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(SR)

TWO-MILE ACCELERATOR PROJECT

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ABSTRACT

A status report on the Stanford Linear Accelerator Project covering the period July 1, 1968 to September 30, 1968 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 twenty-fifth Quarterly Status Report of work under AEC Contract AT(04-3)-400 and the nineteenth 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, 1968 to September 30, 1968. 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. On September 13, 1968, a beam energy of 21.0 GeV was achieved. Beam currents up to 47 milliamperes peak have been obtained. On September 19, the accelerator delivered 500 kW of average beam power (a new high) to the Beam Switchyard.

The terms of Contract AT(04-3)-400 provided for a fully operable accelerator and for sufficient equipment to measure and control the principal parameters of the electron beam; in addition, provision was 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 on January 1, 1964, provides 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. 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. Contract AT(04-3)-515 also provided for the initial stages of operation of the Center after completion of construction.

I. ACCELERATOR OPERATIONS

A. OPERATING HOURS

Manned Hours	July	Aug.	Sept.	Quarter
Physics Beam Hours[1]				
Machine Physics	36	12	20	68
Particle Physics	406	218	355	979
Total Physics Beam Hours	442	230	375	1,047
Non-Physics Hours				
Scheduled Down Time	16	14	25	55
Unscheduled Down Time due to Equipment Failure	43	26	39	108
All Other (Machine Tune-Up, etc.)	43	34	73	150
Total Non-Physics Hours	102	74	137	313
TOTAL MANNED HOURS	544	304	512	1,360

B. EXPERIMENTAL HOURS[2]

1. Particle Physics

(3) Beam Line	Sched. Hrs. Electronic Experiments (a)	Electronic Experiment Hrs.		% (b/a)	Actual Bubble Chamber Hours	Actual Test And Check-Out Hours	Total Experimental Hours	
		Actual Hours (b)	(4) Charged Hours				Actual Hours	Charged Hours
A	924	641	678	69.4	---	121	762	799
B_N	207	116	151	56.0	---	76	192	227
B_C	285	224	250	78.6	232	167	623	649
B_S	460	309	261	67.2	---	293	602	554
C	---	---	---	---	153	284	437	437
Total	1,876	1,290	1,340	68.8	385	941	2,616	2,666

2. Machine Physics

	153	153
TOTAL EXPERIMENTAL HOURS	2,769	2,819

(1) Number of hours accelerator is run with one or more beams excluding accelerator beam tune-up and other non-physics beam time.

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

(3) Refer to Fig. 2 for beam line location.

(4) Total number of experimental hours actually run multiplied by factor (F), where $F = \frac{\text{Average repetition rate}}{180 \text{ pps}}$ (F maximum = 1.5 even if calculated amount exceeds this value). This product represents the hours charged to the experiment.

C. OVERALL EXPERIMENTAL PROGRAM STATUS

1. Electronic Experiments

Approved research hours at beginning of quarter	3,569
Hours charged during the quarter	(1,350)
New hours approved during the quarter	1,657
Approved hours remaining at end of quarter	3,876

2. Bubble Chamber Experiments

	40" BC	82" BC
Approved pictures at beginning of quarter	920 K	614 K
Pictures taken during the quarter	(815 K)	(335 K)
New pictures approved during the quarter	779 K	1,750 K
Approved pictures remaining at end of quarter	884 K	2,029 K

D. BEAM INTENSITY

	July	August	September	Quarter
Peak	32 mA	42 mA	47 mA	47 mA
Average	12 μA	5 μA	15 μA	11 μA

E. KLYSTRON EXPERIENCE

Total Klystron Hours	127,789	71,058	115,283	314,130
Number of Klystron Failures	10	7	8	25

F. DATA ANALYSIS

Spark Chamber Events Measured	9,200	8,404	6,244	23,848
Bubble Chamber Events Measured	16,724	18,497	1,444	36,665

G. COMPUTER OPERATIONS

	July	August	September*	Quarter
Manned Hours				
Computation Hours				
SLAC Facility Group	188	192	---	380
User Groups	454	433	---	887
Total Computation Hours	642	625	---	1,267
Non-Computation Hours				
Scheduled Maintenance	55	36		91
Scheduled Modifications	17	28		45
Unscheduled Down Time and Reruns	14	48		62
Idle Time	4	5		9
Total Non-Computation Hours	90	117	---	207
TOTAL MANNED HOURS	732	742	---	1,474

*New Computer being installed.

H. SPECIAL OPERATING FEATURES

1. Positrons

   Using the "wand" source, approximately 243 hours of interlaced positrons and electrons were delivered to experiments during the quarter.

2. Beam Knockout

   The beam knockout was used for 22 hours of check-out and 411 hours of experimental running during the quarter. It was used at both 10 and 40 MHz.

3. Power Supplies

   The 3.4 MW power supply was run for 259 hours during the quarter in conjunction with the 82" bubble chamber. It was also run for 3 hours of miscellaneous testing.

   The 5.8 MW power supply is being rebuilt and was inoperative all quarter.

   The motor generator facility was run for a total of 604 hours during the quarter. This included 37 hours of miscellaneous testing, 100 hours with the 82" bubble chamber and 467 hours with various spark chambers.

4. Scheduled Shut-Down

   The accelerator was off during the last two weeks of August for a scheduled shut-down.

II. ACCELERATOR IMPROVEMENTS

Klystron life performance to date continues to exceed previous expectations. The mean age of all klystrons on the accelerator as of October 1, 1968 was 7,500 hours compared with 6,570 hours as of July 1, 1968, 5,829 hours as of April 1, 1968 and 5,200 hours as of February 1, 1968. There are currently 78 tubes operating at over 10,000 hours, one of which has operated for more than 12,000 hours.

Drive line repairs were completed during the quarter. Flanges in Sectors 4 through 10 were straightened, refaced and reinsulated and a new switch patch panel was installed for the drive line switch. The four new couplers were installed.

In a continuation of beam break-up studies, cavities 3, 4, and 5 of each 10-foot section in Sector 1 were dimpled during the August shut-down. As part of this program all waveguides in Sector 1 were checked and retuned where necessary. In tests conducted in September it was found that, under the standard conditions of energy, steering and focusing established for comparative beam break-up tests, the current through the accelerator to the switchyard had been increased from 40.0 mA to 42.5 mA, an improvement of 6-1/4%. This is considered to be in fair agreement with theoretical predictions, when the initial spread in beam break-up frequencies existing in Sector 1 accelerator sections before dimpling is taken into account.

The change in the energy contribution of Sector 1 due to phase shifts at 2856 MHz introduced by dimpling has proved to be less than the errors involved in making the measurement. However, a significant phase error was found and corrected in the waveguide feed from klystron 8, and it is possible that the small energy gain from this correction just offset the loss due to dimpling.

The decision to similarly detune Sector 2 or more of the accelerator rests on the outcome of further theoretical analysis of the results obtained in Sector 1.

The positron "wand" operated satisfactorily for experiments in July and August, but an inspection on August 20 revealed that it is beginning to show signs of wear. In order to prevent a failure in operation at some future date, a new "wand" is being built and is scheduled to be installed during the December shut-down.

Design of a new 5" positron "wheel", designed to increase positron yield, has started.

Installation of an expanded, improved communications system was completed during the quarter. The new system is superior in quality of operation and in flexibility to the "talk-a-phone" system originally installed.

Installation of equipment was completed during the quarter which permits remotely balancing beam position monitor diodes from CCR by means of a motor-driven balancing potentiometer. This improvement will make the system more accurate over a wider range of beam currents than it has been in the past.

In a program to improve the personnel protection system of the accelerator, all keybanks are being replaced with new units which will improve the reliability and provide additional safety features for the system. The first eleven keybanks were replaced in September and additional units will be replaced in groups of ten to twelve until the complete system is modified. Modification is expected to be completed by the end of the next quarter.

Full utilization of the accelerator is dependent upon the ability to accelerate several high quality beams simultaneously through the machine. In order to steer and focus the beams of different energies by varying amounts, steering and focusing on a pulse-to-pulse basis is required. It is planned to modify four sectors of the accelerator to provide pulse-to-pulse steering and focusing. The present steering dipoles are satisfactory; eight pulsable power supplies and the required instrumentation will be added. Improved focusing will be accomplished by adding four quadrupole doublets and four pulsable power supplies with the necessary instrumentation. Design of the dipole power supplies and of the focusing quadrupoles has started. The modification is expected to be completed by September, 1969.

III. RESEARCH AREA OPERATIONS AND DEVELOPMENTS

A. GENERAL BEAM SWITCHYARD (BSY) AND RESEARCH AREA DEVELOPMENTS

As recommended by the Scientific Policy Committee, plans were reviewed for the procurement of general purpose beam transport equipment, a large magnet and the associated power supplies, ac distribution and cooling water. The decision to proceed with the purchase of four new 18-D-72 beam transport magnets and six 400 kW power supplies was made. In addition, a number of smaller magnets and power supplies will be purchased. These can be used in some locations in place of the larger, more expensive magnets. The complement of new magnets is the minimum necessary to satisfy the requirements of experimental set-ups anticipated during the coming year without severe scheduling restrictions.

