A Study of $\pi^+ d$ Interactions at 15 GeV/c	UNIV. OF WASH. P. Bastien, L. Kirkpatrick, H. Lubatti UC-BERKELEY H. Bingham, W. Fretter	8/15/70	Inactive
BC-44	Measurement of the Total Hadronic γp Cross Section at Photon Energies Between 0.5 and 1.2 GeV	DESY G. Knies, P. Söding, G. Wolf	8/15/70	Inactive
D-11	Shielding Test	SLAC T. Jenkins, J. Harris	6/16/70	Special Test/ Complete
D-13	Low Mass Particle Search	SLAC J. J. Murray	3/21/70	Complete
D-14	Charpak Chamber Tests	SLAC E. Bloom	6/12/70	Special Test
D-15	Proton Beam Test for BC-36	UNIVERSITY OF COLORADO T. H. Tan, J. Murray	6/17/70	Special Test/ Complete
R2.3	Position Monitor Test	SLAC J. Faust	7/2/70	Special Test/ Complete
NT-3	Fast Cycling Bubble Chamber Development	SLAC H. Barney, R. Blumberg, A. Rogers, S. St. Lorant	12/15/68	Inactive
TD-9	Magnetic Bremsstrahlung	ILLINOIS INST. OF TECH. T. Erber, F. Herlach, H. G. Latel	2/8/69	Special Test
T-12	Wire Chamber Spectrometer Checkout	SLAC S. Wojcicki	6/11/69	Setup
T-13	40-Inch Bubble Chamber Neon Fill Test	SLAC R. Watt	4/24/70	Inactive
T-14	8 GeV Č Counter Test	SLAC D. Sherden	8/25/70	Inactive

Number	Title	Authors	Date Approved	Status
T-65	Shower Counter Test	SLAC W. Toner	6/29/70	Special Test/ Complete
Y-4	Test of Heat Transfer in Two New Slit Modules as Used in the New B-Slit for SL-30	SLAC D. Walz	8/25/70	Special Test/ Complete

Running = Experiment is in data collection phase and was a prime user of accelerator time.
Checkout = Experiment is in checkout phase and used accelerator time for checkout purposes.
Setup = Experiment was being setup in the research yard.
Inactive = Experiment was inactive in the research yard.
In Construction = Beam is under construction.
Ready to Run = Experiment ready for future scheduled run.
Parasiting = Used parasite beam time.
Completed = Experiment completed.
Special Test = Special test run performed.

*Approved for checkout only.

†Approved for parasite time only.

III. RESEARCH DIVISION DEVELOPMENT

A. Physical Electronics

A Bendix time-of-flight mass spectrometer obtained from government surplus has been debugged, repaired and placed in operation. The instrument, which measures mass-to-charge ratios of ions and their relative abundance, can be used as a gas analyzer with very fast response and high resolution. A Loenco chromatograph is being adapted to be used as source for this system.

Scintillation layers for the gallium arsenide statistics tube have been prepared by two methods: settling of luminescent phosphors from a vehicle containing potassium silicate, and evaporation of CsI(Na). The first approach is the more cumbersome one, but it did produce efficient screens on glass substrates. The second technique is much simpler, and results in equally good screens. Further evaluation of these scintillation layers is in progress.

B. Magnet Research

1. Model Wire Chamber Magnet and Shields

Two additional field maps were obtained for different shim configurations. The field uniformity still needs improvement, and further runs are planned. In view of past difficulties with the superconducting shields, these have been entirely redesigned with a simplified configuration.

2. Field Screening Tests

A winding fixture was built to ensure constant tension in the layers of the Nb_xTi sheet, and to reduce the deformation of the assembly by the magnetic field. Several configurations have been tested, and the highest field shielded in the bore was ~9 kG. This was achieved by a combination of constant-tension winding and changing the orientation of the Nb_xTi sheet. It is not yet clear whether this increase in the field exclusion is due to the changed orientation or to the fact that continuous superconducting sheet was used. An effort has been made to procure thinner sheet (0.0015" thick), but up to now the vendor has been unable to roll such a thin sheet. As an interim measure, and to study the effect of temperature, a series of tests at $\sim 2^{\circ}K$ is being prepared. The lower temperature and the superfluid bath theoretically increase the field exclusion efficiency of the superconducting shields by some 25%.

3. 15" Rapid Cycling Bubble Chamber Magnets

The expansion-system driver-coil cable insulation has been completed, and the material is now in the workshop awaiting final winding. The electrical leads have been designed and await final approval. The magnetic design of the cryogenic Helmholtz field coils have been completed.

4. Project Leapfrog Dewar

The coil-off tests at $4.2^{\circ}K$ and $2^{\circ}K$ have been completed. The dewar has an acceptable helium loss at these temperatures. No tests below $2^{\circ}K$ could be made as no pumps of sufficient capacity were available. Several recommendations for modifications to the dewar in the interest of general safety have been passed on to the Leapfrog group.

5. Quench Front Propagation

An analytical solution for the heat propagation across a normal superconducting quench front was derived, with a view toward checking the stability conditions given in SLAC-PUB-182, 1966. The work is being continued.

C. Conventional Data Analysis

1. Hardware

Spiral Reader. (1) The angle-encoding disc modification has been designed and drawings made, and fabrication should start soon. Longest lead time item is expected to be the fiber optics light pipe; completion is scheduled for the end of October. (2) A pulse discriminator card to replace the current AGC circuit is being built. It represents another major attempt to digitize low-contrast film; ionization information will not be produced in this approach. (3) Electronics for automatic fiducial measuring has been built and interfaced to the PDP 9 computer for two of the three views. Background intensity variations also require AGC circuitry here as well. Further hardware testing will require extensive software effort.

NRI system. The fifth machine to be upgraded is now undergoing shakedown in the shop. The sixth and last machine to be reworked should be taken out of service in mid-October.

Scan tables. Upgrading of one scan table is nearly complete, and it should be returned to service in early October. An announcement was made of our intention to declare our two Vanguard scanning machines surplus, and no objections have been received to date. Removal of these two machines will help alleviate some of our space congestion.

Hummingbirds. A "status link" is being installed between the Hummingbirds in the Model 91 building and the Central Lab. This will allow Hummingbird 2 to operate unattended until such time as automatic processing halts, when an audible alarm will sound in the Central Lab indicating that human intervention is required.

2. Programming

Spiral Reader. Work has been started on software for checkout of the automatic fiducial measuring hardware referred to above; a preliminary version is expected to be ready by mid-October.

NRI system. Release 2 of BUCAPS for the 6020-NRI system was put into operation on September 2. All modifications appear to be working and no complaints have yet been received. Specifications for Release 3 have been written and coding has started; it should be ready for checkout by the end of October.

Hummingbird system. (1) Programming for experiment E-48 continues. Single events have been pushed through the system, and an effort is now being devoted to making the system operationally more efficient and faster. It is too soon to say whether the system will be successful. (2) Work has started on programming for Group E's e-ρ spark chamber experiment (E-65), to be run in early 1971. Three people are working part-time on this effort, which will include testing of software with simulated events generated by Monte Carlo methods.

3. Operations

During July, 280,000 frames were scanned in 2000 hours; 45,000 events were measured in 1900 hours. The breakdown by system is as follows: NRI System — 18,600 events; Spiral Reader — 20,000 events; Conventional Measuring Machines — 6400 events. In addition, 93,000 frames were scanned and measured on the cosmic ray experiment on the Hummingbird in 200 hours.

During August, 250,000 frames were scanned in 1600 hours. About 33,500 events were measured in 2300 hours as follows: 15,500 on five NRI tables; 14,000 on Spiral Reader; 4,000 on Vanguards and SPVB. Not included in the above figures are 51,000 events scanned and measured on Hummingbird 2 for the cosmic ray experiment; these events were processed in 102 hours.

During September, 235,000 frames were scanned in 1900 hours. About 32,500 events were measured in 2100 hours as follows: 11,500 on five NRI tables; 15,800 on Spiral Reader; and 5.200 on Vanguards and SPVB. Not included in the above are 60,000 events scanned and measured on Hummingbird 2 for the cosmic-ray experiment; these events were processed in about 130 hours.

D. SPEAR Activities

1. Main Magnet System

Support footings and two survey monuments for module assembly were drilled and poured in Bldg. 101, the assembly building. Concurrent with this, modifications to Bldg. 101 itself have been completed providing us with an additional 10-foot sliding door on the east side of the building for girder handling. As hoped, the 40-ton forklift with slings proved to be an ideal vehicle for transporting the fully loaded module (22 tons) to the ring. Installation of the module, from pickup of the module outside Bldg. 101 by the forklift to final installation on the 3 pre-aligned experimental footings was accomplished in about 1 hour.

The magnet support system was approved. Its cost is about \$100/magnet. Studies undertaken in the precision alignment lab indicate that the magnets are stable even when exposed to considerable external forces.

Alignment stages and tangents were placed on the seven survey monuments forming roughly a North-South line, i.e., the center of SPEAR and the four centers of curvature together with two standard ring monuments. These are presently being monitored at sun-up for stability in both the vertical and lateral directions.

Much of September was spent in ironing out the final technicalities of the standard-magnet-core procurement package; it is now completed. The engineering prototype bending magnet core was received early in October. The engineering prototype quadrupole core was delayed until November due to our insistence that it be made using production jigs and fixtures. This delay will not extend the schedule, however, since we did not not intend to do magnetic measurements and acceptance tests in parallel but rather in series.

Magnetic measuring devices are being fabricated both for the quadrupoles and for the bending magnets. Construction of the fixtures for the standard quadrupole was completed. The SPEAR copy of the turning mechanism was completed, and a long coil using a glass form was manufactured.

The cooling-water system for the reference shunt was completed and the device has been turned over for the installation of electrical connections and testing.

Preparation of the site in Bldg. 109 for the surplus Mag-Amp supply testing continues. Interlocks and controls for the power supplies are under study.

2. Vacuum System

The first prototype chamber-heater tapes for bake-out were installed, and the process of evaluating the bake-out equipment was begun.

All explosion-bonded aluminum-stainless-steel transitions tested performed very well, with no indication of vacuum leaks. Explosion bond No. 3 has seen 74 bake-outs (200°C) and has been spring-loaded for 10 bakes to 300 pounds. This method of joining aluminum to stainless steel is clearly superior to any other method we are currently working with.

All fabrication material has been ordered, and fabrication has started on the distributed ion pumps. It is expected that all pumps will be completed by December 10 and ready for installation.

Preparation for in-house chemical cleaning of the 33-foot module sections was initiated. It is expected that we will be able to clean these sections in-house by our scheduled date.

Tests of ribbing were completed and production ribbing was started. It is expected that the sections will be available for bending within our time schedule.

3. RF system

A linear phase shifter was developed for use in the rf drive system; it has further potential application as a phase-shift-less attenuator in combination with the hybrid junctions.

Measurements on the tack-welded accelerating cavity give an expected shunt impedance of 630 kΩ. For 200 kV peak rf voltage, 32 kilowatts of power will be required. Higher order modes have been measured in the tack-welded cavity and they all show low shunt impedance; they will be checked again in the fully welded cavity. Final mechanical design work on the incorporation of the cavity into its straight section is being completed, after which the cavity will be welded together, cleaned, evacuated, baked, and rf-tested in vacuum.

4. Instrumentation and Control

The decision was made to create the 42.35 MHz rf frequency by multiplying 1.366^{+} MHz by 31. This scheme was chosen to provide a stable phase reference at the revolution frequency for the trigger system and also for the cavity for synchrotron-frequency splitting (which is driven by a multiple of the revolution frequency but not of the rf frequency).

Efforts to build a fast optical beam monitor centered on the high-power metal mirror which reflects the visible light out through the vacuum window. A prototype mirror and mount were built, and a complete thermal and optical test is being set up. The optical system and electronics to process this reflected visible light is still to be designed; design criteria are being worked out. The existing prototype of the Synchrotron Light Intensity Monitor (SLIM) and models of a new structure were tested with a fast time-domain reflectometer system. Thermal and electrical design of the final version have been fixed.

The output amplifier for the beam-position feedback system was completed and has a gain of 8 with less than 5 nsec risetime. The driver for this stage, which must produce 125 volts into 50 ohms, has proved a thorny design problem, but a working model has emerged. A number of possible designs for the feedback electrodes (driven by the above output amplifier) have been studied and a tentative choice was made. The choice is a system of four rods that present a constant 125-ohm impedance to the amplifiers. There rods can be connected to deflect the beam either horizontally or vertically. A prototype was fabricated for tests.

A vacuum-tight prototype of the standard beam position monitor is being built in the shop. It will be used for frequency response studies and also to look at distributed vacuum-pump noise.

5. Beam Transport System

Design of the SPEAR transport system components progressed satisfactorily. We now have in hand or have placed orders for all materials required to construct all of the magnets in the transport system. Construction of prototype magnets and development of specifications for fabrication of transport magnets is proceeding. The main bending magnets of the transport system are to be powered by a surplus power supply which is presently available and has been installed in the Data Assembly Building. This supply is now being connected to the ac power system and will be tested as soon as possible. Power supplies for quadrupole components of the transport system are standard commercially available units, and specifications were submitted to the Purchasing Department for bid and procurement. (There is some possibility that suitable quadrupole magnets and power supplies from PPA may be available for SPEAR, and the attendant systems savings is being analyzed.)

Final assembly of the prototype kicker magnet and its vacuum enclosure was accomplished in July. Studies of its high-voltage feedthroughs were begun. The septum magnet electrical connections were modified to achieve a higher Q circuit.

The final location of the beam in the region of the A-beam high power slit, SL-10, has now been determined for minimum interference. As a result, final coordinates for the location of the primary components of the system are now fixed.

The Experimental Facilities Department fabrication, installation, and test schedule, which was designed to permit delivery of beam to the ring by January of 1972, has been reviewed and found to be technically feasible. The rate of spending implied by this schedule is being developed for review.

IV. RESEARCH AREA FACILITIES

A. Development

1. End Station B

Design of the new beams for end station B is in progress. Three new beams are involved: a) an attenuated electron beam for use in E-65,* b) a separated beam which will initially be used to supply pions for BC-25, and c) a general-purpose separated beam to be used for counter and wire chamber type experiments. This beam is split into two legs, one of which will initially be used by E-68, while the other is planned for use in conjunction with a wire spark chamber facility. Optics design of the initial portions of the beams has been completed, and detailed design of the arrangement of the electron-beam targeting and the upstream portions of the secondary beams is progressing. General layouts of the entire arrangement have been completed and installation is under way.

The 54-inch spark chamber magnet was moved 50 feet from the north end of the south end of its building, in preparation for E-65.

The first rf separator for beam line 20 (E-68) is in fabrication. Installation is scheduled to begin in December.

2. Polarized Photon Beam

A few changes have been made in the ruby laser system in the polarized photon beam to the 82" chamber to increase its second harmonic (SH) output at 0.347 μ. The basic problem was that the divergence of the fundamental beam was considerably larger than the acceptance angle of the SH generator. As a result, the SH energy conversion efficiency was limited to 10-12%. Attempts to obtain marginally acceptable SH yields (about 0.25 joules) for the generation of polarized γ's in the range from 7 to 10.5 GeV resulted in damage to the laser rod.

The following four changes have been made to improve the SH yield, while maintaining a safe power level in the laser:

a. The laser has been apertured internally to a beam diameter of 0.30 inches to improve its mode structure.

b. The cavity length has been doubled to decrease the pulse amplitude by about two at a given pulse energy.

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*Refer to Table 1 for title of numbered experiments.

c. A shorter SH crystal is being used to increase the acceptance angle for SH generation. Also, a switch from KDP to ADP has been made because the latter seems to be more damage resistant.

d. The SH crystal was mounted inside the laser resonator.