The beam line, target and spectrometer set-up for Experiment E-23-Backward π^o Photoproduction, was completed. Build-up of a neutral K-Beam of the Center Beam in End Station B for BC-10-A, Proposal to Investigate $K_2^o p$ Interactions with the 40-inch HBC, was initiated. An experimental platform and shelter and general purpose instrumentation was set up in the K^o beam to allow some parasitic experiments by Hofstadter et al. The 18-D-36 analyzing magnet 8D3 in E-31-Measurement of the Magnitude of η_{00} and its Phase Relative to η_{+-}, was replaced with a larger 29-D-36 magnet obtained on loan from the University of California, Berkeley.

A laser beam test was conducted in the middle of August, the first experiment with clashed electron and laser beams. Using counters only (no bubble chamber) close to expected yield was observed at the bubble chamber. In particular with 16 GeV electrons, 1.79 eV ruby light, 1 joule laser output energy, 0.3 ps electron pulse length and 0.1 ps laser pulse length and with the scattered γ beam collimated within a cone of 1.5×10^{-5} rad half angle, the yield was 800 γ per 10^{11} electrons.

Due to favorable results from tests on the secondary positron beam in the C-Beam the decision was made to move E-37-Measurement of the Total Photoabsorption Cross Section for Hadron Final States, from its original location in End Station B to the C-Beam positron beam. This decision will save considerable effort which would have been required to set up the positron beam for the experiment in the B-End Station. The secondary positron line in the C-Beam is complete; however, considerable work is required in the BSY to make this beam compatible with simultaneous running with the K-Beam to the 82-inch bubble chamber.

Other major activities included: (a) Installation of E-41-Rho Production by Pions - A Test of Vector Dominance, in the C-Beam area. This will require considerable additions to beam transport in the present π beam and will require moving the experimental set-up of E-11b from its present location to the new location in the C-Beam area. (b) Installation of a secondary positron beam and a possible move of the streamer chamber into the C-Beam area. As a result of this move it would be possible to perform experiments using the C-Beam area $\pi^{\pm}$, K^{-}, polarized γ, or e^{+} beams in the streamer chamber. (c) Installation of additional ac power substations, cooling water system, and large power supply facilities in the research yard. Figure 1 is an aerial view of the research yard taken in July.

Energy Absorbers

As a part of the program to develop high power beam absorbers a new beam dump concept* has been developed and tested. The main features of the dump are relatively low production costs, simple assembly procedures, compactness and rather high power absorption capacity. The main power absorption and dissipation medium is a water-cooled bed of 1 cm diameter aluminum spheres. The spheres are contained in an aluminum tube whose dimensions are in accordance with longitudinal and radial shower attenuation in the aluminum water mixture. The power absorption capacity is rated at 400 kW at SLAC beam energies and a flow rate of 85 gpm.

A prototype of such a "Sphere Beam Dump" was tested in the Central Beam in the BSY on September 19. The model was equipped with thermocouples to measure the temperature distribution in the dump during operation, to gain some understanding of its dynamic behavior, and to detect onset of transient conditions which would eventually lead to burnout and destruction of the dump.

The electron beam had a nominal energy of 18 GeV. The water flow rate through the dump was 66 gpm which resulted in a water velocity over the sphere surface of about 1.8 ft/sec. At a pulse repetition rate of 360 the maximum average power delivered by the accelerator and dissipated in the beam dump was 495 kW (this was also a new power record for the accelerator). At this power level the dump performed well. The maximum temperature recorded anywhere in the dump was $170^{\circ}C$, which corresponds to the boiling point of water at the local pressure.

*D. R. Walz, SLAC-TN-68-7.

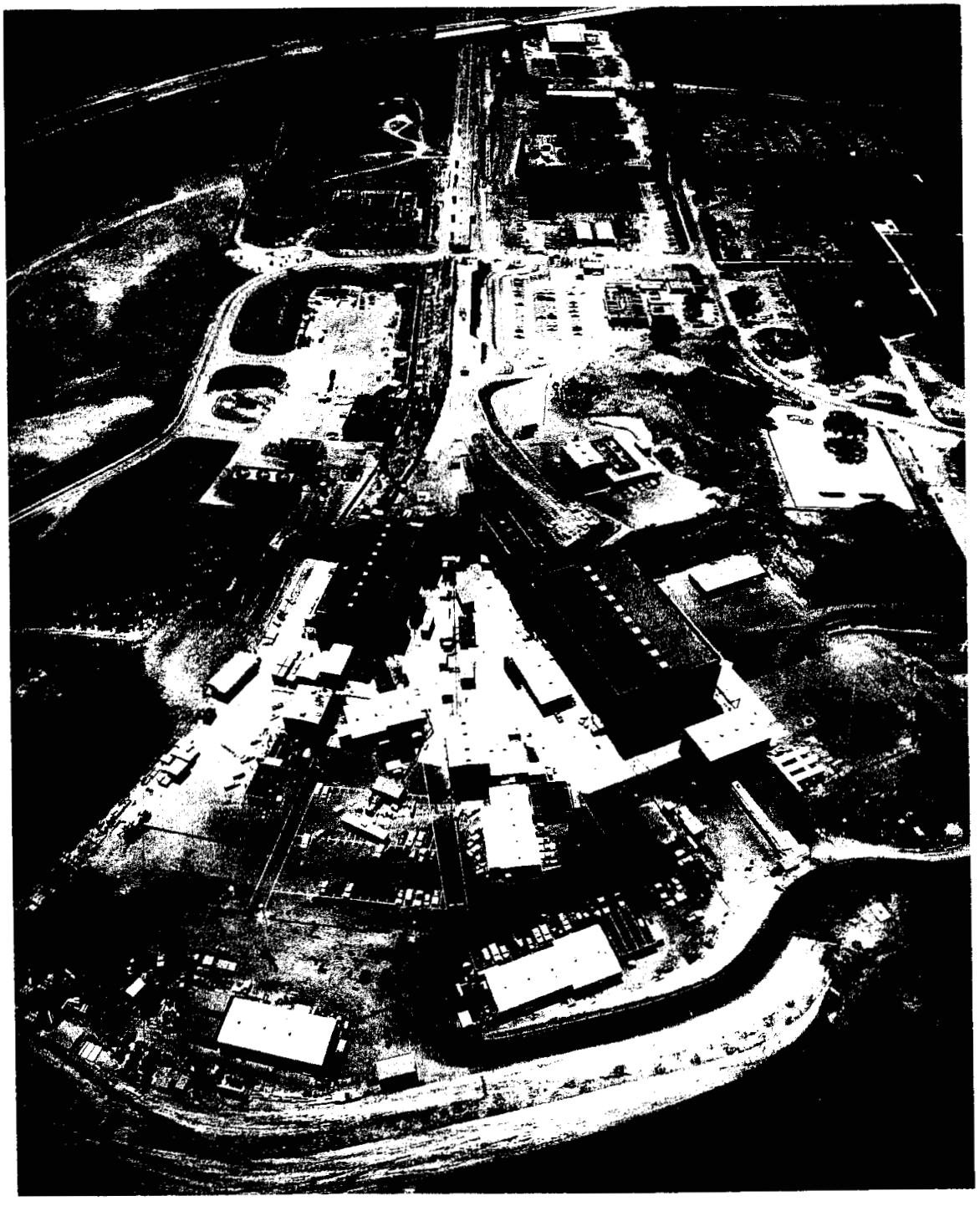


FIG. 1--Aerial view of research yard, July 1968.

Apart from small (10^{o}C) fluctuations as a result of the nucleate boiling, the temperatures in the dump were stable and no transients were detected.

It appears safe to assume that at the design flow rate of 85 gpm the dump is good for average beam powers up to 500 kW.

Liquid Hydrogen Targets

The target cell for the Ritson Experiment E-21b-Proposal for Measurements on the Photoproduction of π^{o}, η, ρ, ω and ϕ Mesons at Small Momentum Transfer t and Photon Energies up to 18 GeV and a Search for Mesons of Other Masses, was fabricated, installed, and successfully operated during July. The E-32 target for study of K scattering from protons was installed July 22. The E-4b high power target for studying inelastic electron scattering was installed in August and operated successfully. This target has heaters and a chimney to increase LH_2 circulation and distribute heat absorbed from the incident electron beam. It is hoped that this circulation will limit density fluctuations caused by beam heating in the target to less than two percent. Results show that due to the increased circulation the density variations were held to less than 5% during high power operation. During the August machine shut-down a triaxial fill and vent system was installed in ESA, and the target reservoir assembly was adapted to it. The E-4b run in September operated with the new system. The H_2 consumption rate was half what it had been on this target.

The target for E-23-Backward π^{o} Photoproduction, was pressure tested and passed during August. This target system was completed and installed in September. The design of the E-37 target was begun. Initial layouts and target schematics have been reviewed and approved by the experimenter.

B. PRIMARY ACTIVITY WITH THE RESEARCH AREA POWER SUPPLIES

1. Large Magnet Power Supplies:
   a. The rebuilt 3.4 MW power supply and the motor-generator set, both put in service during June, continued to operate satisfactorily. Installation of both power supplies is complete, except for minor details.
   b. Rework of the 5.8 MW power supply at the vendor's plant was completed. It was shipped to SLAC at the end of August. It is being installed in a new location; initial tests for the completed assembly are proposed for November.
   c. The 5.0 MW power supply was delivered in September. Plans call for testing during October, contingent upon receipt of the rectifier transformer.