With these four changes, it is possible to obtain upwards of 0.5 joules of SH at 2/3 of the "safe" power level established in the last half of the previous blue laser run. If the damage mechanism is power-dependent, this new arrangement is quite promising. However, the final judgment cannot be made without the acid test of a long blue-laser experiment. (J.E. Murray)

3. Coherent Bremsstrahlung Facility

A coherent bremsstrahlung facility, producing high intensity beams (10^9 equivalent quanta per pulse) of high energy linearly polarized photons, is now in operation. A goniometer which precisely positions a diamond radiator is located in the A beam in the beam switchyard, just upbeam of the bremsstrahlung target changer, TC-20. The position of the diamond is monitored and controlled from the ESA counting house. The system was designed and built by a group at MIT headed by L. Osborne. The facility was used by Experiment E-45 (Measurement of π^+ Photoproduction with Polarized Photons - L. Osborne, MIT) in May and June 1970. Experiments E-50b (Asymmetry in the Photoproduction of π^0 Mesons from Hydrogen by Polarized Photons - D. Ritson, SLAC), and E-70 (Measurement of the Asymmetry in Compton Scattering of the Proton with Linearly Polarized Photons - B. H. Wiik, SLAC) are scheduled to use the facility.

4. General

The hole behind beam dump east for E-56a was completed in September and equipment installation began.

The aluminum conductor for the 70D43 magnet was shipped to SLAC in August. The contract for the core iron was awarded.

B. Operations

1. Hydrogen Bubble Chamber Operations

The 82-inch chamber was filled with deuterium in July. 230,865 pictures were taken for BC-26 with deuterium. It was refilled with hydrogen and expanded 1,164,465 times for BC-5, BC-33, BC-30 and D-15. The 20 million expansion mark was passed during July. The chamber did not run during August.

In September the 82-inch HBC took 133,876 pictures for BC-30 before an internal leak in the refrigeration system terminated the run.

The 40-inch HBC did not run during the period. It is being modified for a faster pulse rate and a hydrogen refrigeration system is being installed.

2. Spectrometer Facilities Operations

In August, the end station was prepared for the continuation of E-50/52 using a new arrangement of Compton carriage which will allow the entire block house containing the detectors to be lifted out by the crane and placed in a similar carriage at another radius later.

Experiment N-49b parasited in the 8 GeV/c spectrometer. This was the first usage of the rebuilt hodoscope, which now has only one half the initial number of momentum counters. The gas Cerenkov counter was also rebuilt with a new plexiglass spherical mirror in it.

Experiment E-49b began taking data during September using the 8 GeV/c spectrometer in end station A. Since most of the equipment they required had been prepared in order for them to parasite in the previous cycle, only minimum set-up work was required.

The general rearrangement of the Counting House instrumentation continued. As a part of this rearrangement the high console which contains all of the beam monitoring and spectrometer control equipment is being moved to a central position, so that it can be utilized by groups centered on either of the two computers.

3. Liquid Hydrogen Target Operations

The new target test facility outside the Cryogenics building was completed in August. The target for E-49b was the first one tested. The epoxy joint between the aluminum foil and the stainless steel cell structure was found to be leaking. After some delay, repairs were effected.

The target on the ESA pivot was installed in September. It is a complicated condensation-type target which has two separate cells, one for hydrogen and one for deuterium. The target has fans in both the liquid hydrogen and liquid deuterium cells. These fans circulate the liquid hydrogen and thereby remove the gas bubble formed by the beam from the beam path, keeping the density of the liquid in the beam constant. After solving numerous problems with the target, it operated satisfactorily for about the first half of the cycle. Unfortunately, at this time the fan in the deuterium cell ceased to function. However, the run continued, using the 1.6 GeV spectrometer to monitor the target density.

4. Power Supply Operations

Some of the high voltage feed-throughs on the 5.8 MW power supply transformers were found to be cracked and leaking oil. The insulators were replaced and the mounting was modified to prevent undue stress in the future.

V. ACCELERATOR IMPROVEMENTS

Work continued during the quarter on the additional pulsed focusing quadrupoles. It is probable that the first four quadrupole pairs will be used to replace the four previously installed because of the failure of one of the quadrupoles in Sector 28. Steps have been taken to correct this fault in the new quadrupoles and the old ones will be modified. It is planned to provide pulsed focusing and steering in 16 sectors in addition to the four already completed. Power supplies for quadrupoles and steering magnets will be procured by December 1970 and the final quadrupoles will be installed by December 1971.

Work continued on the off-axis injector. Fabrication of the pulsed alpha magnet was started in September and continues as the quarter ends. The pulsed power supply will be built after completion of the magnet. The pulsed gun modulator neared completion. It is planned to complete the conversion from dc to pulsed operation by the end of calendar year 1970 at which time simultaneous use of the on-line and off-axis injectors on a pulse-to-pulse basis will be possible.

The last four units for pulsed beam loading compensation were installed and checked out during the quarter. Six channel operation is now provided in five sectors.

Design of the pulsed phase closure system was essentially completed during the quarter and quotations on phase shifters have been requested. The system will be modified to provide four independent phase closure adjustments, an improvement over the existing system which can handle only three beams and under certain operating conditions develops an adverse interaction among the three.

Engineering on the pulse generation system continued during the quarter and design of beam knockout plates was started. A continuing program to upgrade oscilloscope triggering and the E.G.G. fast pulser to improve operation and reliability is under way.

Work continued during the quarter on consolidation of the two control rooms. The display system has been ordered with delivery promised in October. A TV monitor was delivered in September and rejected as unsuitable for this use. An alternate monitor has been ordered for delivery in October and this will be evaluated. After selection of a suitable monitor, seven or eight additional ones will be ordered. An improved touch panel was designed and partially fabricated, but completion has been delayed until final selection of the TV monitor has been made. Test of the link system between the two computers, which was scheduled for September, has been delayed because of the breakdown of one of the computers.

Fabrication of an additional main frame in the data assembly building was completed during the quarter. Some cable connections have been made and additional cables and coaxial terminations will be provided, as required, to handle the normal expansion of experimental requirements.

Work continued on improvements to the profile monitor system in the beam switchyard. Five relay boxes were fabricated and checked out during the quarter and fourteen more have been ordered. Cabling has been installed and the relay boxes will be installed as downtime permits, beginning with one or two in October.

Installation of a magnet warning system continued during the quarter. At quarter's end 50% of the magnets in the beam switchyard had been hooked up and the balance will be connected during downtime, finishing in November. The system provides a flashing red light when magnet power is on and the switchyard is open.

Work continued on improvements to the SDS 925 computer interface equipment in the Data Assembly Building (DAB). A digital input multiplexer for new beam interlock inputs was fabricated and partially checked out. Final checkout will be completed after installation in its final location, a newly procured rack due in December. A computer serial data terminal, part of the link between the SDS 925 and PDP 9 computers, is in the design stage.

Expansion of the data system to improve and speed up reporting to and from the Central Control Room (CCR) and the computer of various signals along the machine continued during the quarter. This program will continue through calendar year 1971.

Fabrication of the B-beam slit was completed and installation was in progress as the quarter ended.

Design of improvements to the position monitor system began during the quarter. It is planned to replace tunnel diodes with high burn out crystal diodes to eliminate the existing gap in coverage between the thermionic and tunnel diodes. It is also planned to replace 110 V coaxial switches with 24 V switches to eliminate 110 V current from the main frame and to imporve operation of the switches which are beginning to fail.

VI. KLYSTRON STUDIES

A. Development

1. High Power Klystrons

In general no major improvements have taken place during the past quarter. Our present vendors are continuing manufacture of tubes for replacement of those still due under the extended warranty contract which expired June 20. During this period they are continuing a low priority program of tube improvement aiming at a 270 kV operation tube required by the request for proposals sent out for the new tube procurement.

SLAC's development has also been slowed down by the need to rework some of the tubes which had failed in bake during the previous quarter.

2. Klystrons for Superconducting Accelerator

A tube with improved cooling in the output section has been built and tested during the quarter. Unfortunately the output match was not optimized in the tube. By using a triple stub transformer it was possible to obtain a peak power output of approximately 15 kilowatt at a duty cycle of about 5%. When the duty cycle was increased to between 50 and 100%, thermal detuning was observed in the tube and the same power could only be obtained for slightly different input conditions. Unfortunately tests had to be discontinued when arcing took place in the triple stub tuner under CW conditions and the window cracked. The tube has since been rebuilt and is ready for tests at the end of the quarter.

Cathode life tests are continuing without any difficulties on the 2 diodes, one with oxide cathode, the second with dispenser cathode. No variation in emission has been observed in nearly 6,000 hours of operation.

3. High Power Windows

Some additional SLAC window failures have been observed in tubes operating at 265 kV. Tests which were begun during the last quarter have indicated the need for additional cooling on the waveguide adjacent to the window and all SLAC tubes built in the future will include cooling blocks brazed to the waveguide. Window temperature reductions of at least 30°C have been observed by the use of the brazed cooling blocks, and we expect the rash of high power window failures due to excessive temperatures to be cured by this technique.

4. Special Problems

Computer program. Work is continuing on adaptation of the Wessel-Berg theoretical analysis to computer use. Various difficulties have been encountered which have prevented completion of the large signal analysis.

B. Operation and Maintenance

The number of operating hours for the quarter was substantially equal to that of the previous quarter. The number of high power klystron failures decreased to 13 from 18; probably a simple statistical variation.

1. High Power Klystron Operation

Table 2 summarizes the usage and failures for all klystron vendors since the beginning of operation. As can be seen there appears to be no major change in the overall behavior of the tubes in the gallery, and the data is plotted in Fig. 3.

The tube age distribution of both living and failed tubes is given in Fig. 4. It is interesting to note that almost 15% of all tubes in the gallery have more than 20,000 hours of operation. The mean and median age of the tubes are approximately 11,500 hours.

Analysis of the data of Fig. 4 results in the curves of failure and survival probability shown in Fig. 5.

We are continuing to examine the operating failures in the four sectors which operate at 265 kV. For this quarter the MTBF in those sectors is approximately 60% of the overall MTBF. However, we believe it is still too early to draw definite conclusions. For one thing the total sample is very small (3 failures at 265 kV), for another the mix of the tubes from the different vendors is substantially different in the high voltage sectors than in the rest of the machine. There is no question, however, that in general the replacement rate is higher for the high voltage sectors than for the rest of the machine.

2. High Power Klystron Maintenance

Although the number of failures decreased during the quarter the total number of klystron tube replacements increased since the last quarter with a ratio of replacement to failure of approximately 3:1. Filament circuit shorts in the pulse transformer tanks contributed to approximately 20% of all replacements.

Figure 6 shows the operating experience for all high power klystrons since the beginning of operation.

TABLE 2

KLYSTRON MTBF

Dates	PER QUARTER				CUMULATIVE			
	Operating Hours	Failures Number	Failures Mean Age	MTBF	Operating Hours	Failures Number	Failures Mean Age	MTBF
To 6/30/66					129,400	19	260	7,200
To 9/30/66	111,000	8	610	14,000	240,400	27	360	9,000
To 12/31/66	154,000	11	1,100	14,000	394,400	38	575	10,300
To 3/31/67	207,000	13	1,490	15,900	601,400	51	810	11,800
To 6/30/67	287,000	9	2,490	32,000	888,400	60	1,060	14,800
To 9/30/67	330,500	25	2,860	13,300	1,218,900	85	1,590	14,500
To 12/31/67	263,000	21	3,520	12,500	1,481,900	106	1,980	14,100
To 3/31/68	309,500	17	4,800	18,200	1,791,400	123	2,360	14,700
To 6/30/68	306,000	15	3,820	20,400	2,097,400	138	2,520	15,200
To 9/30/68	314,200	24	5,500	13,100	2,411,600	162	2,960	14,900
To 12/31/68	349,800	23	8,350	15,200	2,761,400	185	3,630	15,000
To 3/31/69	328,600	20	6,610	16,400	3,090,000	205	3,930	15,100
To 6/30/69	335,000	16	7,280	19,700	3,425,000	221	4,190	15,400
To 9/30/69	179,800	8	11,670	22,500	3,608,100	229	4,450	15,750
To 12/31/69	303,600	10	10,230	30,400	3,911,700	239	4,690	16,300
To 3/31/70	358,700	32	9,950	11,200	4,270,400	271	5,270	15,800
To 6/30/70	257,200	18	11,350	14,300	4,527,600	289	5,650	15,700
To 9/30/70	259,600	13	9,600	20,000	4,787,100	302	5,810	15,800

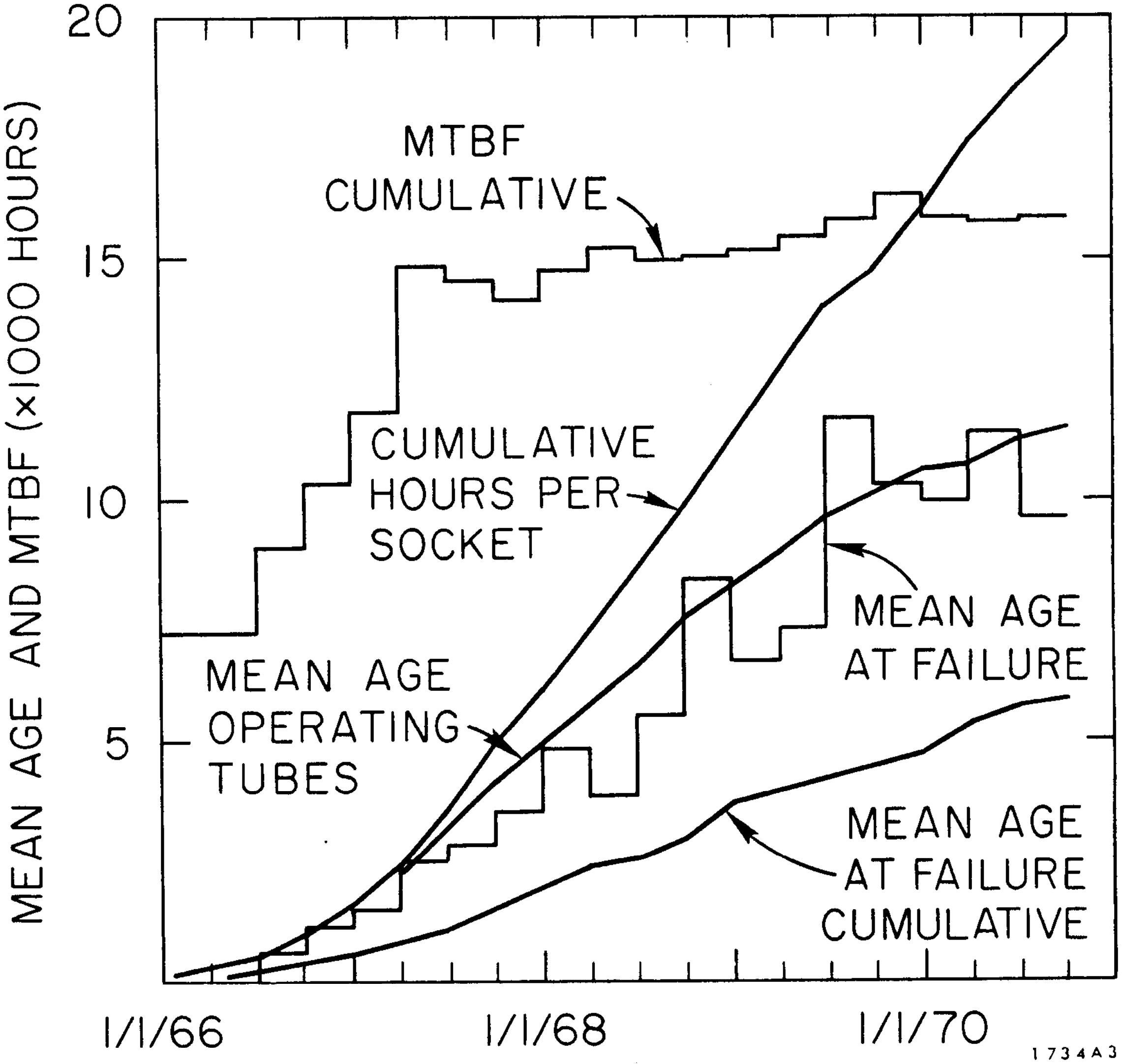


FIG. 3--High-power tubes: cumulative MTBF, mean age, mean age at failure, cumulative age at failure, and cumulative hours per socket, Sept. 30, 1970.

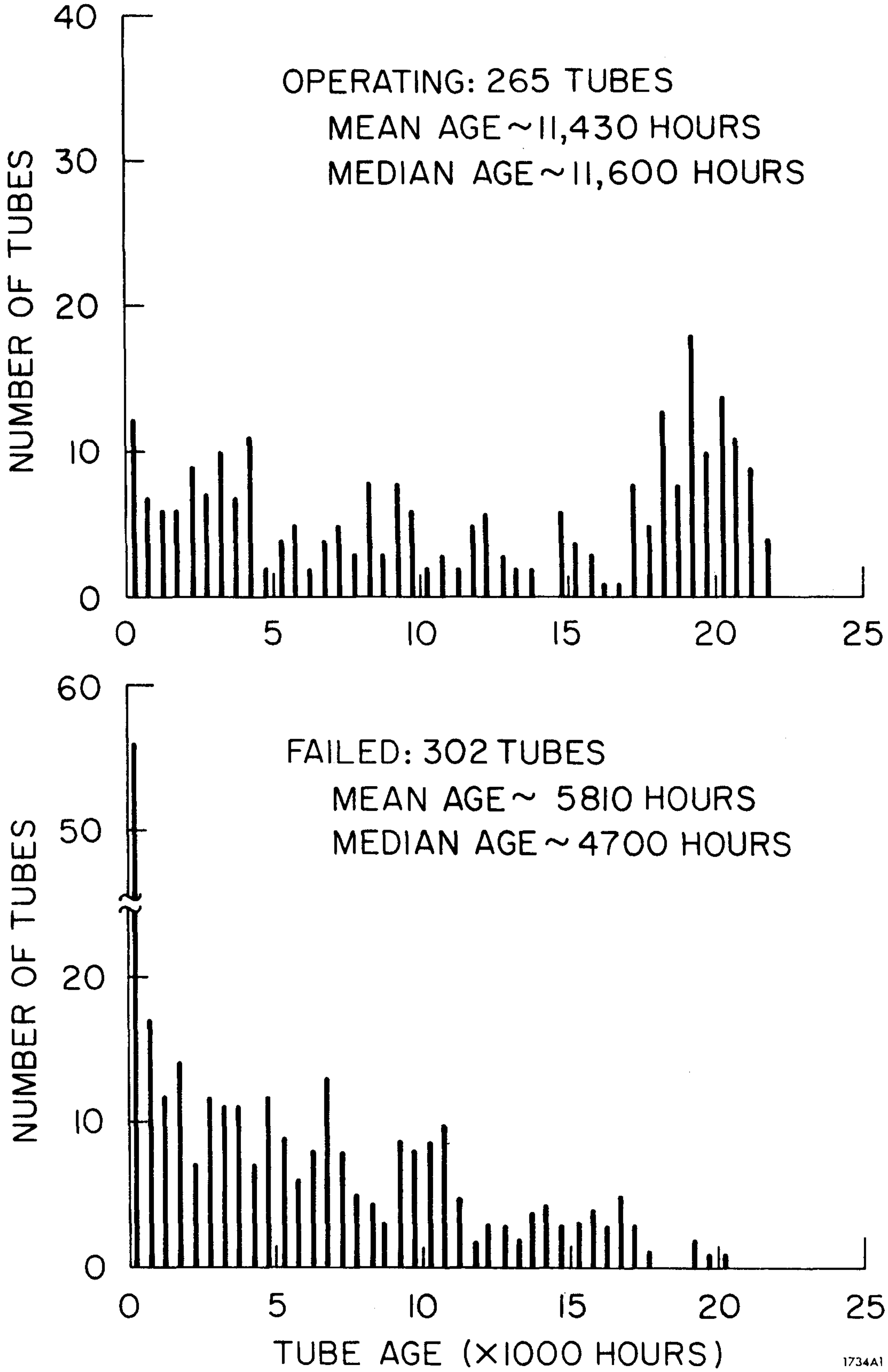


FIG. 4--High-power tubes: tube age distribution of both operating and failed tubes, Sept. 30, 1970.

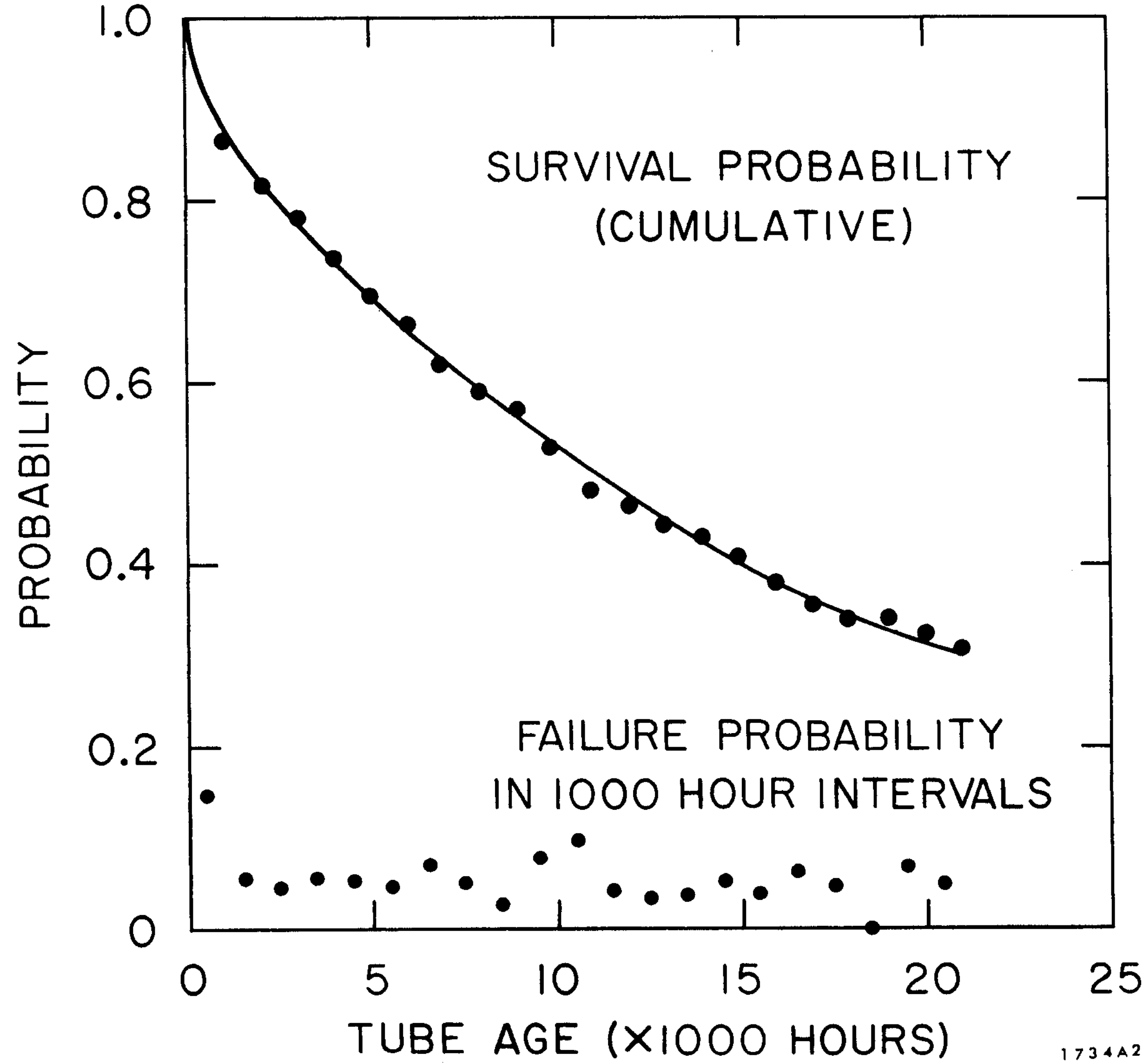


FIG. 5--High-power tubes: survival and failure probability, Sept. 30, 1970.

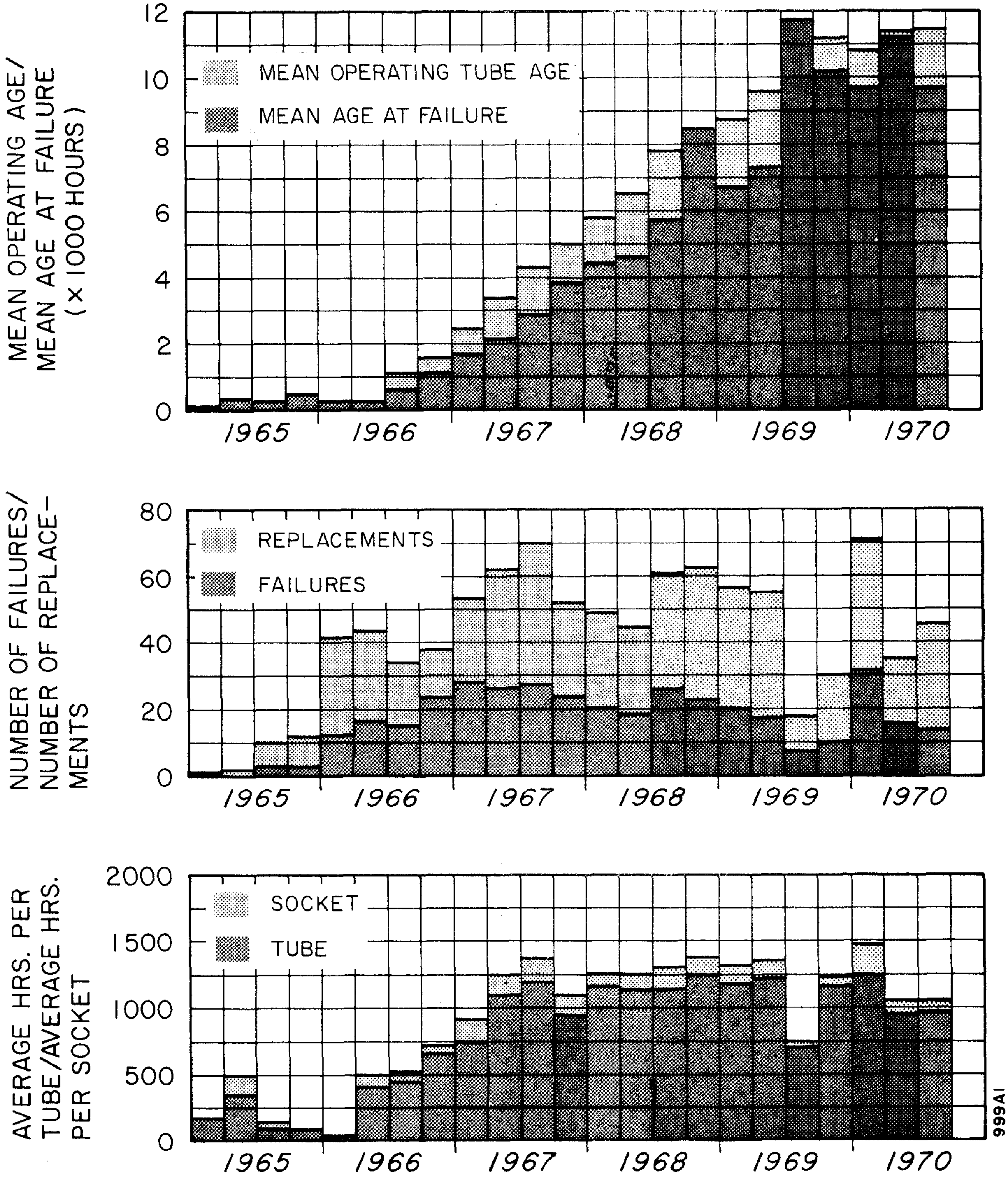


FIG. 6--High-power tubes: operating experience through September 30, 1970.

3. Driver Amplifier Klystrons

There were no failures of SLAC built driver amplifiers during the quarter. One Eimac tube failed after almost 22, 000 hours of use.

4. Main Booster Klystrons

No failures, no replacement and few trouble reports.

5. Vacuum System

A major vacuum failure occurred in drift Sector 28-9 caused by arcing between the pulse quad magnet coil and the bellows which is the vacuum chamber. The vacuum was lost in 3 sectors. The temporary replacement of the drift section allowed resumption of beam operation within less than 24 hours of the accident, and a further change of drift sections took place during the following shutdown period to reinstall a beam stopper in drift Section 28-9.

A 3-inch valve seat had to be replaced at Stations 3-2 and 7-4, necessitating letting up Sectors 3 and 7 during shutdown periods.

6. Mechanical Maintenance

Major modifications in the klystron maintenance and handling area were necessary because of the installation of film processing facilities in our previous storage area. In addition to the normal maintenance of equipment and magents, a special program has been completed to allow us to maintain in operation the ion pumps on klystrons in storage. This work included the design and fabrication of special ion pump magnets and addition of necessary outlets on storage racks. Power supplies for the ion pumps are on order at this time.

VII. MECHANICAL ENGINEERING DEPARTMENT

(October 1969 - September 1970)

A. Accelerator Engineering and Maintenance

1. Accelerator Physics Support

Blind tuning of the accelerator to raise the beam breakup threshold was completed. The hydraulic tuning tool designed during the previous year worked extremely well.

Mounting of the pulsed quadrupoles, built during the previous year, onto drift section strongbacks was completed and these drift sections were installed at Sectors 11, 25, and 29, bringing the total number of pulsed and quad pairs installed to 4. One of the quads of the first pair installed (at Sector 28) failed in September, 1969. A coil shorted to ground, burning a hole in the vacuum chamber and letting a portion of the accelerator vacuum system up to air. The drift section with the failed quad was removed and a spare drift section was installed. Operation without pulsed quads at Sector 28 proved difficult, so the drift section with pulsed quads, which had been installed at Sector 11, was moved to Sector 28 during the following shutdown.

As a result of the failure, the pulsed quad design was re-evaluated and some minor design changes were made. The new design provides a greater thickness of insulation in the bore of the quad and places a thin grounded tube between the coils and the vacuum chamber. The greater insulation thickness increases the strength of the insulating epoxy layer, thereby decreasing the likelihood of epoxy cracking and subsequent electrical breakdown. The grounded tube will protect the vacuum chamber should a short occur. Fabrication of parts for additional pulsed quads was begun and preparations are being made for assembling the quads and for mounting then on drift sections.

Design and fabrication of an off-axis injector was completed and the unit installed. Magnetic shielding and a bucking coil were added to eliminate the effect of injector solenoidal field on the beam being injected from the off-axis gun. The accelerator has operated successfully with either the off-axis gun or the straight ahead gun. A pulsed α magnet has been designed and is currently in fabrication. This magnet will allow the intermixing of beams from the two guns on a pulse-to-pulse basis.

2. Accelerator Maintenance

Alignment of accelerator sections on their support girders (quarter point alignment) continued. Nearly half the accelerator was checked and realigned where necessary during the last year. Of the 120 girders observed, 9 were found to be out of alignment by more than .015 inch. Of these, two were out by more than .020 inch (.024 inch maximum). Three sectors remain to be checked and aligned to complete the alignment sequence started approximately two years ago.

The personnel protection beam stopper and actuator design was improved. The stoppers located at 2-9, 20-9, and 28-9 were modified and reinstalled. Profile monitor actuators were also improved.

Shielding blocks were removed from the material access ways at Sectors 9, 14, 24, and 30. Health Physics determined that the shield blocks were not necessary at those locations. The blocks have been put to use in the research yard. Removal of the blocks has eliminated the need for large equipment to open the material access ways.