2. Installation of the last four 400 kW power supplies delivered in June was begun. Modifications and improvements on the existing 360 kW and 400 kW power supplies are nearly completed.
3. Failure of a rectifier transformer and of reversing switches on spectrometer power supplies resulted in significant loss of operating time during September. These items have been repaired; however, improvement plans and plans for back-up equipment are being made to prevent future loss of beam time.
4. Fabrication of a new precision prototype 3000 A shunt was begun. Design was continued on a 10,000 A shunt. A modulating power supply was built for use with the Helmholtz coils for Experiment E-4b.
5. In the past, failure of pulsed power supplies for various pulsed magnets in the BSY have caused loss of beam time. Although considerable improvement has been made, these supplies are still a problem area. Engineering studies for improving reliability in operation and also in ease and speed of switching to spare units are underway.

Specifications for construction of 400 kW beam transport power supplies have been completed. Request for bid on six of these units have been issued to suppliers.

C. BSY CONTROL ROOM IMPROVEMENTS

The new cathode ray tube (CRT) display for the Beam Switchyard Computer was delivered and installed during July. To allow proper operation of this device with the existing computer programming system, several modifications to the computer input/output channel were required. These were built and installed by SLAC, and at month's end all electronics systems associated with the CRT display were operating. In parallel with the electronic installation, work continued on the programming changes required to display magnet currents and interlock status on the CRT. Most of the programming for the magnet current display was completed by the end of July. This feature will allow simultaneous display of all magnet currents available to the computer on the face of the CRT. Programming for the display of interlock status is still in the conceptual phase. This will provide complete display on the CRT of the BSY and RA conditions that led to a beam trip-off. At present the interlock system requires several racks of display panels, located at a distance from the primary operating console. After beam shut-off due to an interlock trip, the operator must scan these racks of lamps to determine the cause. The computer scanning and data processing capability coupled with the fact that at most only a

few interlocks trip at any one time, allows all of this function to be compressed onto the lower quarter of the CRT face.

D. BUBBLE CHAMBER OPERATIONS AND DEVELOPMENT

40-Inch Bubble Chamber

In early August, the 40-inch chamber took 303,888 pictures: 130,195 for HBC-3, 172,168 for HBC-2, 1,525 for HBC-10. During the run period, considerable difficulty was experienced with failures in the drive piston system; however, an average picture rate of 69,000 per day was maintained with a pulse period of 0.6 seconds. The machine was shut down and started warm-up on August 12.

During September, the chamber was opened for the installation of a scintillator hodoscope. This hodoscope will be used in HBC-10, A Proposal to Investigate $K_2^0 p$ Interactions with the 40-inch HBC. The job is now complete except for the bending and installation of the light pipes.

82-Inch Bubble Chamber

The 82-inch chamber was out of operation in July while a new expansion bellows was installed to replace one which failed after 2-1/2 million pulses. The failure was caused by a small welding bead which fell between the sheet metal of the bellows and the nipple the sheet metal was welded to.

A new commercial bellows was installed in a short time and the machine was in operation with only three weeks lost time. The commercial bellows failed after only 60 thousand pulses, probably because of a faulty construction technique.

The chamber was idle again during August while a new bellows was built in the SLAC machine shop. This bellows was installed in the chamber and ready for operation in the middle of September. The shop started the construction of a second bellows to be used as a replacement in the event this one fails. Although it is difficult to predict how long a bellows will last, we are concerned about the lifetime of the one we now have because of a poor butt joint between the curved and straight section of the bellows tubing. The poor joint is a result of a mismatch in the tubing diameter and could not be replaced as it was the last tubing available for at least two months. The decision was made to go ahead with the installation of this less-than-perfect bellows because it might be quite all right and, if so, we would have a million pictures in the two months. Or it might fail after a week or so and we would remove it and wait for the completion of the new one.

During September the chamber ran, with 25 percent outage for minor repairs, for 1.1 million pulses and took 334,738 pictures for BC-4. The pulse rate was twice a second during all but six hours of the run. The new fast camera performed very well and most of the troubles it gave were minor.

E. DESCRIPTION AND STATUS OF APPROVED EXPERIMENTS

During the 1-2 July 1968 meeting of the Program Advisory Committee, E-34 was approved for a 50-hour nonextendable run to validate the present preliminary data. Also, E-23 was granted two extensions at this meeting.

During the 4-5 August 1968 meeting of the Program Advisory Committee, the following decisions were made: E-38 was approved for 86 hours, include setup and data-taking time, E-39 was approved for 225 hours, E-40 was approved for 320 hours, E-41 was approved for 350 hours at 180 pps, and E-4b was granted a 200-hour extension. BC-13 approved for 100 K pictures with π^- at 5 and/or 7.5 GeV, BC-14 approved for 200 K pictures with π^+ at 13.0 GeV with the recommendation that a partial data analysis be made prior to further time allocation.

During the 27-28 September 1968 meeting of the Program Advisory Committee the following decisions were made: E-21c was approved for a 235-hour extension to take low density hydrogen target data; BC-4 was approved for an extension of 500 K pictures of π^+ on p at 7 and/or 10 GeV; BC-6 was approved for 100 K pictures of monoenergetic γ in D_2 at 3 GeV; BC-15 was approved for 250 K pictures of π^- in D_2 at 7 GeV; BC-17 was approved for 500 K pictures of K^+ in D_2 at 12 GeV. BC-18 was approved for 430 K pictures of monoenergetic γ in D_2 at 4.25 GeV and BC-19 was approved for 100 K monoenergetic γ in D_2 at 7.5 GeV.

Table I is a list of presently approved high energy experiments. Figure 2 is a Research Area plan drawing showing the various experiments.

Descriptions of the experiments approved at the Program Advisory Committee Meeting and status of experiments run during the quarter follow.

E-34-Electron-Deuteron Quasi-Elastic Scattering

It was proposed to use the 8 BeV/c spectrometer to measure the energy spectrum of electrons quasi-elastically scattered from a liquid target. At each of several values of q^2 between 2 and 6 $(BeV/c)^2$, measurements would be made at three different angles allowing the cross section to be separated and G_{en} and G_{mn} to be measured. Measurements of the cross section at one angle for q^2 between 6 and 10 $(BeV/c)^2$ would also be made to allow G_{mn} to be measured.

The accuracy of the higher q^2 measurements may be limited by backgrounds resulting from electroproduction of pions at the (3,3) resonance.

E-38-Proposal for an Experiment on μ^+e^- Scattering

This proposal is to measure the differential cross section for the process $\mu^+ + e^- \rightarrow \mu^+ + e^-$ as a function of final electron energy near the kinematic limit and at the muon momenta available from the SLAC muon beam. It will use the muon beam constructed at SLAC by Dr. Martin Perl. With 100 kW average electron beam power of 17 GeV/c electrons, this beam delivers 0.6×10^5 μ/sec at 12.0 GeV/c and 1.0×10^5 μ/sec at 10.0 GeV/c, with a $\pm$ 1.5% momentum spread.

The electrons scattered by 12 GeV/c muons have momenta between 0 and 6.28 GeV/c. The experiment will be arbitrarily limited to electron energies above 4.5 GeV. Although the cross section in this region is small, about 4 μb, the momenta of the scattered muon and electron are of comparable magnitude, much different from the original beam momentum and the momenta of other possible secondaries. This situation is exploited in the design of the experiment.

The muons will produce electron secondaries in the 1.1 gm/cm^2 of low Z target material. The μ^+ and e^- will then be separated and dispersed by a bending magnet. The geometry will be defined by simple telescopes and the electron energy measured by pulse height analysis in a shower counter.

The cross section for 10 GeV/c incident muons will also be measured for scattered electrons between 3.20 GeV/c and 4.77 GeV/c. The only change needed in the experimental arrangement will be a reduction of the field in the deflecting magnet.

Monte Carlo calculations indicate that 10^4 events in the region of interest will be necessary to obtain $\pm$ 10% statistics. With a safety factor of two, this would require 86 hours of 100 kW average electron beam power of 17 GeV electrons. Since the radiative corrections to single photon exchange are predicted to produce a 10% - 20% depression of the cross section, we should detect the presence of that effect. The calculations also indicate that we will be able to locate the position of the kinematic limit accurately. In previous accelerator experiments, the vanishing of the cross section has been completely masked.

E-39-Study of Photoproduction of Neutral Bosons at Medium Four-Momentum Transfer

This proposal requested 225 hours of beam time to study the photoproduction of neutral bosons in the region of photon energies between 6 GeV and 16 GeV, and for squared momentum transfers to the recoil proton between 1.5 $(GeV/c)^2$ and 4 $(GeV/c)^2$. The experiment will use the 8-GeV spectrometer to detect the recoil protons which have a momentum greater than 1.5 GeV and come out at angles between 40^o and 60^o in the laboratory. The 8-GeV spectrometer, with its large flight path, is ideally suited to identify the proton by means of time-of-flight using the chopped beam available at SLAC. For instance, at the highest momentum transfer [4 $(GeV/c)^2$] the recoil proton takes 3.7 nanoseconds longer than π mesons and 2.7 nanoseconds longer than K mesons to traverse the spectrometer.