3. Positron Source

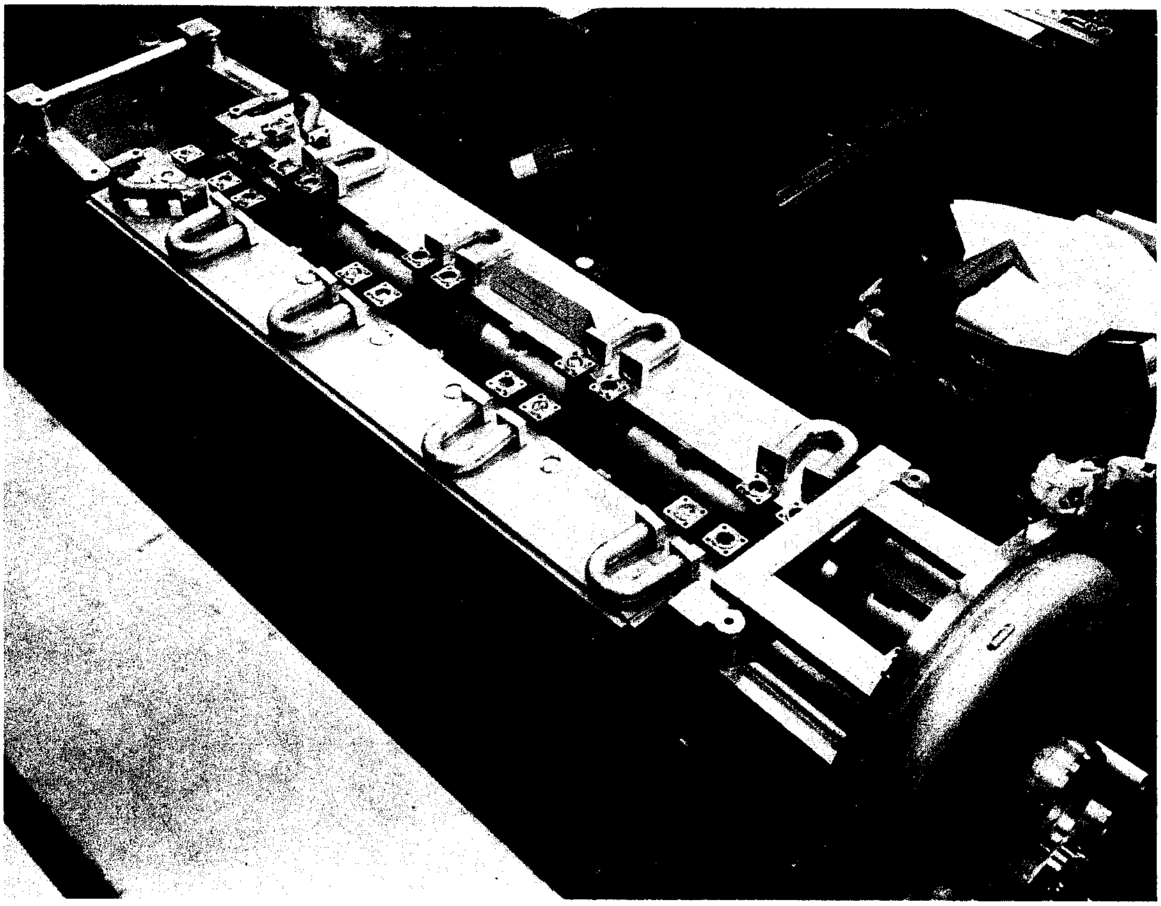
A stationary stepped target was designed, fabricated, and installed for test purposes. The stepped target design allowed the positron yield to be determined for three tungsten target thicknesses and four copper thicknesses. Based on test results obtained with the above target, we are planning to design a 3/4 inch long tungsten positron source target.

B. <u>Beam Switchyard Improvements</u>

1. B-Beam Slit

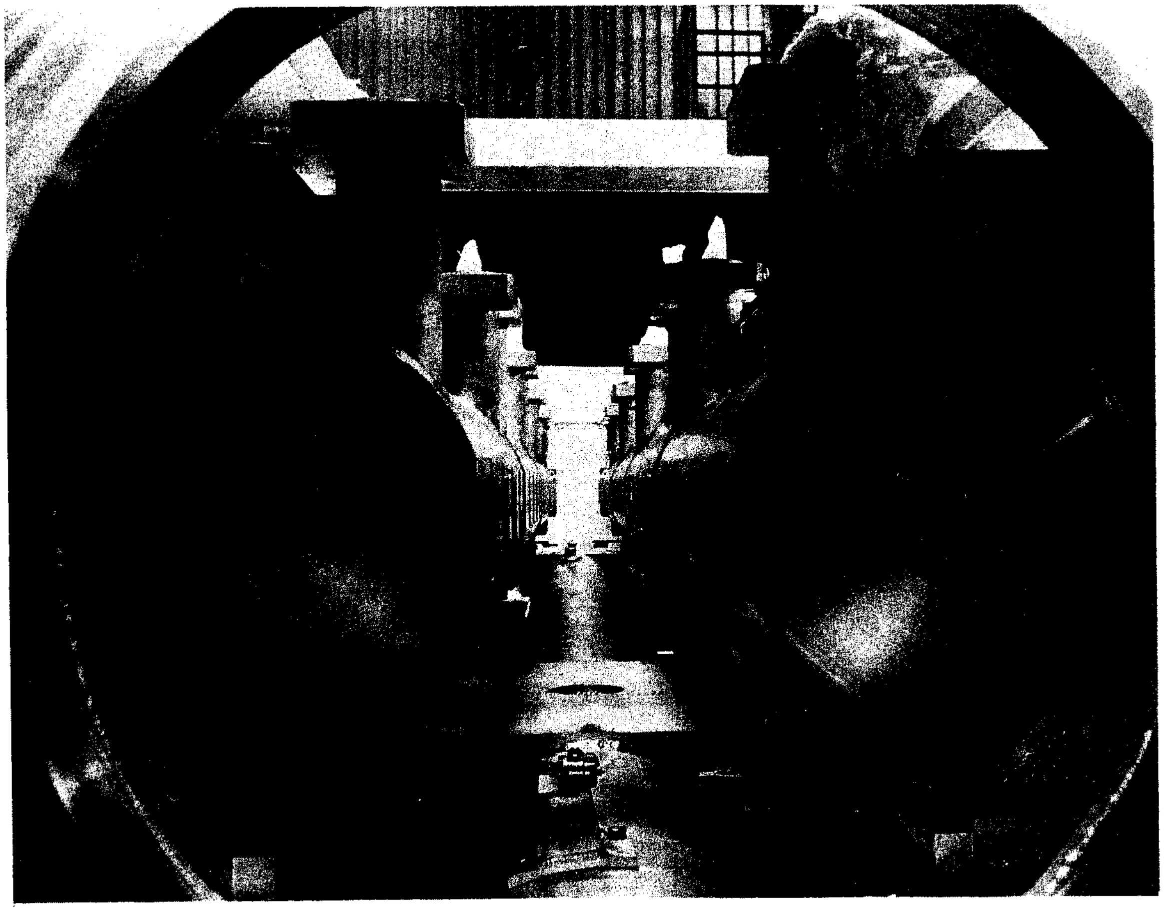
Fabrication and assembly of the new B-beam slit was completed during the quarter. Installation in the beam switchyard is tentatively scheduled during the November and December shutdown periods.

Figure 7 shows a view of the internal assembly. The collimating jaws are formed by an array of modules and are continuously adjustable over a momentum range of $0 \leq \Delta P/P \leq 5\%$. Figure 8 gives a view in beam direction and shows the steps machined on to the collimating face of the modules which enable the jaws to be closed beyond the center line. This feature allows the slit to be used as a high-power beam stopper in the personnel protection system. A total of 4 aluminum modules followed by a copper-tungsten module form a jaw. The modules contain water-cooled aluminum spheres as power absorption medium. A typical module is pictured in Fig. 9.



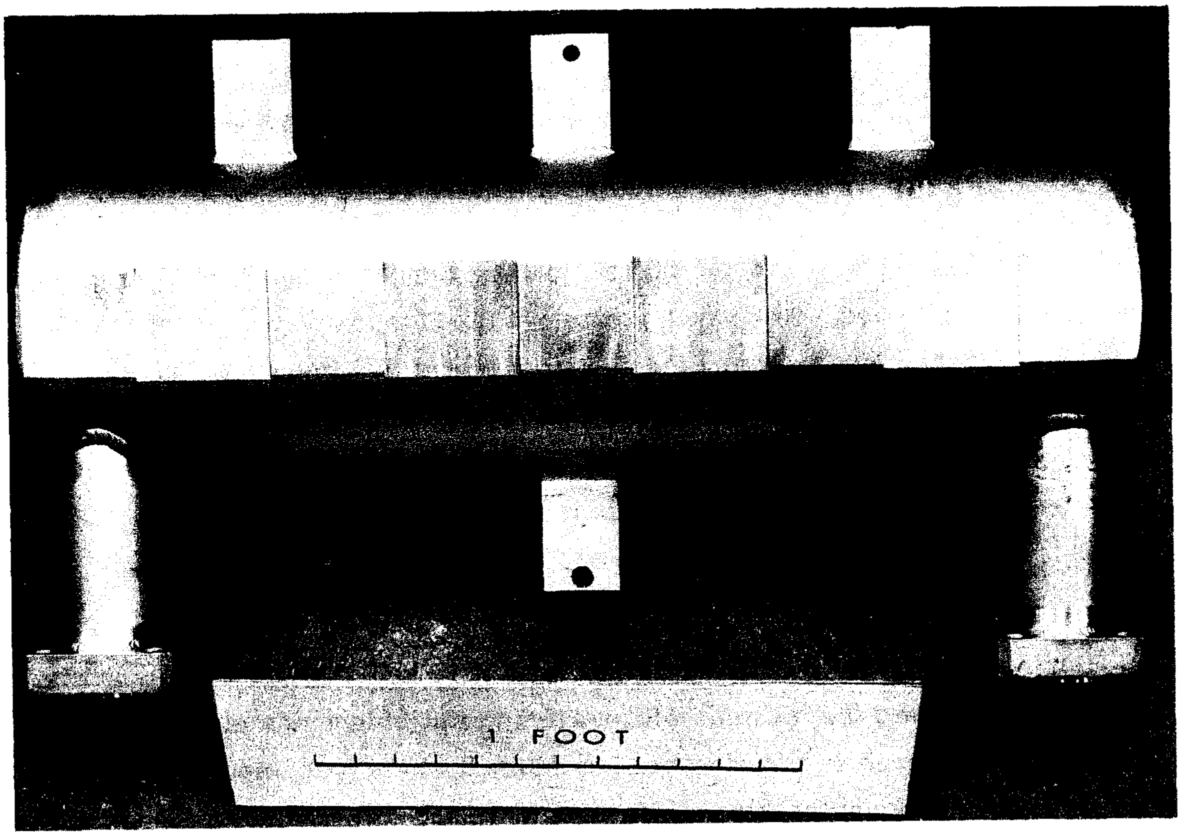
1753A8

FIG. 7--Top view of B-beam slit jaw assembly.



1753A9

FIG. 8--Down-beam view of jaw assembly.



1753A10

FIG. 9--A typical jaw module.

Two such slit modules were power-tested in the central beam area of the BSY on Sept. 10, 1970. Thermocouples were used to measure the axial temperature distribution along the collimating face of the modules and the lateral temperature distribution at the shower maximum of the electromagnetic cascade. The nominal incident electron beam energy was 18 GeV, the peak current was about 70 mA, and the pulse width was approximately 1.6×10^{-6} sec. Useful data were obtained for pulse repetition rates varying in increments of 60 pps from 60 to 300 pps. At 300 pps the average beam power incident on the modules was approximately 600 kW. At this power level the temperatures in the modules were stable, even though several thermocouples indicated that the boiling temperature of water at the local pressure was reached. The new B-beam slit SL-30 should thus be capable of safely absorbing and dissipating the design power of 500 kW. After completion of the experiment the test apparatus was used as a power absorber to establish a figure for the maximum average power currently available from the accelerator. At a pulse repetition rate of 360 pps the accelerator delivered 750 kW. At this power level the modules failed due to melting of the collimating face.

2. Beam Stoppers

During the period, the beam stopper improvement program was completed. Within this program the internal microswitch arrangement was changed to reduce the mechanical shock on the switches (as a result of the placement or removal of the beam stopper from the beam line), and to achieve a more positive signal of the stopper position.

A burn-out safety feature was also incorporated. It consists of a thermal radiation heat sensor package which operates as follows: A fuse is mounted on the stopper housing at an axial depth which corresponds approximately to the shower maximum of the electromagnetic cascade in the copper cylinder for SLAC energies. The fuse consists of a tube that radially penetrates the vacuum shell of the stopper. Its internal end is sealed off with a cast diaphragm of a low-melting-temperature alloy (indium-bismuth-tin, $T_{melt} = 58^{o}C$). For greater efficiency and to achieve a short response time a heat collection disc is attached to the tube in the plane of the diaphragm. A small platinum resistance thermometer is attached to the back of the disc and allows monitoring of its temperature. If beam power is accidentally deposited in the uncooled copper cylinder and if the beam shutoff ionization chamber of the stopper and the temperature sensor fail, the diaphragm will melt. This will let the beam transport vacuum system up to air, thus shutting off the beam long before the stopper is damaged. A new fuse can easily be installed in a matter of minutes.

A new stopper, ST-61, was installed in the C-beam during the period. It upgraded this area to the standards of the rest of the beam switchyard and added operational flexibility.

3. Vacuum System

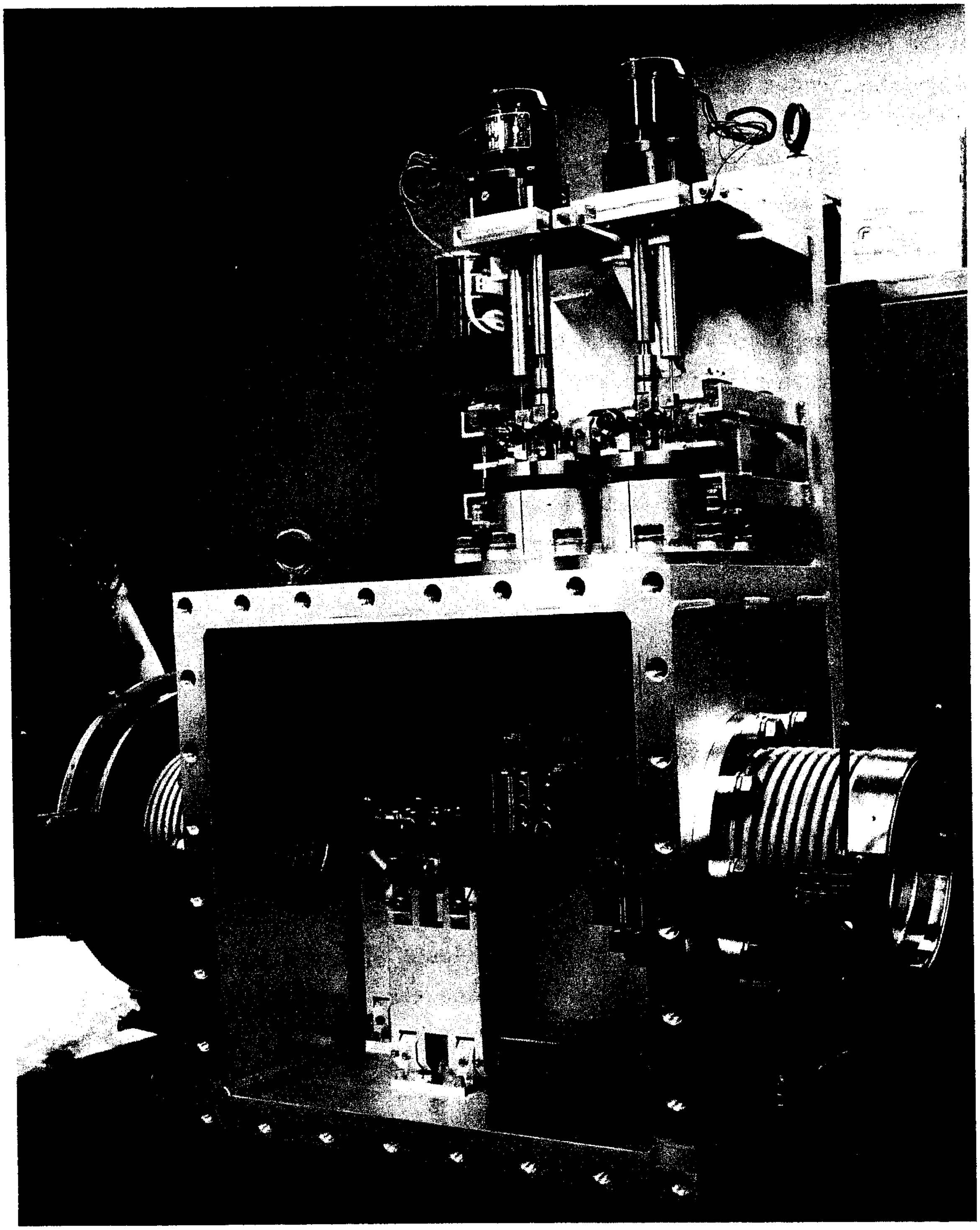
A new permanent vacuum roughing pump has been installed in the previously unused pump house on the C-beam. It is located above the BSY shielding. The system enables roughing of the beam line between isolation valves IV-4 and IV-60 without requiring access to the BSY. It should result in major time savings during shutdown periods. Remote vacuum gage display in the Main Control Room will allow diagnosis in the event of C-beam vacuum failure involving closure of the isolation valves.