E-40-High Statistics Study of the Production of Charged ρ^+-Mesons, Neutral ρ^o Mesons, f^o Mesons and Nucleon Isobars by Pions

The object of this experiment is to measure with high statistics the differential cross section and when appropriate the density matrix for the resonances in the following reactions:

$\pi^+ + p \rightarrow \rho^+ + p$, $\rho^+ \rightarrow \pi^+ + \pi^o$ $\qquad$ $\pi^\pm + p \rightarrow \pi^\pm + N^{*+}$, $N^{*+} \rightarrow p + \pi^o$, $n + \pi^+$

$\pi^- + p \rightarrow \rho^- + p$, $\rho^- \rightarrow \pi^- + \pi^o$ $\qquad$ $\pi^- + p \rightarrow f^o + n$, $f^o \rightarrow \pi^+ + \pi^-$

$\pi^- + p \rightarrow \rho^o + n$, $\rho^o \rightarrow \pi^+ + \pi^-$ $\qquad$ $\pi^\pm + p \rightarrow$ higher mass boson resonances

The data would be taken at 8 and 13 GeV/c, using a pion beam from the present muon beam and the present muon scattering apparatus.

The unique aspects of the ρ experiments are very large angular acceptance, covering about 90% of all possible ρ decay angles, with very high acceptance for very small four-momentum transfers; gamma-ray detection of the π^o in $\rho^\pm$ decay; and, a statistical level about 50 times higher than present bubble chamber experiments.

The unique aspect of the isobar experiment is that the statistical level is about 50 times larger than present bubble chamber measurements, and while not comparable in statistics to single arm spectrometer experiments, the direct identification of the decay state should considerably reduce the background under the isobar peaks. The isobar data is acquired simultaneously with the ρ data.

For the f^o production the angular acceptance is partial and therefore the f^o information may be of more limited use than the ρ^o information. However, it is expected to obtain $(d\sigma/dt)$ with good statistics.

Good statistics are also expected on higher mass boson resonances such as the g meson which decays to $\pi^{\pm} + \pi^{o}$ and $\pi^{+}\pi^{-}$. Also, a good search for other resonances will be possible. This search differs from the missing mass spectrometer searches because the decay products, $\pi^{\pm} + \pi^{o}$ or $\pi^{+} + \pi^{-}$, will be observed. This should give increased sensitivity and also will show up very peripherally produced resonances, which cannot be detected by the missing mass spectrometer method.

E-41-Rho Production by Pions - A Test of Vector Dominance

This proposal is to study the reaction $\pi^{-}p \rightarrow \rho^{o}N$ at 8 and 16 GeV with a wire spark chamber spectrometer and on-line computing system. The experiment will test the validity of the vector dominance model to an accuracy of 5 to 10% by a comparison of the π-ρ data with existing data on the single-pion photoproduction from the proton and neutron. Existing data test vector dominance to a level of $\pm$ 30% and no significant data exist in the small momentum transfer region where a very sharp spike appears in the photoproduction data. This experiment, which observes about 100,000 ρ mesons at each energy, will also gather a great deal of data on other interesting reactions which can be analyzed after the ρ data have been understood.

BC-6-Proposal to SLAC for Study of the One-Pion Exchange Contribution to γ-Nucleon Scattering (in 40-Inch Deuterium Bubble Chamber)

Studies of the reaction $\gamma + p \rightarrow p + \pi^{+} + \pi^{-}$ at high energies have exhibited the dominance of ρ^{o} mesons in the final states, produced primarily by the mechanism of diffraction dissociation, with an undetermined, but probably small, contribution from one pion exchange (OPE). This proposal is to investigate this OPE contribution by examining γ-nucleon interactions in deuterium.

1. The reaction: $\gamma + D \rightarrow (p)_{s} + p + \pi^{-} + \pi^{o}$ where the subscript s indicates a spectator nucleon, permits a direct measurement of the $\gamma n \rightarrow p\rho^{-}$ cross section. Since no contribution to this final state can be made from diffraction dissociation and since OPE is expected to dominate other mechanisms of ρ production, it is possible to make a direct measurement of the $\rho\pi\gamma$ coupling constant.
2. The γ-D interaction provides a rich source for ρ^{o} photoproduction studies as well as for ρ^{-} studies. Whereas in hydrogen only ρ^{o} production can be studied in deuterium three reactions can produce mesons:

   (a) $\gamma + D \rightarrow p_{s}p\rho^{-}$

(b) $\gamma + D \rightarrow n_s p\, \rho^0$

(c) $\gamma + D \rightarrow d\, \rho^0$

It is expected that the reaction (c) will proceed almost exclusively by the diffraction dissociation mechanism while the reaction (a) should be dominated by OPE; (b) could, in principle, involve either pion exchange or an essentially diffraction type process not off the deuterons as a whole but off the quasi-free proton in the deuteron.

Other reactions which can be studied in this film include

(a) $\gamma D \rightarrow p_s p\, \pi^+ \pi^- \pi^-$

(b) $\gamma D \rightarrow p_s p\, \pi^-$

(c) $\gamma D \rightarrow$ Strange Particles

HBC-13-A 3,000,000 Picture 7.5 GeV/c π^-p Exposure in the 82" Bubble Chamber

This proposal is to extend the present studies by the U. of Illinois on π^-p interactions at 5 and 7.5 GeV/c by a factor of 3 to allow more significant answers and, in conjunction with other experiments, to add useful information about momentum dependences in the following areas.

1. $A_1, A_{1.5}$ resonance: statistically important but not completely definitive indications of the A_1 and $A_{1.5}$ resonances in $\rho^0\pi^-$ at 1.06 and 1.17 GeV have been observed.
2. A_2 meson: At 5 GeV/c the spin parity and decay modes of the A_2 meson have been analyzed. The structure of the A_2 reported in counter experiments from CERN has not been observed. With a resolution of 8 MeV, standard deviation, in the three π decay mode at 7.5 GeV/c, a similar splitting should be observed if the effect is not limited to a small momentum transfer.
3. B meson: Analysis of the U. of Illinois data indicates an assignment of 1^+ for the spin parity of the B meson, but it also allows 2^+, 3^-, ... Due to possible interference effects with N^*'s, an accurate mass and width is not yet available.
4. 3-pion and 4-pion studies: In the reactions $\pi^-p \rightarrow p\pi^+\pi^-\pi^-$ the U. of Illinois has observed possible enhancements at 1.46 and 1.6 GeV; the former has not yet been reported in the literature, and the decay distributions of the latter does not show the $f\pi$ mode reported in the literature. In the 4-pion data an enhancement near 1.25 GeV and structure around 1.7 GeV has been observed.

5. Other topologies: Two prong events and strange particle events need to be examined in greater detail.

HBC-14-Proposal for 7.5 and 13 GeV/c, π^+ and π^- Exposures in the SLAC 82" HBC

A study of πp interaction 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 800,000 pictures taken in the 82" 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-15-Proposal for an Exposure of the 82-Inch Deuterium-Filled Bubble Chamber to a 7 GeV/c π^- Beam at SLAC

This proposal is to continue the University of Rochester study of $\pi^- n$ interactions at 7 GeV/c. A preliminary 80,000 picture exposure of the 80-inch BNL chamber is presently being analyzed, but a substantially larger exposure is required for a thorough examination of the more important questions. The interest is focused primarily on two items:

1. Searches for multipion resonances with I-spin = 2, and
2. Study of $\pi^- n$ scattering in the I = 2 channel.

The reasons for studying these problems in the $\pi^- n$ system are mainly of an experimental nature. The reactions $\pi^- d \rightarrow p$ spectator pX^{--}, where X^{--} is a multipion system, are well constrained while the analogous reactions in the $\pi^+ p$ system are either poorly constrained or are under-constrained and therefore cannot be studied.

There have recently been indications of possible resonance states which could not be accommodated in the particle-classification scheme based on the nonrelativistic quark model. These results make it all the more important to do a high statistics experiment in order to ascertain the existence (and properties) of 27 multiplets of SU(3).

The results of the Rochester search for I = 2 objects produced in association with a nucleon have been reported (Vienna, 1968). It is believed that at least a factor of three more in data is essential for this experiment and therefore a

250,000 picture exposure of the 82-inch chamber was requested. The procedures will be as described in the above-mentioned report. First, all the film will be scanned for events which have two possible low-momentum protons (odd-pronged events with one dark track and even-pronged events with one dark track and even-pronged events with two dark tracks).

Another high priority item to be examined is the diffraction production of multi-meson systems from the deuterium target. As yet final procedures for efficient handling of the coherently produced events have not been developed, but once this is accomplished these events will be processed without much delay.

HBC-16-K^+-p Interactions Around 7 GeV/c

The K^+-p interactions have several broad categories of interest.

1. Production of new resonances and determination of their properties.
2. Production mechanisms and interactions such as the $K\pi$ interaction.
3. Anti-hyperon production, associated production and infrequently produced reactions.

K^+-p exposures of 100 to 200 K pictures have been taken at 5, 5.5, 7.4, 10, and 12 GeV/c. These data indicate the possibility of structure of various types, but as yet the statistics are inadequate to make definite statements. It is clear that to unravel all these interesting situations it is necessary to obtain much higher statistics since many cuts are necessary in a typical analysis. Further, if true, these effects should persist as the energy is varied.

Similar arguments can be spelled out for many other channels in this film. We mention a few here such as associated production, anti-hyperon production of $\overline{\Lambda}$, $\overline{\Sigma}$, $\overline{\Xi}$, the search for +1 strangeness baryons, and +2 strangeness bosons such as KK and KKπ where low statistics have prevented definitive statements. Johns Hopkins has also been particularly active in analysis of the production models such as Ross-Yam, one particle exchange mechanisms, and variation of density matrix elements. It seems that as suggested by Chew and others that many different processes or ways of looking at things are simultaneously descriptions of these phenomena.