4. Equipment Failures

Two equipment failures during the period deserve to be mentioned. The first was the burnout of jaw # 4 on the Halo Collimator C-12, as shown in Figs. 10 and 11. The jaw is a water-cooled tunsten module, protected by an ionization chamber against deposition of power in excess of its rating of 20 kW. The ionization chamber apparently failed, allowing deposition of approximately 40 kW. This in turn destroyed the module and allowed major quantities of water to enter the vacuum system.

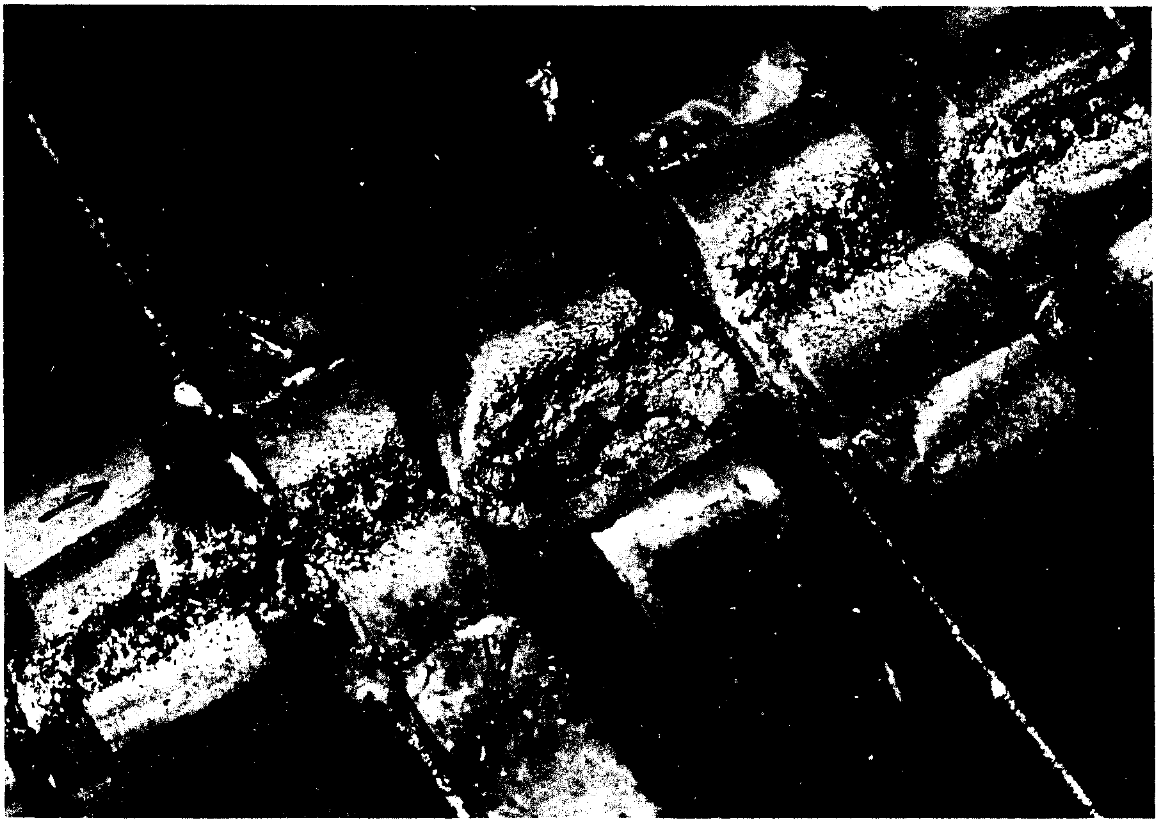
The destroyed module showed a brittle, granular appearance of the burned-out section, littered with small metal particles of spherical geometry, suggesting that melting had taken place. These particles were found to be of copper and nickel, which are present in the sintered tungsten module at a concentration of 8% to make it free machining and to bind the brittle tungsten matrix together. The sintered mixture does not have the high-temperature properties of pure tungsten. Pure tungsten will be used in the future for applications involving deposition of primary beam power.

There was also a failure in the tuneup dump D-10, as shown in Fig. 12. A hole was burned through the A-beam channel in the dump, resulting in a catastrophic water-to-vacuum failure. The burned-out section of the channel is shown in Fig. 13; note the three spheres visible in the burnout.



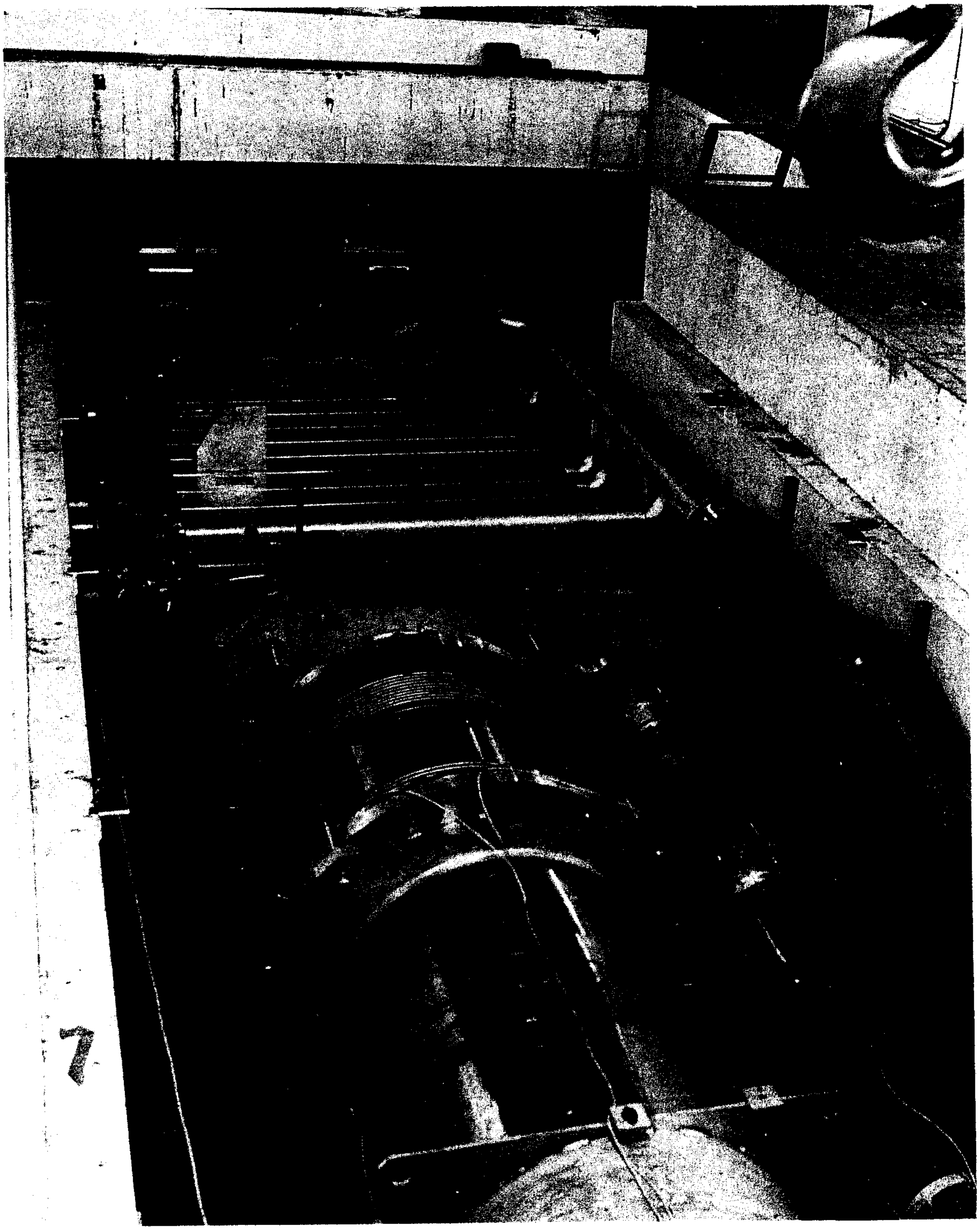
1753A11

FIG. 10--Halo collimator C-12. Beam direction left to right.



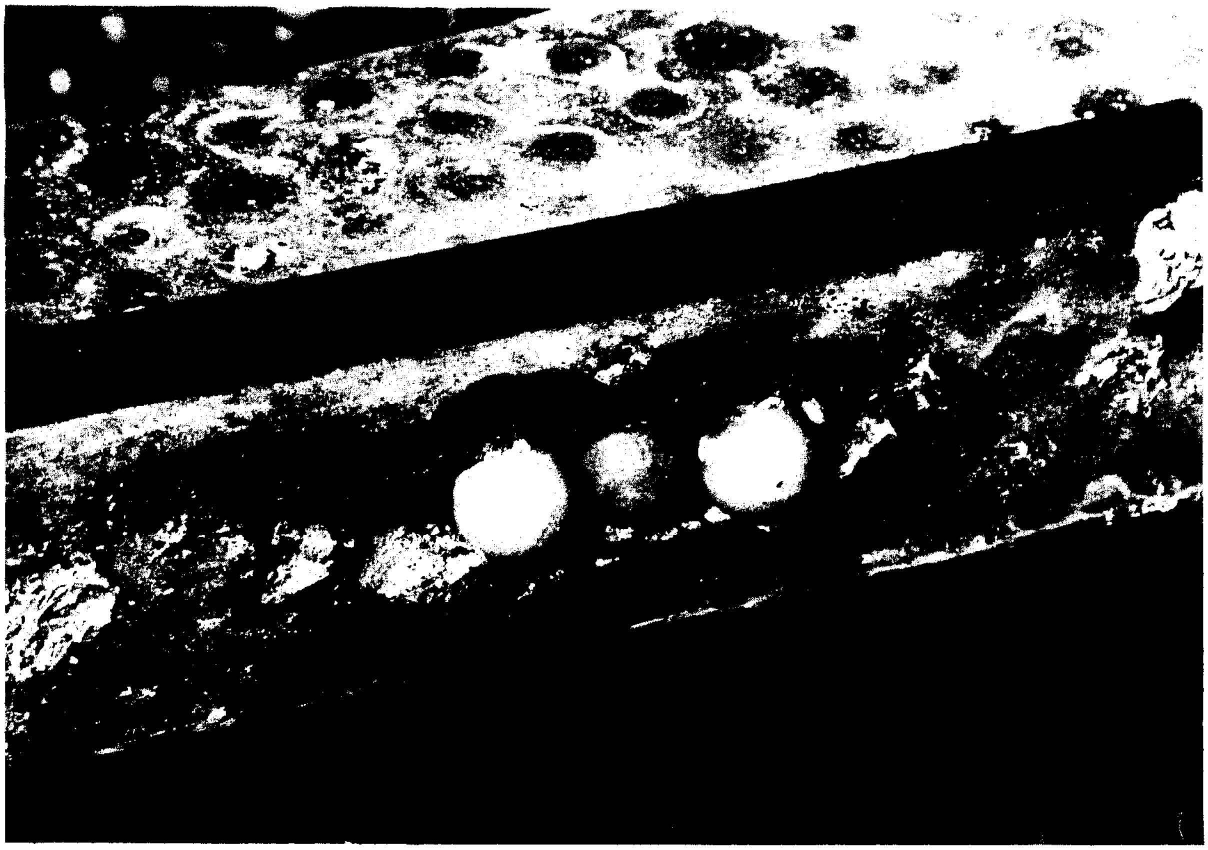
1753A7

FIG. 11--Damaged jaw from collimator C-12. Beam direction left to right.



1753A5

FIG. 12--Tuneup dump D-10 installed in BSY. View is downstream.



1753A6

FIG. 13--Failure in A-beam transport channel from dump D-10.

Investigation revealed that during the 24 hour period preceding the burnout, the average beam power delivered by the accelerator ranged up to 610 kW, with approximately 480 kW just prior to burnout. The accelerator showed some instabilities during this running period and the subbooster in Section 30 tripped off just prior to failure. This resulted in a 4% reduction of the beam energy. Thus the full beam power was deposited into the tuneup dump on the low-energy side of the A-channel. An unfavorable flow pattern of the cooling water complicated the situation.

Failure occurred on the low-energy side of the channel and at an axial depth corresponding to the shower maximum in aluminum at the experimental energy. The 500 kW limit for power absorption in the dump thus probably has to be revised downward by 50 to 100 kW. The limit was based on experimental data from a beam dump using the same power absorption medium (water-cooled aluminum spheres). However, the flow configuration in the dump experiment was more favorable.

Two corrective measures were taken. First, the water flow in the area of the shower maximum was improved by removing some aluminum spheres. This increases the heat flux level at which transition from nucleate boiling to film boiling and potential burnout occurs. Second, a calibrated power-limiting SEM foil assembly was installed in front of the dump window. Its output is interlocked with the beam. This allows normal beam operation at power levels much in excess of the 400 to 500 kW limit placed on the dump, while at the same time offering protection against accelerator failure or operator error.

VIII. ACCELERATOR PHYSICS

(October 1, 1969 - September 30, 1970)

Introduction

This section summarizes the activities of the Accelerator Physics Department over the past year. It does not include topics on Instrumentation and Control, which were reported in the preceding Quarterly Status Report. For further information and details, the reader is referred to the papers listed below.