Lastly, the Q and L K$\pi\pi$ region have been studied at 5.5 GeV and it appears that only an enormous increase in data will resolve how many resonances are in these regions. In particular it is noted that CERN data with the largest statistics of high energy K^+ data published, at 5 GeV/c showed some definite structure in

the Q region. At 5.5 GeV/c the Johns Hopkins with higher statistics and the same cuts showed no structure. This difference could be due to either fluctuations or the result of interference between a wide resonance and background. In either case, more events at several close energies are necessary.

BC-17-A Search for 1^+ K^* Mixing Effects by Coherent Production on Deuterium at 12 GeV/c

This proposal is to study strange boson production from the reaction

$$K^+ d \rightarrow K^+ \pi^- d \quad . \tag{1}$$

This reaction presumably proceeds via Pomeranchuk exchange and should produce bosons in the Q and L peaks. This particular reaction may be able to settle the question whether or not K^* mixing occurs. If the two 1^+ K^*'s belonging to the A_1 and B nonets undergo particle mixing and if the Pomeranchuk is a unitary singlet, then they should both be produced in this reaction. Thus, two distinct peaks at about 1250 and 1360 MeV in the $K\pi\pi$ mass spectrum would be observed. If there is no mixing between these two K^*'s, only the K^* belonging to the A_1 nonet, presumably the K^* (1250), should show up. In the experiment of Denegri et al., with K^-d, they have observed the Q and L peaks but have not observed any structure on the Q peak on the basis of 240 events. Estimating the expected cross section from their results, this experiment should obtain over 1500 events for reaction (1) which should be enough to observe the above-mentioned effect. To do this it will be necessary to obtain good momentum resolution.

It is also planned to study other reactions, and in particular a search for higher mass strange bosons in reactions such as

$$K^+ d \rightarrow K^0 \pi^+ \pi^- pp \quad , \tag{2}$$

$$K^+ d \rightarrow K^+ \pi^- pp \quad , \tag{3}$$

will be attempted. Reaction (1), because of the diffraction dissociation mechanism, emphasizes the spin parity series 1^+, 2^-, 3^+, etc., while reaction (3) can only occur for the spin parity series 0^+, 1^-, 2^+, etc. Furthermore, the search for K^* decay into the $\bar{\Lambda}N$ channel through reactions such as $K^+ d \rightarrow \bar{\Lambda} ppp \pi^-$, for example, will be continued.

BC-18-Proposal for a 4.25 BeV γ-Deuterium Experiment in the SLAC 40-Inch Bubble Chamber

This proposal is to study vector meson production in an attempt to test the Vector Dominance Model and measure direct photon vector-meson coupling and the partial decay widths, $\Gamma(V^{o} \rightarrow \pi\gamma)$. This will be done by studying the results of this γ-d experiment and by comparing it with the γ-p experiment at the same energy, which is currently in progress by the same group at the Weizmann Institute. Also, an attempt will be made to determine the reaction mechanism of several reactions as well as the total γ-d cross section at 4.25 BeV.

BC-19-A Proposal for γ-d Experiment with an Annihilation Beam of 7.5 GeV in the SLAC 40-Inch Bubble Chamber

This proposal is to study photoproduction in deuterium at 7.5 GeV, which energy is substantially above the practical upper limit of the only other γ-d experiment of around 5 GeV. The SLAC 40-inch deuterium chamber will be exposed to a 7.5 GeV positron-electron annihilation radiation to obtain an initial 100 K pictures (of a 400 K request). The background of wide angle Bremsstrahlung radiation with a maximum photon energy of 12 GeV will yield additional events of even higher energy. The exposure will yield 35 events per μb cross section or 5,000 events on neutrons at 7.5 GeV. Also, 400 cases of coherent vector meson production on deuterium are expected. Any resonances having a cross section of about 1 μb will be detected and their production mechanism determined. A determination of the total photoproduction cross section on deuterium will be made at 7.5 GeV by subtraction of Bremsstrahlung events in a 30,000 picture exposure where electrons are used instead of positrons. The total cross section on deuterium will be compared to that on protons at the same energy.

TABLE I

TABLE OF PROGRAMMED EXPERIMENTS

Number	Title	Authors	Date Approved	Status
1	Proposal for a Survey of the μ-p Inelastic Interaction at High Energy	(Group E) J. Brown, J. Cox, F. Martin, M. Perl, T. Tan, W. Toner, T. Zipf	2/13/66	a
4	Proposals for Initial Electron Scattering Experiments Using the SLAC Spectrometer Facilities: 4a Electron-Proton Elastic Scattering 4b The Electron-Proton Inelastic Scattering Experiment 4c Comparison of Positron-Proton and Electron-Proton Elastic Scattering	SLAC-MIT-CIT SLAC (Group A) W. Panofsky, D. Coward, H. DeStaebler, J. Litt, L. Mo, R. Taylor MIT J. Friedman, H. Kendall, L. VanSpeybroeck CIT C. Peck, J. Pine	2/13/66	a
5	A Proposal for a Photoproduction Experiment Using the Two Meter Streamer Chamber and Magnet	(Group D) I. Derado, D. Drickey, D. Fries, R. Mozley, A. Odian, F. Villa, D. Yount	2/13/66	a
7	Proposal for a Survey Experiment on Photo-Meson Production Processes at Backward Center-of-Mass Angles	(Group F) D. Ritson, R. Anderson, D. Gustavson R. Prepost	2/13/66	d
10	A Proposal to Study Photoproduction at Forward Angles Using the SLAC 20 GeV/c Spectrometer	A. Boyarski, F. Bulos, R. Diebold, B. Richter	2/13/66	d
11b	A Proposal to Investigate CP Violations in Electromagnetic Interactions through Diffractive f^0 Photoproduction	STANFORD A. Boyarski, A. Brody, F. Bulos, W. Busza, R. Diebold, S. Ecklund, R. R. Larsen, D. W. G. S. Leith, B. Richter LRL L. Kaufman, V. Perez-Mendez, A. Stetz, S. Williams	8/23/66	a

Table of Programmed Experiments (cont'd) - 2

Number	Title	Authors	Date Approved	Status
14	Proposal for Testing 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	d
21b, 21c	Proposal for Measurements on the Photoproduction of π^o, η, ρ^o, ω and ϕ Mesons at Small Momentum Transfer t and Photon Energies Up to 18 GeV and a Search for Mesons of Other Masses	STANFORD R. Anderson, D. Gustavson, J. Johnson, R. Prepost, D. Ritson N.E. UNIV. R. Weinstein, M. Gettner CAL TECH R.L. Walker, G. Jones, D. Kreinick, A.V. Tollestrup	3/11/67	a
23	Backward π^o Photoproduction	STANFORD B. Gittelman, A. Minten, B. Wiik, R. Anderson, J. Litt, D. Yount	6/22/67	a
29	Search for T-Violation in Inelastic e-p Scattering	U.C. BERKELEY O. Chamberlain, G. Shapiro, H. Steiner, H. Weisberg, C. Morehouse, T. Powell, P. Robrish, S. Rock, S. Shannon STANFORD R. Taylor, L. Mo, E. Bloom, J. Litt MIT H. Kendall, J. Friedman	12/16/67	d
31	Measurement of the Magnitude of η_{00} and its Phase Relative to η_{+-}	STANFORD D. Dorfan, M. Schwartz, W. Wojcicki	11/6/67	b

Number	Title	Authors	Date Approved	Status
32	A Proposed Study of K_1^0 Mesons Regenerated from a K_2^0 Beam Incident on Hydrogen	STANFORD E. B. Dally, D. J. Drickey, E. Seppi, R. Zdanis CORNELL L. N. Hand HARVARD P. G. Innocenti	12/16/67	b
34	Electron-Deuteron Quasi-Elastic Scattering	STANFORD E. Bloom, D. Coward, H. DeStaebler, J. Dress, J. Litt, R. E. Taylor MIT J. Friedman, G. C. Hartman, H. W. Kendall CAL TECH B. C. Barish	7/2/68	d
37	Measurement of the Total Photoabsorption Cross Section for Hadron Final States	UCSB D. Caldwell, V. Elings, W. Hesse (Student), R. Morrison, F. Murphy STANFORD D. Yount	5/11/68	d
38	Proposal to Stanford Linear Accelerator Center for an Experiment on $\mu^+ e^-$ Scattering	UNIV. OF WASHINGTON S. Neddermeyer, N. Scribner, P. Kotzer, G. Eilenberg, T. Koss	8/5/68	d
39	Proposal to Study Photoproduction of Neutral Bosons at Medium Four-Momentum Transfer	CAL TECH A. Tollestrup, J. Pine, R. Gomez, R. Barish, C. Peck, F. Sciulli, B. Sherwood	8/5/68	d
40	High Statistics Study of the Production of Charged $\rho^{\pm}$ Mesons, Neutral ρ^0 Mesons, f^0 Mesons and Nucleon Isobars by Pions	SLAC J. Cox, B. Dieterle, W. Kaune, M. Perl, J. Pratt, J. Tenenbaum, W. Toner, T. Zipf	8/5/68	d
41	Rho Production by Pions - A Test of Vector Dominance	SLAC F. Bulos, W. Busza, G. Fischer, E. Kluge, R. R. Larsen, D. W. G. S. Leith, B. Richter, H. Williams IBM M. Beniston	8/5/68	d