1. Linear Accelerators, edited by P. M. Lapostolle and A. L. Septier (North Holland Publishing Company, Amsterdam, 1970); Chapters B.1.1, B.1.2, B.1.4, B.2.3 and E.2.
2. "Superconducting accelerator research and development at SLAC," by P. B. Wilson, R. B. Neal, G. A. Loew, H. A. Hogg, W. B. Herrmannsfeldt, R. H. Helm and M. A. Allen, SLAC-PUB-749, submitted to Particle Accelerators, June 1970.
3. "Magnetization and susceptibility measurements of polycrystalline niobium," by H. Brechna, M. A. Allen and J. K. Cobb, SLAC-PUB-775, presented at the 1970 Applied Superconductivity Conference, Boulder, Colorado, June 15-17, 1970.
4. "Analysis of critical power loss in a superconductor," by Mario Rabinowitz, SLAC-PUB-714, presented at the 1970 Applied Superconductivity Conference, Boulder, Colorado, June 15-17, 1970.
5. "Recent and planned improvements of conventional electron linacs," by G. A. Loew and R. B. Neal, SLAC-PUB-800, presented at the Proton Linear Accelerator Conference, NAL, Batavia, Illinois, Sept. 28 - Oct. 2, 1970.
6. "Computation of the properties of traveling-wave linac structures," by R. H. Helm, SLAC-PUB-813, presented at the Proton Linear Accelerator Conference, NAL, Batavia, Illinois, Sept. 28 - Oct. 2, 1970.
7. "A new precision measurement for beam transport type magnets," by D. Horelick and J. Cobb, SLAC-PUB-750, presented at the 3rd International Conference on Magnet Technology, Hamburg, Germany, May 19-22, 1970.
8. "Electromagnetic and mechanical properties of niobium cavities for a superconducting electron linear accelerator," by W. B. Herrmannsfeldt, R. H. Helm and R. R. Cochran, SLAC-PUB-811, presented at the Proton Accelerator Conference, NAL, Batavia, Illinois, Sept. 28 - Oct. 2, 1970.

A. Injection System

1. Two Gun Assembly

In November 1960 a second gun was added to the injector. The second gun is at an 105° angle to the accelerator axis and an inflecting magnet bends the beam onto the accelerator axis. Initial tests revealed that this system worked well with the solenoid around the injector accelerator section turned off, but with the solenoid at its normal current, the stray fields bent the beam from the off-axis gun into the wall of the vacuum chamber. A bucking coil was installed which approximately cancels the fields from the solenoid in the vicinity of the off-axis gun. This solved the problem. The off-axis gun was first used for machine operation in March of this year, and has been in routine use since that time. The beam from the off-axis gun appears to be as good in all respects as the beam from the on-axis gun.

In the spring of 1971 we hope to install a pulsed inflection magnet which will permit interlacing beams from the two guns on a pulse-to-pulse basis. This will make possible better pulse shapes when beams of very high and very low peak currents are required at the same time.

2. Electron Guns

During the year a new higher current gun requiring less grid drive was designed. One of these guns has been built, and was installed on the accelerator in the off-axis gun position in July 1970. This gun delivers 5 amperes peak current with cathode voltage of -80 kV and 800 volt grid-cathode pulse. More importantly, this gun delivers 2 amperes with about 300 volts grid drive, as compared with 1000 volts required by the original gun. This lower voltage is very important for generating very short pulses.

The high-current gun has operated just over 2000 hours as of November 1970. The other gun on the accelerator was converted April 21, 1966, installed February 19, 1968, and has been operated 16,757 hours.

3. Time-of-Flight

The high current gun coupled with a fast pulse train generator purchased from Edgerton, Germeshausen and Grier Inc., Goleta, California, has significantly improved the time-of-flight beam capability. This combination can deliver a train of 5-nanosecond-long pulses with continuously variable spacing for experiments requiring high currents but not very good time resolution. Combined with the

40 MHz chopper it can deliver 10-pico-second-long pulses (a single rf bunch) with spacings which are almost any multiple of 12.5 nanoseconds. As many as 3 differently structured time-of-flight beams have been interlaced at one time.

Some work has been done on improving the time-of-flight beam monitoring. The accelerator Master Trigger Generator has been modified so that it can be synchronized with a subharmonic of the 40 MHz chopping frequency. This provides a stable external trigger for viewing a time-of-flight beam on an oscilloscope at any location where the accelerator trigger is available.

Various nonintercepting time-of-flight beam pick-ups have been tried. The best so far is also the simplest. It consists of a ceramic cylinder brazed into a section of 2.5 cm diameter drift tube so as to provide a 1/2 cm long insulated gap in the conducting beam pipe. Around the circumference of this gap, at roughly 72^{o} intervals, four 50Ω composition resistors are soldered across the gap. In the fifth location ($360^{o}/72^{o} = 5$) a 50Ω 7/8" OD Spiroline coaxial cable is attached with its center conductor contacting on one side of the gap and the outer conductor contacting on the other side. This cable runs approximately 20 meters to the sampling scope. Adjacent rf bunches which are 0.35 nanoseconds apart are almost completely resolved by this pick-up.

B. Drive System

1. Master Oscillator

During the last year the three master oscillators underwent minor modifications and repairs. The three units are now identical. The drawings have also been updated to reflect the recent modifications. The units have been operating well and the new modifications should greatly improve their reliability.

2. Main Boosters

Main booster no. 1 has been modified to match the no. 2 unit which was modified during the year from October 1968 to September 1969. The two are now identical. Maintenance has become easier and reliability is improved.

3. Subboosters

The subbooster klystron and modulator continue to perform in a satisfactory manner. Along with routine maintenance, a program to install a fast recycling system has been under way for the past year. The previous recycle time was on the order of 20-30 seconds, the time required to run a variac down and up again. The new system is electronic and recycles the modulator in about 0.1 second.

The modifications are performed during long shutdowns and should be completed for all 31 units within the next year.

4. Main and Subdrive Lines

There have been no problems with the main drive line during the last year. The repair program for the expansion sections located between each sector has proceeded at a slightly slower pace than previously anticipated. At the beginning of the program four expansion sections were scheduled for repair and installation per month or machine cycle. Transportation and repair time has been longer than expected and the average repair cycle for four expansion sections has been 2 to 3 months. This program is expected to continue through December 1971.

The repair work on the subdrive lines has continued in a programmed manner. Sectors 18 through 30 have been refurbished to original specifications as of October 1970. During October, November and December of 1969, the directional couplers of Sectors 1 through 13 were silver plated and returned to service. The subdrive lines in Sectors 1 through 18 are being reworked to original specifications as fast as is consistent with operating schedules and available time.

The subdrive line center conductor problem described in a previous status report has not been solved except by resoldering when required. Some sections of the subdrive lines seem to be more subject to this problem than others. This is probably due to changes in procedures or personnel during the time the lines were being manufactured. Electrical tests are now used as a diagnostic for correct reassembly.

During the tuning and aligning of the directional couplers it was noticed that some couplers were erratic. This erratic effect was traced to a "cold solder" joint in the coupling loop ground plane. The problem is now being eliminated by fabricating an auxiliary spacer block to make the assembly mechanically rigid. Only Sectors 1 through 18 will be modified to include this improvement.

Nearly all of the subbooster output monitor directional couplers were modified to eliminate an unnecessary center conductor captivation assembly. Its removal has improved the total performance of the subdrive line system.

The new plastic foam drive line insulation was completed, eliminating handling and other problems associated with the original fiberglass insulation.

5. Varactor Frequency Multipliers

Twenty-three out of 35 varactor frequency multipliers were modified by eliminating unused input attenuators and failing output filter-coupler components. The resulting benefits are: improved reliability, easier tuning and aligning, and increased power output. The increase in output power will allow the use of klystrons that require more than normal drive power but would have been unusable before the modifications were completed. The modification program is scheduled to be completed on or before June 1971.

6. Rf Separator

The new subbooster type of driver for the central beam rf separator has been installed and in use for about 6 months. Installation and tests were accomplished with minimum difficulty. Installation of the solid state 476 MHz rf amplifier was delayed because its gain was insufficient to supply the varactor frequency multiplier with the necessary 4 W of power. Instead, a temporary klystron amplifier in the 2856 MHz part of the circuit was used until a second unit could be constructed. Tandem operation of two units will supply the required 4 W of power. This installation is scheduled for early 1971.

7. Pulsed Phase Closure

The pulsed phase closure improvement has been delayed because the possible supplier of a conventional phase shifter was slow in responding to a request for quotations. The new pulsed phase closure system will now use the same type of circulator as previously installed and a new style of phase shifter will be employed. A very simple type of motorized sliding short will replace the precise and expensive conventional type of phase shifter. No major changes will be required in the Instrumentation and Control (I & C) portion as only an addition of 3 more controls and readout signals will be required.

8. Isolator-Phase Shifter-Attenuator

Fifty spare attenuating vanes with the original epoxy-to-iron powder ratio have been obtained. Other ratios yielding less attenuation per unit length were abandoned because the range of attenuation originally required to cover possible variations in drive power could not be relaxed. The spare vanes will be installed as required. Nine isolator-phase shifter-attenuator units have been repaired with new vanes and new center conductors. The nine units now meet original specifications. Several alternate methods have been examined to lower the total power absorbed by the vanes by 3 dB. One solution would be to install fixed 3 dB attenuators in front of each isolator-phase shifter-attenuator combination. Another solution might be to install a 3 dB directional coupler at the input of each subdrive line. Both of these solutions appear too costly. The latest method under investigation is to replace the first 40 ft of copper center conductor by an identical length of stainless steel conductor. Only the first directional coupler needs to be adjusted by about 3 dB. The power loss in the 40 ft of center conductor is about 3.4 dB. The heat generated will be transferred to the present water temperature stabilized outer conductor. Transfer of heat from the inner to outer conductor will be by conduction, convection and radiation. The lines are filled with dry nitrogen pressurized at about 0.5 lb above 1 atmosphere.

9. Injector Drive Line Switches

The subdrive line waveguide transfer switch has operated without failure since it was installed. The main drive line coaxial transfer switch was replaced with temporary "U" links to allow repairs and tests to proceed on the standby main booster without danger of tripping off the on-line unit. Since the "U" links were installed on June 24, 1970, the no. 2 main booster has been the on-line unit. The output power stability of main booster no. 2 appears to be better than that of the no. 1 unit. The reasons for the difference are not understood at this time since the two units are identical electronically. The probable cause of the difference is that the 2 klystrons are slightly different.

No further degradation of the 3-1/8 inch diameter drive line gas barriers has been observed.

10. Research Area Main Drive Line Distribution

Beam knock out and/or 476 MHz reference signals are now available for users in the research area. This includes such areas as end stations A, B, and C, DAB (now MCC) and the streamer chamber. If further distribution is required, it can be effected by extra cables and/or amplifiers.

11. Energy Transient Compensation

The PIN diode modulators which gate the rf drive to the klystrons in stations 27-7 and 27-8 have remained available for use as required by the machine operators in CCR. The modulator drivers, however, have been reworked to provide separate controls for gate width and gate timing. This new system makes it easier for operators to effectively utilize the two stations for filling energy "gulches" in the beam.

C. Phasing System

The automatic phasing system has performed satisfactorily during the past year. No further modifications have been made to the system. Routine maintenance has been carried out at the beginning of each accelerator operating cycle.

D. Beam Position Monitors

The beam position monitors on the accelerator have continued to operate satisfactorily, and no changes have been made in the system during the past year. In the beam switchyard, the special I. F. receiver system installed with position monitor P13 has been removed, as the experiment requiring it has been completed. All tunnel diode detectors have been replaced by IN4127 crystal detectors. These have been found to have a greater dynamic range than tunnel diodes, and their replacement cost is very much lower.

E. Beam Breakup (BBU)

The program of BBU improvement by "dimpling" was completed during the first week of November 1969, when Sectors 12, 18, 21, 24, 27, and 30 were detuned by 4 MHz. Subsequent transmission tests showed that the BBU current threshold in the switchyard now stands at 77 mA for a 1.6 μsec pulse length.

F. Magnetic Measurements

A new improved system for performing a harmonic analysis on multipole magnets was developed during the year. The system is built around the electronics and data logging features of the rapid magnet mapper. Only a few modifications were needed in the control section. The transducer is an asymmetric coil of copper wire which can be stepped azimuthally around the aperture of the multipole in 200 steps. The wire bundle is at a constant radius from the center of the multipole. The volt-second integrations resulting from each step are logged on magnetic tape. Also logged on tape for each data point are the step-number, current in the magnet, position data and date. For analysis, the data is processed by computer programs which perform a Fourier analysis of the data points and return the coefficients of the characteristic waveform representing the magnet. We have a series of short coils of various diameters which can be used for 2-dimensional measurements and a new long coil for making full length magnet measurements.

The method of using a long coil for making measurements on multipoles is much faster and more accurate than the previous system of making many 2-dimensional measurements and performing a numerical integration to express the total magnet quality. In addition, this system makes a precise measurement of magnet strength which was not possible with the old continuously rotating system.

We have recently completed a new automatic mapper system for the 82" hydrogen bubble chamber magnet which is also driven by the rapid magnet mapper console. This system allows accurate positioning of the coil transducers in the magnet by means of slo-syn motors. We are planning a map of the 82" magnet in January 1971.

During the year a number of measurements were made for a wide range of customers; one of the major jobs has been the measurement of the prototype magnets for the SLAC storage rings. We have measured the 6Q20 quadrupole under many conditions, made changes in configuration, and measured it again. The design is now complete. Essentially the same procedure was used on the 10D90 bending magnet prototype, the 7S10 sextupole prototype and the 6Q40 quadrupole prototype. For the quadrupoles and sextupoles, the method of harmonic analysis for designing the magnets proved very successful.

We are now planning several large scale jobs for the coming year: (1) measurement of all storage ring magnets, (2) measurement of all storage ring transport magnets, (3) mapping of 82" HBC magnet, (4) mapping of the 70D43 magnet and (5) remeasurement of A-line magnets installed in the BSY.

G. Positron Source

In order to find out if higher positron currents could be obtained for low repetition rate beams such as the beams which are used for bubble chamber experiments and will be used for filling the electron-positron storage ring, a test was made using several tungsten and several copper radiators of various thicknesses. The optimum tungsten radiator, about 1.9 cm thick, produced more than twice as many positrons as the optimum copper target which was about 5 cm thick. The best specific yield (ratio of accelerated positrons to 6 GeV electrons incident on the target) was 9% using the tungsten target.

This same target was used in a test to see how many positrons could be produced in a single 7-nanosecond-long pulse suitable for filling a single rf bucket in the electron-positron storage ring. In this short pulse test, using the Fast Pulse Generator mentioned earlier, a peak current of 15 mA of positrons in a 7-nanosecond-long pulse was accelerated almost to the end of the accelerator. Approximately 1/2 of these were lost due to collimation when the beam was decelerated to

1.5 GeV at the end of the accelerator. Approximately 3.5 mA peak passed through a 1% slit and reached a monitor in the end station.

H. SAD Committee

The SLAC Advanced Design (SAD) Committee has continued the work which led to the feasibility study for a two-mile superconducting accelerator. Much of the effort this year went into designing Project Leapfrog and associated equipment which are described in the next section of this report.

In addition, several new proposals have been made to recirculate the SLAC beam. Preliminary details for these can be found in SLAC-PUB-800. Two essential variations of this proposal are:

a) To bend the beam back to the injector and pass it through the accelerator tube a second time. Accelerating fields would be provided by pulsing the modulators and klystrons twice in a row within approximately 25 μsec, the time needed for the beam to return to the injector a second time. By using the energy stored in the existing modulators but by splitting their pulse lines so that two thyratrons can be fired in succession, it is possible to gain a factor of $\sqrt{2}$ in beam energy.

b) To recirculate the 20 GeV beam approximately 120 times (about 2.8 msec) until the klystrons can be fired again on their normal duty cucle. A short superconducting accelerator section would be placed in the recirculating beam line to provide the energy needed to replace the losses due to synchrotron radiation. Many questions of magnet optics, synchrotron phase stability, conservation of phase space, etc., need to be answered. A complete cost study is also required. This scheme has the advantage that it could double the energy of the accelerator (although at reduced current). There would also be the possibility of using the system as a pulse stretcher, increasing the duty cycle of the 20 GeV beam by a factor of 100.

I. Superconducting Accelerator Studies

The objective of this program is to establish the feasibility of converting the present accelerator to a superconducting version with a higher energy gradient and improved duty cycle. The effort within this project is divided roughly into two parts. A program of rf cavity studies and related measurements is being carried out in an attempt to reach a better understanding of the fundamental rf properties of superconducting materials. A program of basic measurements alone would neglect the systems aspect of a superconducting accelerator. Furthermore, many problems only become apparent in the actual attempt to build an operating device. For this reason project Leapfrog has been initiated. The goal of this project is to build a two-foot long, superconducting test accelerator using a traveling-wave resonant structure. A progress report on project Leapfrog, a description of the basic materials research program, and short reports on other studies directed toward the eventual construction of a two-mile superconducting accelerator are given in the following sections. Additional information concerning the superconducting accelerator research program at SLAC will be found in SLAC-PUB-739.

1. Superconducting Materials Studies

X-band cavity measurements. A variety of measurements have been made during the past year on niobium TE_{011} and TM_{010} mode cavities at X-band frequencies. The first series of measurements on two different TE_{011} mode cavities (in this mode only magnetic field is present at the superconducting surface) gave residual Q's on the order of 10^9 and rf magnetic quenching fields on the order of 300 gauss. The highest Q obtained was 5×10^9. A degradation in Q was often seen between successive runs, and this was attributed to the fact that the cavities were not protected by a low temperature vacuum window. Migration of contaminants from the room temperature vacuum system into the interior of the cavities was thought to be the probable cause of the observed degradation.

A TE_{011} mode cavity was next constructed in which the indium gasket at the top end plate was replaced by an electron beam welded joint. An rf vacuum window was also added close to the cavity. This cavity gave the best results attained to date. In a series of measurements, residual Q's in the range 10^{11} to 10^{12} were reached, with magnetic breakdown fields from 750 to 950 gauss. It was found that exposure to dry nitrogen at room temperature produced no measurable degradation in Q or breakdown field. Exposure to room temperature air did, however, result in a reduction in residual Q by two orders of magnitude, and a decrease in breakdown field by a factor of two. After refiring the cavity at $2000^{\circ}C$, it was found that the Q and breakdown field were restored to the original high values.

Other measurements have been made on TE_{011} mode cavities with various objectives in mind. It was found that a superconducting niobium cavity with a 3/16 inch wall can exclude an external dc magnetic field exceeding 3000 G, if it is cooled down through the transition temperature before the field is applied. A cavity filled with liquid helium was measured to test the effect of cooling the inner surface at high rf field levels. Instabilities made it impossible to obtain accurate high power measurements, but it was reaffirmed that the loss tangent of superfluid helium is indeed very low ($< 10^{-11}$).

One measurement was made on a TM_{010} mode cavity operating at 8.6 GHz. The Q value and breakdown field were not dramatic ($Q_0 \approx 10^8$ and $H_{br} \approx 100$ G), probably because the cavity received a significant exposure to air after high temperature firing and before being assembled. Care will be taken in future measurements to reduce or eliminate the exposure to air after firing.

A paper and a SLAC technical note are currently being prepared which contain some of the more significant experimental results obtained to date in the cavity measurement program.

Theoretical studies. In all measurements made up to the present time on superconducting niobium cavities, the observed level for rf magnetic field breakdown has been considerably less than the thermodynamic critical field. It has been speculated that poor thermal conductivity, which results in local heating in the immediate neighborhood of any small normal regions due to defects or trapped flux within the superconducting penetration depth, may play an important role in explaining the observed breakdown. Extensive theoretical calculations based on this model have been made (M. Rabinowitz, SLAC-PUB-708 and SLAC-PUB-714). The calculations seem to provide a reasonable fit to the available experimental data. Further comparisons between theory and experiment are planned for the near future.

The possible sources of residual power loss in superconducting cavities have also been examined (M. Rabinowitz, SLAC-PUB-777). It is shown that if the losses are due to small normal regions on the order of the coherence length in size, then the residual surface resistance will vary with frequency as ω^2, in agreement with experimental observations. Residual losses due to both stationary and oscillating fluxoids are also examined.

Calculations of the theoretical superconducting surface resistance have been made for the frequency range 1-100 GHz and for temperatures between 1.25°K and 4.22°K, using a computer program developed by J. Halbritter at the Institute for Experimental Nuclear Physics, Karlsruhe, West Germany (P. Wilson, SLAC-TN-70-35).

Magnetic susceptibility measurements. An apparatus has been developed at SLAC for measuring the magnetic susceptibility of small superconducting rods about 3mm in diameter. The mutual inductance between two coaxial coils wound over the superconducting sample is measured using a low level 100 KHz probe signal superimposed on an externally applied dc magnetic field. The departure from the perfect diamagnetic state is observed as a change in the mutual inductance and a consequent unbalance from a null as indicated by a phase-locked detector. The method is extremely sensitive to even a slight penetration of the dc field into the superconducting sample. This technique could be useful in screening samples for purity, or in making a rapid assessment of various processing techniques, if a correlation between low frequency susceptibility and microwave surface resistance can be established.

In one series of measurements the apparatus was used to examine niobium samples with a range of tantalum content from 700 to 4000 ppm. A decrease in H_{c_1} of about 12% was measured from the lowest to the highest impurity content (H. Brechna, M. A. Allen, and J. K. Cobb, SLAC-PUB-775).

Thermal conductivity studies. Measurements on the thermal conductivity of superconducting niobium are continuing. These studies are being carried out in cooperation with personnel from the Magnet Research department. Thermal conducitivity is a parameter of obvious importance in the design of a superconducting accelerator structure. In addition, magnetic breakdown effects may depend upon thermal conductivity, as previously discussed.

Initial results have been obtained from measurements on niobium rods about 3/4 in. in diameter. The thermal conductivity at $1.85^{\circ}K$ is relatively high, about $0.4W\ (^{\circ}K\text{-cm})^{-1}$. For a temperature rise of a few degrees above this value, however, the thermal conductivity decreases by an order of magnitude. The measurements will next be extended to obtain the thermal conductivity for samples in the form of hollow cylindrical tubes. This geometry more closely approximates the situation of an accelerator structure immersed in liquid helium. The total thermal impedance, including the Kapitza resistance at the metal-liquid helium interface, will be measured. The experiment is important because good values for the Kapitza resistance for niobium are not available in the published literature. Initial estimates indicate that it may be appreciable, and must be taken into account in the design of a superconducting structure.

Field emission measurements. Additional results have been obtained during the past year in field emission measurements on room temperature niobium samples. The electric field enhancement factor, β, is measured by applying voltages up to 150 kV across a small gap between two electrodes under ultra high vacuum conditions. The observed field emission current normally arises from a discrete number of sharp "whiskers" on the surface of the sample. A principal objective of the study is to determine the conditions which can lead to the production of such whiskers, and to find methods which might remove them or reduce their effect.

Considerable success has been achieved in reducing the field emission from whiskers on a niobium surface by sputtering. The sputtering takes place when a small amount of an inert gas, such as argon, is introduced in the system while the whiskers are field-emitting. Bombardment by positive ions then reduces the sharpness of the whiskers. In this way the enhancement factor in a typical case was reduced from $\beta = 250 - 300$ to $\beta = 45$.

An optical system also has been set up for observing the Lilienfeld transition radiation. Small spots of light appear on the anode which give an indication of the number, location, and relative size of the field-emitting whiskers.

Radiation damage studies. Some small niobium rods were irradiated in the SLAC beam in an attempt to assess the effect of radiation damage on the superconducting properties of the sample. In particular, magnetic susceptibility measurements were made before and after irradiation. A slight degradation was observed in the value of the lower critical field ($H_{c_1} = 1350$ G before irradiation). There was, however, a large uncertainty in the dose given to the sample.

Measurements of this type have not been pursued further because the correlation between susceptibility and rf properties has not been established. Irradiation at room temperature of a TE_{011} mode cavity, which has been evacuated and sealed off, will be attempted next. Ideally the irradiation should be done at liquid helium temperatures, since at room temperature a substantial fraction of the defects which are produced will anneal out. The low temperature experiment is, however, considerably more complex, and it seems desirable to do the simpler room temperature experiment first.

2. Project "Leapfrog"

During the past year, work has begun on the design and construction of a short superconducting accelerator. This accelerator, which will first be tested without an electron beam, will be a 15-cavity structure with the output coupled back to the input by rectangular waveguide, forming a traveling-wave resonant ring (see Fig. 14). The entire ring will be built of niobium.

The accelerator structure. The accelerator will operate in the $2\pi/3$ mode at 2856 MHz. A number of possible cavity shapes for the structure have been examined using the LALA and TWAP computer programs (see section 4, Superconducting Linac Structure Studies). The cavity geometry which has been chosen is a modification of the conventional "pillbox" cavity, wherein the back of the cavity is curved into an ellipse which blends smoothly into a narrow disk wall, which in turn blends into an enlarged disk tip, also of elliptical cross section. Brass models of the structure have been made to check mode frequencies, r/Q, and group velocity. All are in very good agreement with the computations.

Another computer program has been used to examine the frequency shifts which will occur as a result of small structure deformations caused by the high rf fields propagating inside it. These calculations have a bearing on the mechanical design, and on the specifications applied to the ring tuning devices, to be discussed below.

Various methods of fabricating the accelerator structure from sheet niobium have been investigated. Test "half-cavities" were made by hydroforming and electroshaping, but these proved to be insufficiently uniform, and coining is now indicated as the preferred method of fabrication. Punches and dies have been made, and preliminary samples are expected within two weeks. The half-cavities will be joined by internal electron-beam welds run at the maximum and minimum diameters.

The rectangular waveguide loop. After a careful survey of alternative methods, it was decided to make the small quantity of S-band rectangular waveguide required for Leapfrog by bending L-sections from niobium sheet stock, making internal electron-beam (E. B.) welds to form U-channels, and finally joining two U-channels with E. B. welds to form rectangular pipe. The L-sections have been made by a bending-coining operation, resulting in an excellent surface finish. The waveguide will be fabricated in 1-foot sections.

Coupling between the rectangular waveguide and the accelerator will be accomplished by stepping to a quarter-height low-impedance guide which in turn E-field couples to the accelerator through the beam aperture of the end cavity. Design work on a brass model is nearing completion.

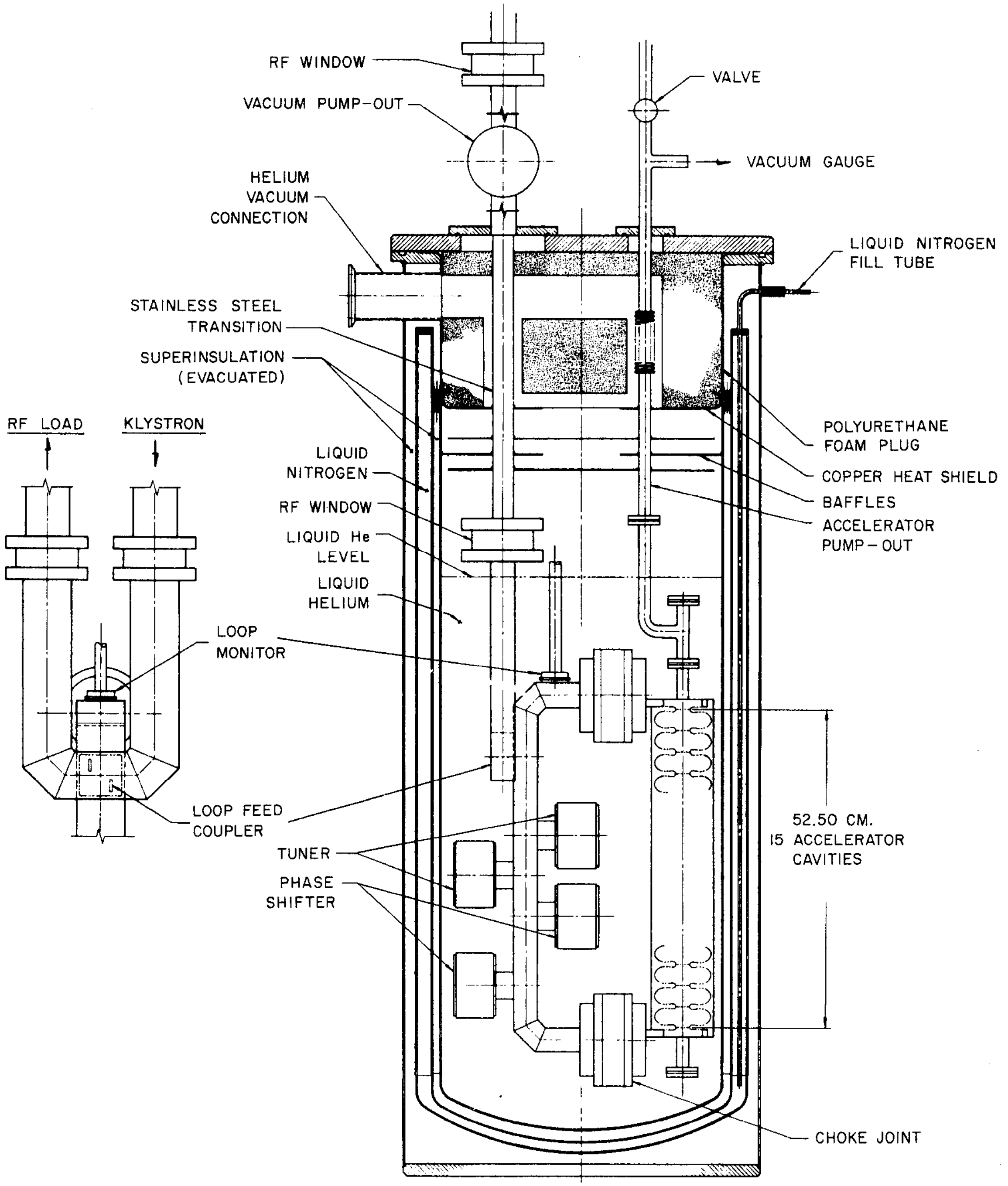


FIG. 14--Dewar assembly for the Leapfrog test accelerator.

Power will be fed into the resonant ring by means of a 45 dB cross-guide coupler. A model has been tested at room temperature. It has the required coupling, and indicates an intrinsic directivity better than 40 dB, increasing to 70 dB when operated with a tuned load-arm.

A 70 dB waveguide-to-stripline coupler is being developed. This will be used for monitoring the forward power in the resonant ring.

The waveguide loop will be joined to the accelerator couplers by means of double take-apart choke flanges. Spacers will be inserted between the double flanges, and their length will be adjusted to obtain an integral number of wavelengths around the loop. A model flange has been built and tested.

<u>Loop phasing and matching systems.</u> Successful operation of the high-Q superconducting resonant ring demands that the phase and match within the loop be held to very close tolerances. For instance, assuming $Q_L = 1.5 \times 10^8$, a change of 8×10^{-4} degrees in the electrical length of the loop is sufficient to detune the loop resonance by half a bandwidth. Similarly, a discontinuity in the loop giving rise to a reflection coefficient of 1.4×10^{-5} will present a short circuit to the generator feeding the loop. The reflection coefficient has to be less than 1.4×10^{-7} to keep the backward wave in the loop below 1% of the forward wave. Moreover, computations on the effects of radiation pressure inside the accelerator structure, mentioned earlier, clearly show that the loop will be progressively detuned during the buildup and decay of rf fields at each end of a pulse. For these reasons, fast-acting servo-driven tuners are being developed.

Loop phase errors will be detected by comparing the phase of the monitor coupler signal with the phase of the rf drive from the generator (klystron). Comparison will be made in a synchronous detector which is essentially a fast analog of the detector used in the present SLAC automatic phasing system. The error signal developed when the differential phase is nonzero will be processed in an analog-digital-analog (ADA) system and applied to a high-voltage amplifier. This amplifier drives two tuning plungers in the rectangular waveguide loop.

A similar system will compare the monitor coupler signal with the wave reflected back to the klystron. Error signals proportional to the orthogonal components of the reflected wave will be produced and amplified to sequentially drive two more plungers in the waveguide loop. These plungers will move to cancel the mismatch which causes the reflected wave.

Development of all the microwave stripline components required for these systems is proceeding satisfactorily. The components include couplers, phase modulators, fast diode switches, phase bridges, and detector mounts. Prototypes of the ADA logic circuits and HV amplifier have been built and tested.