Table of Programmed Experiments (cont'd) - 4

Number	Title	Authors	Date Approved	Status
BC-3	A Proposal for a Photoproduction Experiment in the SLAC 40-Inch Bubble Chamber Exposed to Monochromatic γ-Ray Beams (4 GeV Annihilation Photons)	WEIZMANN INSTITUTE Y. Eisenberg, E. Ronat, A. Shapira, G. Yekutieli	8/12/67	a
BC-4	K^+p, π^+p, and π^-p Interactions Near 12 GeV/c (82-Inch HBC)	LRL M. Abolins, O. Dahl, P. Dauber, P. Eberhard, S. Flatté, L. Galtieri, M. Alston-Garnjost, J. Kirz, G. Lynch, J. Murray, F. Solmitz, L. Stevenson	12/16/67	a
BC-6	Proposal to SLAC for Study of the One Pion Exchange Contribution to γ-Nucleon Scattering (in 40-Inch Deuterium Bubble Chamber)	OAK RIDGE H.O. Cohn, R.D. McCulloch UNIV. OF TENNESSEE G.T. Condo, W.M. Bugg	9/28/68	d
BC-10	A Proposal to Investigate $K_2^0 p$ 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	c
BC-11	A Proposal for a Bubble Chamber Experiment with the Polarized Laser Induced Photon Beam	Spokesman: Günter Wolf	5/11/68	e
BC-13	Proposal for a 3,000,000 Picture 7.5 GeV/c π^-p Exposure in the 82" Bubble Chamber	UNIV. OF ILLINOIS G. Abrams, G. Ascoli, B. Crawley, B. Eisenstein, R. Hanft, U. Kruse, D. Mortara, T. O'Halloran, R.D. Sard	8/5/68	d

Table of Programmed Experiments (cont'd) - 5

Number	Title	Authors	Date Approved	Status
BC-14	Proposal for 7.5 and 13 GeV/c, π^+ and π^- Exposures in the SLAC 82" HBC	MIT P. L. Bastien, D. Brick T. Dao, B. T. Feld, R. I. Hulsizer, L. Kirkpatrick, V. Kistiakowseky, H. Lubatti, D. Miller, A. Nakkasyan, G. Ouannes, I. Pless, A. Sheng, T. Watts, F. Winkelmann, J. Wolfson, R. Yamamoto	8/5/68	d
BC-15	Proposal for an Exposure of the 82-Inch Deuterium-Filled Bubble Chamber to a 7 GeV/c π^- Beam at SLAC	UNIV. OF ROCHESTER T. Ferbel, W. Katz, P. Slattery, S. Stone, H. Yuta	9/28/68	d
BC-16	K^+-p Interactions Around 7 GeV/c	JOHNS HOPKINS UNIV. A. Callahan, B. Cox, L. Ettlinger, A. Pevsner, R. Sekulin, R. Zdanis	8/5/68	d
BC-17	A Search for 1^+ K^* Mixing Effects by Coherent Production on Deuterium at 12 GeV/c	LRL BERKELEY D. G. Coyne, A. Firestone, G. Goldhaber, J. A. Kadyk, G. H. Trilling	9/28/68	d
BC-18	A Proposal for a 4.25 BeV γ-Deuterium Experiment in the SLAC 40" Bubble Chamber	WEIZMANN INSTITUTE Y. Eisenberg, B. Haber, U. Karshon, L. Lyons, E. E. Ronat, A. Shapira, G. Yekutieli	9/28/68	d
BC-19	A Proposal for a γ-d Experiment with an Annihilation Beam of 7.5 GeV in the SLAC 40" Bubble Chamber	TEL AVIV UNIVERSITY G. Alexander, I. Bar-Nir, A. Brandstetter, S. Dagan, J. Gunhaus, A. Levy, Y. Oren	9/28/68	d

a. Experiment is in data collection phase and was a prime user of accelerator time during the quarter.
b. Experiment is in initial check-out phase and used accelerator time for check-out purposes.
c. Experiment was being set up in the research yard during the quarter.
d. Experiment was inactive in the research yard during the quarter.
e. Bubble chamber beam is under construction and check-out.
f. Experiment ready for future scheduled run.

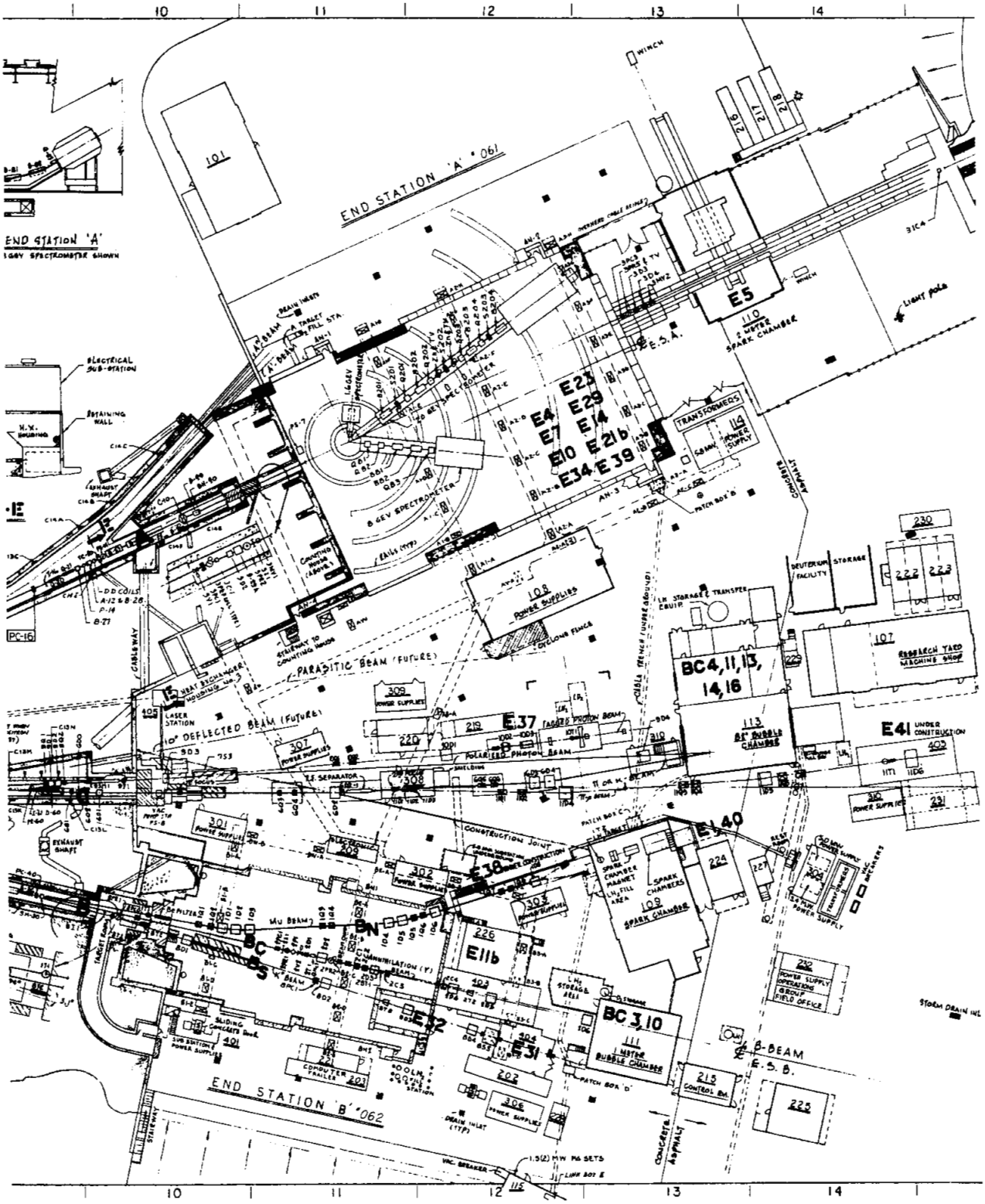


FIG. 2--Experiment locations.

IV. RESEARCH DIVISION DEVELOPMENT

A. PHYSICAL ELECTRONICS

Stable Secondary Emission Monitor (SEM)

A 3-inch unit is being assembled with foils of silver-coated aluminum and gold-coated aluminum, in order to demonstrate unequivocally whether ion-cleaned silver is responsible for the demonstrated stability, or whether ion-cleaned gold would serve as well. In addition, the effects of relativistic rise will be measured on silver and gold in the same vacuum system.

Transparent Conductive Coating for Mylar Streamer Chamber Windows

A production run of 20 feet of 5-foot-wide mylar was completed. For a coating with a resistance of roughly 1000 ohms/square, spectrophotometer measurements show the transmission between 5500 A and 6500 A to be about 95% relative to an uncoated mylar sample. The uncoated mylar itself is only about 80% transmitting over the same wavelength interval, so the coating is a very minor perturbation.

Tests of the coated Mylar showed that the conductive coating was removed by sparks. It was then decided to add a grid to the spark chamber. The transparent coating was at least as stable as the opaque aluminum on commercially aluminized mylar.

Alkali-Halide and Semi-Conductor Secondary Emitters

The ultra-high vacuum chamber for measurements with alkali-halide films and semi-conductor crystals has been assembled, leak tested, and is at present undergoing a baking at 400°C. The system appears in good order, and it is expected that pressures of 10^{-10} to 10^{-11} will be obtainable. A decision as to the advisability of continuing work on alkali-halides (electron-phonon interaction) is being reconsidered, as work with semi-conductors exclusively may be substantially more profitable with a similar investment of time and money. The result of the study of emission statistics on alkali-halides, discussed below, will give an indication as to which way to go.