The tuners themselves present an unique problem. Each tuner must operate in high vacuum at liquid helium temperature with no sliding friction and minimal heat dissipation. It must respond in milliseconds, have a position resolution of two tenths of a microinch, and yet have a total range of movement of about a quarter inch.

A prototype tuner which comes close to meeting these specifications has been built. The motor is a piezoelectric "bender" disk which will be driven by the HV amplifiers mentioned above. This disk imparts the fine movement to the tuning plunger: approximately 1.25×10^{-5} inch per volt at room temperature, and 2.5×10^{-6} inch per volt at $4^{o}K$. The fine tuning range is limited to about 10^{-3} inch; movement over a quarter inch range is achieved by using an electromagnetic double-clutch "incher" mechanism which, when cycled once, moves the bender disk operating plane by about 5×10^{-4} inch. The tuning plunger is 1 inch in diameter, and is inserted in the narrow wall of the rectangular guide. It has been designed with a compact choke giving better than 100 dB rf isolation between the waveguide and the tuner motor. While the prototype tuner shows considerable promise, many details of fabrication and assembly remain to be worked out.

The 45 dB loop-feed coupler will be part of the resonant-ring high-vacuum system. Its input and load arms will be brought out of the helium-filled dewar via two sets of ceramic windows, the lower pair being just above the liquid helium, and the upper pair being at room temperature. The intermediate waveguides will be connected to a separate vacuum system and will, for part of their length, be constructed of thin-wall stainless steel, to provide thermal isolation.

The drive system. The Leapfrog accelerator will require 860 W of CW drive power, which will be furnished by a prototype 20 kW CW klystron being developed at SLAC. A 1 kW CW klystron amplifier is also available. Klystron drive will be provided by a crystal-stabilized Gunn diode oscillator, followed by a TWT amplifier. The level of rf power circulating in the resonant ring will be controlled by a PIN diode switching regulator which chops the CW drive signal into the klystron. The chopper duty cycle will be determined by the amplitude of the loop monitor coupler signal. The electronics required for this control function has been developed and tested.

The dewar. Leapfrog will first be run with the accelerator axis vertical, permitting the use of a conventional dewar vessel which opens at the top only. The accelerator ring will be supported by a platform over a pit containing the dewar, so that assembly can be completed, and all adjustments and inspections can be made before raising the dewar into position for the experiment.

The dewar is of stainless steel construction, with a conventional nitrogen jacket and evacuated superinsulation. It has an internal diameter of 18 inches, and is designed to operate with 34 inch depth of liquid helium. The tested boil-off rate at $2.5^{\circ}K$ is 2 liters per hour.

3. Fabrication and Processing Facilities

Electron beam welder (E.B.W.). The 25 kW Hamilton Standard electron beam welder was used extensively during the first half of this year. Techniques and operator skills for producing E.B. welds of various depths in niobium and other metals were developed and some cavities were welded. In July the welder was closed down for major modifications. The original chamber, approximately 2 feet in diameter by 5 feet long, has been replaced by a rectangular chamber 5 feet wide, 6 feet high and 9 feet long. Work pieces may be either held in a rotary fixture, or supported on an X-Y table having 4-1/2 feet of travel. The original gun, power supplies, and controls are retained. The chamber is pumped by two 20-inch oil diffusion pumps. A vacuum of 8×10^{-7} torr has been reached. All modifications are essentially complete, and the welder is ready for use again.

High temperature, high-vacuum furnaces. A small rf induction-heated furnace has been available for high-temperature processing niobium parts. This furnace is capable of heating components not exceeding 2-1/4 inches diameter by 3 inches long to a temperature of $2000^{\circ}C$ in a vacuum approaching 10^{-10} torr. However, the limited hot-zone size and occasional difficulty with temperature nonuniformity led to the design and construction of a larger, resistive-heated furnace.

This furnace, recently completed, has six woven-tungsten mesh heaters, forming a cylinder 7 inches in diameter and 12 inches long. The working hot-zone is 5-1/2 inches diameter by 8-1/4 inches long. The heater is surrounded by multiple baffles and a copper cold-wall. A stainless steel cylinder forms the outer vacuum enclosure. A vacuum of 1.7×10^{-9} torr at $2200^{\circ}C$ has been achieved. It is anticipated that this furnace will be used for vacuum-processing most of the components and subassemblies required for the Leapfrog experiment.

4. Superconducting Linac Structure Studies

A number of accelerating structures which might be useful for superconducting linacs have been analyzed at SLAC using two different computer programs. The first program is the Los Alamos LALA computer code which has been adapted for the SLAC IBM 360/91 computer. The second is the Traveling-Wave Accelerator Program (TWAP) developed by R. H. Helm. This program differs from LALA in that it uses a functional expansion of the fields, rather than the mesh method. The theoretical basis for this program has been described in a paper presented at the 1970 Proton Linac Conference (R. H. Helm, SLAC-PUB-813). These two programs are approximately equivalent in accuracy and versatility, although each has certain strong points that make one or the other the preferred choice in a particular application.

The design of the Leapfrog accelerating structure has been considered using both LALA and TWAP. In addition to the rf properties, the mechanical rigidity against deformations is an important property of a potential structure for a superconducting accelerator. At high rf field levels the forces due to the electric and magnetic fields at the cavity walls can cause a significant mechanical deformation and consequent shift in resonant frequency. For the case of the Leapfrog structure a frequency shift of about 147 Hz can be expected when the peak field in the structure is 1000 G. Additional details concerning the electromagnetic and mechanical properties of the Leapfrog structure are given in another paper presented at the 1970 Proton Linac Conference (W. B. Herrmannsfeldt, R. H. Helm and R. R. Cochran, SLAC-PUB-811).

A related problem of importance for a superconducting structure is the effect of heating at high rf field levels due to the finite thermal conductivity of the structure wall material. The problem is complicated by the fact that both thermal conductivity and surface resistance can be strong functions of temperature. An approximate calculation taking these effects into account has been made by M. Lee and W. Herrmannsfeldt.

5. Cryogenic Refrigeration Studies

Large scale low temperature refrigeration presents a problem of obvious importance for a two-mile superconducting linear accelerator. During the past year studies have continued on possible systems which might provide the necessary refrigeration in the 1.0 to 1.85°K temperature range. Cryogenic compressors have been reviewed, and it has been concluded that they do not appear to be economically feasible for continuously operating systems. The use of He^3 as an intermediate heat transfer fluid, however, looks attractive for the realization of thermodynamically efficient systems. These and other results of the study are reviewed in a paper presented at the 1970 Cryogenic Engineering Conference (G. Ratliff and S. J. St. Lorant, SLAC-PUB-769, paper E-1, to be published in Advances in Cryogenic Engineering, Vol. 16).

J. Accelerator Optical Alignment System

Alignment of the accelerator continues as in the past several years. In 1970 there have been no singular points, but trends in misalignment apparent in previous years continue to show up. Specifically, target 12-3 continues to move upward and to the south, but the movement was only about 0.020 inches in 1970. The "great valley" fill area, Sectors 13-15, continues to sink at about 0.040 inches per year. A careful look at the vertical misalignment data for Sectors 19 through 26 suggests that the "tilting" of this area is continuing, with 19 sinking and 26 rising. The differential of this motion, between Sector 19 and Sector 26 is approximately 0.080 inches for 1970. This represents a minus to plus 0.040 inches vertical error in the alignment of the accelerator per year. One interesting horizontal "trend" appears in the western 1/3 of the accelerator. There is a tendency for this section to have a southward error, which is more pronounced in Sectors 1, 2, and 3. Here it is nominally 0.015 to 0.020 inches in 1970. Sector 5, however, appears as an inverse "dog leg" in this trend.

Theta level errors continued to be greater than 1/2 but less than 1 division on the level vial in 30% of the stations.

Alignment equipment operated well in 1970, with a normal amount of maintenance and repair.

Long Path-Length Interferometer

Research has continued to determine the feasibility of building a long path-length optical interferometer in the SLAC alignment pipe. Some counting electronics have been assembled. An improved optical isolator now prevents light from re-entering the laser, thus no longer affecting the lasing frequency. Counting of fringes has been effected over a 1200 foot path length. Data from such counting is not yet conclusive.

IX. PLANT ENGINEERING

Three general plant projects were completed during the quarter and the facilities were placed in use. These were: extension of the central utility building and the installation of two 50-ton chillers; installation of a neutral particle test facility (pit and utilities) located on the extension of the end station A beam line; upgrading of Buildings 102 and 104 in the target yard by the incorporation of offices, rest rooms, and work shop space.

Provision of conventional facilities in support of the colliding beam storage ring to be located in SLAC's north target yard is underway. A contract has been placed for the underground utilities and field work started in September. Engineering is well along on the necessary site improvements and bid invitations for this construction will be issued in October. Procurement has been initiated for buildings to house the power supplies, control equipment, and the interaction pits. Scoping is complete on above-ground utilities and design is expected to start early in the next quarter. This overall effort is the major item in the current plant engineering program and represents a substantial commitment of engineering and drafting time for several more months.

Field work is in progress on several projects, the principal ones being as follows:

1. Film Processing Facility. An on-site film processing operation is to be housed in approximately 1,250 square feet of available space in the north portion of the test laboratory substation building. Adaptation of the space for this purpose is 10% complete.

2. Computer Building Security. Field work on an enclosure fence at Building 214 has started. This work and special glass replacement of exterior windows is scheduled for completion in October 1970.

3. SLAC 230 kV Tap Line. Hardware is on order for dead-ending Pole Structure #35; installation is scheduled for November 1970.

4. Utility Tunnel Extension. Liner plates for a 17-foot extension of utility tunnel B-4 in the target yard have been ordered. A contract for the excavation and installation has been placed and work is about to begin.

Preliminary work on various other items, as stated below, is underway:

1. B-Beam Equipment Shelter. Bids will be opened on October 7, 1970 for a metal building to be installed in the target yard to house the equipment for Research Experiment E-68.

2. Research Yard Fire Alarm Extension. Bids will be opened on October 13, 1970 for extending the annunciator zone capacity from 12 to 16 and providing separate systems for the BSY, end station A, end station B, and the research yard.

3. Accelerator Improvements. Procurement has been initiated for a 2 MVA unit substation and 5 kV contactors to be added to the research yard electrical utility system.

4. Cooling Tower Cell. This project will increase the capacity of the BSY cooling water tower by adding a cell to the three already in service. Design has begun.

5. Fire, Safety, and Adequacy of Operation Conditions. Eleven projects applicable to SLAC's conventional plant facilities have received FY-71 programmatic approval from the Atomic Energy Commission. Design has now started.

6. Superconducting Accelerator. An engineering study for the conversion of the SLAC two-mile machine is being continued.

The department's sizeable program of plant utilities operation and minor modifications to buildings as a general service to SLAC was continued. The extension of utilities and adaptation of buildings in the research yard for changing experimental requirements will require an expanded effort during the next quarter.

Journal Articles

SLAC-PUB-749
SUPERCONDUCTING ACCELERATOR RESEARCH AND DEVELOPMENT AT SLAC. P. B. Wilson, R. B. Neal, G. A. Loew, H. A. Hogg, W. B. Herrmannsfeldt, R. H. Helm, M. A. Allen. 49 p. Submitted to Particle Accel.

SLAC-PUB-758
ACCELERATOR COMPUTER SECTOR MEMORY. W. C. Struven. 16 p. Submitted to DECUSCOPE.

SLAC-PUB-759
HIGH SPEED ANALOG DATA PORT FOR A PDP-9. W. C. Struven. 10 p. To be submitted for publication.

SLAC-PUB-764
ANALYSIS OF DIFFERENTIAL AND TOTAL CROSS SECTION DATA FOR HIGH ENERGY pp AND $p\bar{p}$ INTERACTIONS. Wolfgang Drechsler, Roberto Suaya. 13 p. Submitted to Phys. Rev. Lett.

SLAC-PUB-768
BOUNDS ON SCATTERING AMPLITUDES. Martin B. Einhorn, Richard Blankenbecler. 55 p. Submitted to Annals Phys. (N.Y.).

SLAC-PUB-770
π^0 PHOTOPRODUCTION FROM HYDROGEN AT 6 - 18 GEV. R. L. Anderson, D. Gustavson, J. Johnson, I. Overman, D. M. Ritson, B. H. Wiik (SLAC); R. Talman (Cornell U.). 9 p. Submitted to Phys. Rev. Lett.

SLAC-PUB-777
POSSIBLE SOURCES OF RESIDUAL POWER LOSS IN RF SUPERCONDUCTING CAVITIES. Mario Rabinowitz. 9 p. To be published in Nuovo Cim. Lett.

SLAC-PUB-778
ASYMMETRY IN π^+ PHOTOPRODUCTION FROM A POLARIZED TARGET AT 5 AND 16 GEV. C. C. Morehouse, M. Borghini, O. Chamberlain, R. Fuzesy, W. Gorn, T. Powell, P. Robrish, S. Rock, S. Shannon, G. Shapiro, H. Weisberg (UCRL, Berkeley), A. Boyarski, S. Ecklund (SLAC), Y. Murata (Tokyo U.), B. Richter, R. Siemann (SLAC), R. Diebold (Argonne). 13 p. Submitted to Phys. Rev. Lett.

SLAC-PUB-779
SCALING, DUALITY AND THE BEHAVIOR OF RESONANCES IN INELASTIC ELECTRON-PROTON SCATTERING. E. D. Bloom, F. J. Gilman. 11 p. Submitted to Phys. Rev. Lett.

SLAC-PUB-780
THE STANFORD STORAGE RING-SPEAR. B. Richter. 18 p. To be printed in Kerntechnik.

SLAC-PUB-781
LONGITUDINAL EFFECTS OF COLLIDING BEAM SPACE CHARGE FORCES IN ELECTRON-POSITRON STORAGE RINGS WITH CROSSING ANGLES. John R. Rees. 17 p. Submitted to Particle Accel.

SLAC-PUB-782
FIELD THEORY REALIZATION OF THE DROPLET MODEL. Shau-Jin Chang (Illinois U., Urbana, and SLAC). 43 p. Submitted to Phys. Rev.

SLAC-PUB-784
NONSINGULAR SCATTERING EQUATIONS. T. A. Osborn (SLAC and Oxford U.). 14 p. Submitted to Phys. Rev.

SLAC-PUB-785
CONNECTION BETWEEN INELASTIC PROTON-PROTON REACTIONS AND DEEP INELASTIC ELECTRON SCATTERING. S. M. Berman (Imperial Coll., London, and SLAC); M. Jacob (CERN). 11 p. Submitted to Phys. Rev. Lett.

SLAC-PUB-786
PHASES IN VECTOR MESON PHOTOPRODUCTION. Jon Pumplin, Leo Stodolsky. 8 p. Submitted to Phys. Rev. Lett.

SLAC-PUB-791
ACAUSAL DISPERSION RELATIONS AND A FUNDAMENTAL LENGTH. Michael Creutz, Robert Jaffe. 12 p. Submitted to Phys. Rev.

SLAC-PUB-793
PREDICTIONS FOR HIGH ENERGY ELASTIC AND INELASTIC SCATTERINGS IN ϕ^3 THEORY. Shau-Jin Chang (Illinois U., Urbana, and SLAC), Tung-Mow Yan (SLAC). 12 p. Submitted to Phys. Rev. Lett.

SLAC-PUB-805
A LAGRANGIAN CALCULATION OF "SOFT" MESON PRODUCTION AT 12.3 GEV/c. Hyman Goldberg (Northeastern U. and SLAC). 10 p. Submitted to Phys. Rev. Lett.

SLAC-PUB-806
COMMENTS ON "REALIZATION OF AN ARBITRARY SWITCHING FUNCTION WITH A TWO-LEVEL NETWORK OF THRESHOLD AND PARITY ELEMENTS." Keith W. Henderson. 5 p. Submitted to IEEE Trans. on Computers.