The tube for the measurement of secondary emission statistics is now capable of giving well characterized results for high-energy primary electrons (.25 to 2.0 MeV) from a Sr^{90} source. Measurements on a bulk density CsI film have been obtained successfully. While a careful study of the response function of the detector used is under way, and a program for data analysis is being fully developed, an attempt will be made at solving some field emission problems in the tube which do not presently allow obtaining statistics at low primary energies. A computer program for the simulation of statistical spectra has been completed, and the first results are promising for the explanation of the statistics of secondary emission from bulk density (uncharged) films of alkali-halides.

A detailed report on transmission secondary emission from thin films of alkali-halides has been published as SLAC-86.

RF Superconductivity Materials Research

The helium recovery system was installed and approval obtained to operate it. Cryogenic thermocouples are on order, and calibrated germanium thermometers are being investigated. Lead plating onto mandrels which will subsequently be removed was investigated, and preliminary results indicate that excellent surface finishes are available by such techniques. Preparation of electrodes for field emission measurements by this process are underway.

Preliminary field emission measurements have been made using copper, and lead-plated copper electrodes. For unbaked copper electrodes, the field enhancement factor, β, has ranged from 112 to 156. For baked ($250^{\circ}C$) copper electrodes, β has been reduced to values between 45 and 75. For lead-plated copper electrodes, the enhancement factor varies between 42 and 122. During measurements, as the current density on the plated electrodes became large, a marked decrease (by a factor of 1.8) in β was observed. With continued electric field stress at lower emission currents, the value of β slowly rose to the original value. Typical emission currents at a macroscopic field of 2×10^5 V/cm could range from $\sim 10^{-9}$ A to $\sim 10^{-6}$ A, from an electrode of area ~ 0.8 cm^2. The variation is attributable to the strong dependence of the emission current on the electric field; for example, reducing β from 300 to 100 reduces the emitted current by a factor of about 10^6.

B. MAGNET RESEARCH

Magnetization Equipment for Superconducting Materials

A device for measuring magnetization of Type I and Type II superconductors parallel and perpendicular to the external magnetic field was completed. First tests on Nb(60%)Ti showed that the drift of the operational amplifiers during experiment will give a measurement error of less than 1%. Further improvements to the circuitry should result in an accuracy of 10^{-3} or better. A 50-kG magnet (not stabilized) with a bore of 1" burned after several quenches and must be rewound. A new coil, producing about 50 kG, is being prepared.

Flux Pump

A coil based on Nb_3Sn ribbon was wound, and is intended to shield the magnetic field produced by the main coil from the flux pump which operates in a field less than 100 gauss. By energizing this coil in series with the main magnet, it was possible to reduce the field at the flux pump considerably. However, we are currently working to find the appropriate location of the shielding coil and the flux pump with respect to the main coil.

Supercritical Helium

Using the existing 7-watt ADL liquefier, it was possible to produce supercritical helium in a test device with a temperature of $4.8^{o}K$, at a pressure of 12 atm, and a flow rate of approximately 200 liters per hour. Further improvements are in process.

Hollow Conductor

Manufacture of an experimental setup to measure heat transfer coefficient, viscosity, and thermal conductivity of supercritical helium has begun. The design of this device was done by our group; procurement is done by the Bubble Chamber Group.

Current Leads

In order to perform high-current tests on the leads mentioned in earlier reports, we have acquired another 2000-ampere surplus power supply, without regulation. The regulation system for this power supply will be built by the group.

Bubble Chamber Magnet

A new superconducting version, based on composite strips, was calculated as an alternate solution to the hollow conductor version.

Publications

Two papers were presented at the superconductivity information meeting at Brookhaven, 6/23/68 - 7/19/68: "Materials and Conductor Configurations in Superconducting Magnets" (SLAC-PUB-464), and "Radiation Effects on Superconducting Magnets" (SLAC-PUB-469).

C. CONVENTIONAL DATA ANALYSIS

Film measuring machine MPF #5 was delayed because of troubles with the computer, but these have been straightened out, and work is continuing. A teletype for monitoring the data for production by the on-line system has been installed and is being checked out. Along with this, a clock is being installed on the MPF's. A new set of electronics for reading the present encoder for MPF has been designed and built and is expected to be tested within the next 4 weeks.

The two Vanguard scanning tables have now been up-dated and put into operation. Progress on the SPV-A's and the Spiral Reader is also satisfactory.

D. HEALTH PHYSICS DEVELOPMENT

We have completed a new TLD reader incorporating a new electrometer and a new heating system. The electrometer is a MOSFET circuit with a system to protect the gate against over-voltage. The heater system employs an infra-red dectector looking at the bottom of the planchette. Its output is used to control the heating current, so that it heats in a step function, essentially, with a top controlled to a couple of degrees. Net result is a reader that is faster, more stable, and with about twice the precision (± 0.9% S.D. for loose powder at 10r) of any commercial reader. Since we need heat the planchette to only 240°C instead of ~315° as in the past, black body radiation is undetectable, permitting lower dose measurements. Our old reader will be rebuilt to this system as soon as we can spare it long enough.

E. COMPUTATION RESEARCH

In addition to a large amount of development work associated with the arrival of the 360/91 and with the development of the Graphic Interpretation Facility, major progress has been made in the following areas.

Language Studies

The first language effort is a compiler-compiler project aimed at developing a compiler-writing system which we would make use of in development of special console languages such as text editors, file-processing languages, graphics languages, and so forth, as well as an experimental tool for the writing of more

conventional compilers. The language definition has been completed and a major effort for the specification of its implementation has been completed. Scanning routines to scan the input string and routines for manipulating the transition tables are now being programmed.

The second language effort is less general and is aimed at the writing of control programs in small computers. The initial problem of writing a control program such as MIDAS program for the IBM 1800 or the re-writing of such a program is sufficiently time-consuming and complex that a higher-level language for writing such programs has been proposed. The design of a resource allocation model and language has been completed and the layout of the implementation is under way. The initial test of the resource allocation language will be to write the MIDAS control program in that language and measure the performance of the program written in this language vs. the program written in machine language. The MIDAS program itself will be described in a forthcoming SLAC-PUB and will be presented at the IEEE 15th Symposium on Nuclear Science.

Control of Computing Systems

This is a followup to our earlier report on graph programming models. These models are intended to permit the display of explicit parallelism in computer programs and to permit asynchronous utilization of resources for a given computation. At the earlier reporting the mathematical soundness of the model had been proven. That is, the various processors applied to the computation could run at different speeds in different executions, and one is guaranteed to obtain the same result. Subsequently the language for this model has been refined. A number of different applications have been programmed in the model, including list processing applications, symbolic computation applications and numerical computation. At present a simulator for the model is being developed which will be used to study the resource demand functions for particular computations. We are also at present working on scheduling algorithms for such a model of computation, and are examining hardware implications of such a model. A number of results that come out of this will be used in the design of multicomputer systems and the control of data accessing and very large data files.

Access Control and File Security

A substantial effort is underway on the design of access control mechanisms that guarantee the security of large files. Current operating systems leave the user vulnerable to malicious or accidental reading and writing of his auxiliary

storage files. The degree of sophistication of the operating system varies considerably from machine to machine and system to system, but none of them has a system that will permit interrogation or updating of parts of a file without full access. The goal of this project is to design a system that would permit searching and acquiring aggregate data from certain parts of a file without altering that data or without associating it with its particular file head. For example, with a personnel file it is important to be able to acquire aggregate data on certain personnel items, such as salary or medical condition, without the association of the particular items to the individual names in the file. Such files are also important in procurement and budget activities. Generalized access control work functions have been developed; we expect to experiment with their use in a variety of file processing applications.

V. PLANT ENGINEERING

Construction of the General Services Building was virtually complete by the end of the quarter and occupancy by the using groups is now starting. A view of this new facility is shown in Figs. 3 and 4. Construction of SLAC's other major building project, the Central Laboratory Addition, was continued. The job is 81% complete and occupancy is scheduled to start about January 1, 1969.

A substantial expansion of the electrical and mechanical utilities supporting the computer program was completed in September. This work was part of the overall project of installing the new IBM 360/91 at SLAC, and involved difficult problems of scheduling and adaptation.

Other projects are in various stages of progress. Engineering is underway on: increases in LCW cooling and pumping capacity in the research area; installation of a 5 MVA transformer near End Station B; relocation of the front entryway incident to the widening of Sand Hill Road along the north boundary of SLAC; updating of the SLAC Master Plan to accommodate future building placements and additions; relocation of the Central Laboratory library; procurement of relocatable space for use in the research area. Work continued on several projects, percentage of completion being as shown: provision of a sandblasting facility for the craft program (50%); erection of a deuterium storage facility (20%); rebuilding and rehousing of the 5.8 MW power supplies (40%). Field work will start in October on: excavation of the hilly area north of Sector 12 to preclude lateral movement of the accelerator housing in that vicinity; a new parking lot north of the Craft Building; storm drain system protection measures near the east end of the Fabrication Building.

The program of plant utility operation and minor modifications to buildings as an overall service to SLAC was continued. Of particular interest was a test of the low conductivity water service in the research area to determine operating characteristics at higher-than-normal temperatures. The test commenced September 27th with an increase in the supply from 85°F to 105°F for one hour. Since that time the inlet temperature has been held at 95°F. Several high operating temperatures have been noted but no serious difficulties have been encountered as yet.

The highest peak electrical demand to date was registered on September 25, 1968 at 43.45 megawatts.

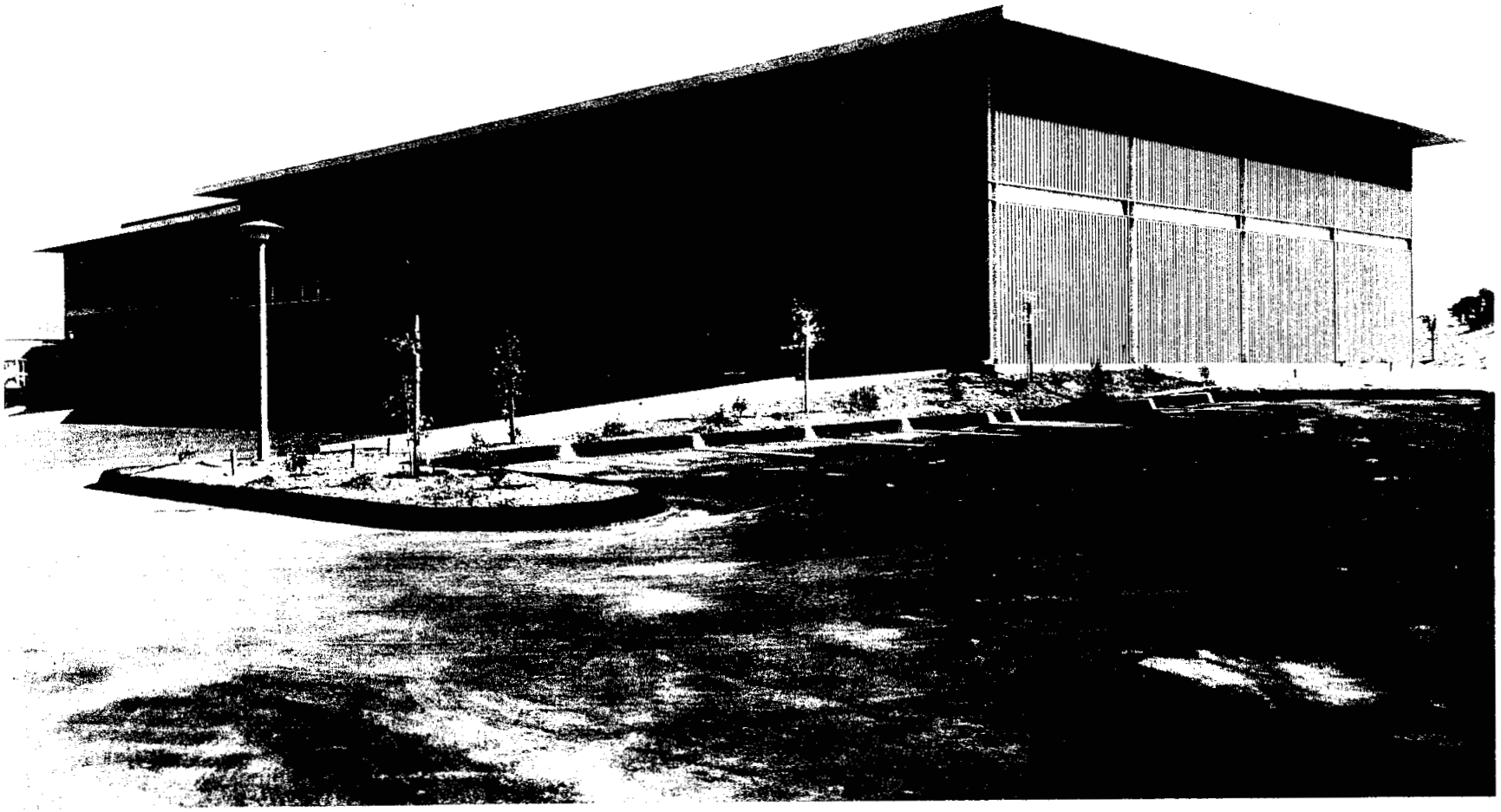


FIG. 3--General Services Building, looking southeast.

FIG. 4--General Services Building, front entrance.

VI. KLYSTRON STUDIES

A. DEVELOPMENT

1. High Power Klystrons

The majority of SLAC work has been directed towards the further understanding of the gas and arcing problems which have reduced the yield to an unacceptable level. At the end of the quarter, it appeared that the gas problem would be resolved by better treatment of some of the materials used in the tube prior to final assembly.

RCA has begun tests on the first modified tube with the objective of achieving a power output in excess of 30 MW at a beam voltage of 270 kV. Although the results of the first vehicle were somewhat disappointing, there appears to be a good program now on hand to reach the stated objective.

Litton is still hampered by many technical problems including what appears to be gassiness and excessive arcing. To date their approach to the arcing problem has been to decrease the voltage gradients between focusing electrode and anode. Unfortunately, gun oscillations have been present in the majority of the tubes built with increased spacing. Fortunately, however, one of the Litton problems which has existed for some time has been solved by a reasonably simple modification in the magnet structure. Many Litton tubes exhibited backswing voltage breakup which was often accompanied by changes in perveance and run away temperature conditions on the anode. Analysis indicated that the phenomenon was probably connected with a smooth bore magnetron oscillation. This oscillation was eliminated by introducing slight asymmetries in the magnetic field between the cathode and the anode, and as a result the tubes which showed "burning" have been returned to satisfactory operation.

2. High Power Window Development

Studies are continuing on the stability of various types of coating to successive exposures to vacuum bake. As mentioned earlier*, the RF sputtered coating appears to be the most stable, but evaporated coatings appear to have better recovery characteristics; that is, their resistance increases most as the sample is cooled from bake temperature to ambient.

*Quarterly Status Report, 4/1/68 to 6/30/68, SLAC-90.

3. Vacuum

The quadrupole gas analyzer has been acceptance tested, including a quantitative analysis of its performance for various characteristics. The equipment will be valuable in analyses of gas evolution problems which may be particularly bothersome for the superconducting accelerator, as well as present gassing problems we are experiencing with SLAC-built tubes.

4. Driver Amplifier Klystrons

Fabrication of driver amplifier klystrons is continuing with no major difficulties.

B. OPERATION AND MAINTENANCE

During the quarter we experienced 26 high power klystron failures for a total operating time of approximately 314,000 hours. There were 15 spares available for immediate installation, and 77 spares without permanent magnets. The driver amplifier klystrons operated approximately 42,000 hours in the gallery and 2,800 hours in the Test Lab. There were 9 driver amplifier failures in the gallery, and 7 spares available at the end of the quarter. Main booster klystrons operated 2,800 hours without failure.

1. High Power Klystron Operation

Table II gives the summary of tube usage and failures since the beginning of the machine's operation. This table includes all Sperry failures, but since Sperry tubes are no longer in use it appears desirable to consider the operation statistics without including the Sperry hours and failures. The results are given in Table III, which indicates that the cumulative mean time between failure (MTBF) has been between 14,000 and 15,000 hours for the last 6 quarters. The MTBF computed in the table are plotted in Fig. 5a. The cumulative hours per socket, the mean age of all operating tubes, and the mean age at failure per quarter are shown in Fig. 5b. The mean age at failure during the last quarter was 5570 hours compared to a mean operating tube age of 7500 hours at the end of the quarter.

The tube age distribution at the end of the quarter is shown in Fig. 6, which indicates a median age of 8850 hours, and that one third of all tubes on the machine have operated more than 10,000 hours. The survival and failure probability curves obtained from the data to date are shown in Fig. 7, which indicates a probable failure rate of approximately 5% per 1000 hours, except during the first 1000 hours of life. Again it appears that a real wearout mechanism of the tubes has not yet been reached.

TABLE II

KLYSTRON USAGE AND FAILURES

Overall

Dates	Operating Hours		Failures			
			Quarter		Cumulative	
	Quarter	Cumulative	Number	Mean Age @ Failure	Number	Mean Age @ Failure
To 6/30/66	118,000	156,000	17	234	39	256
To 9/30/66	127,000	283,000	14	594	53	350
To 12/31/66	176,000	459,000	23	1070	76	575
To 3/31/67	228,000	687,000	28	1670	104	860
To 6/30/67	303,000	990,000	26	2166	130	1130
To 9/30/67	335,000	1,325,000	27	2881	157	1433
To 12/31/67	265,500	1,590,500	23	3833	180	1739
To 3/31/68	311,000	1,901,500	20	4487	200	2013
To 6/30/68	307,500	2,209,000	18	4620	218	2225
To 9/30/68	314,200	2,523,200	26	5569	244	3089

TABLE III

KLYSTRON USAGE AND FAILURES

Excluding Sperry Tubes

Dates	Per Quarter			Cumulative		
	Operating Hours	# of Failures	MTBF	Operating Hours	# of Failures	MTBF
To 6/30/66	-	-	-	129,400	19	6,800
To 9/30/66	111,000	7	15,900	240,400	26	9,250
To 12/31/66	154,000	11	14,000	394,400	37	10,700
To 3/31/67	207,000	13	15,900	601,400	50	12,000
To 6/30/67	287,000	10	28,700	888,400	60	14,800
To 9/30/67	330,500	25	13,200	1,218,900	85	14,350
To 12/31/67	263,000	21	12,500	1,481,900	106	14,000
To 3/31/68	309,500	20	15,500	1,791,400	126	14,200
To 6/30/68	306,000	17	18,000	2,097,400	143	14,700
To 9/30/68	314,200	26	12,000	2,411,600	169	14,300

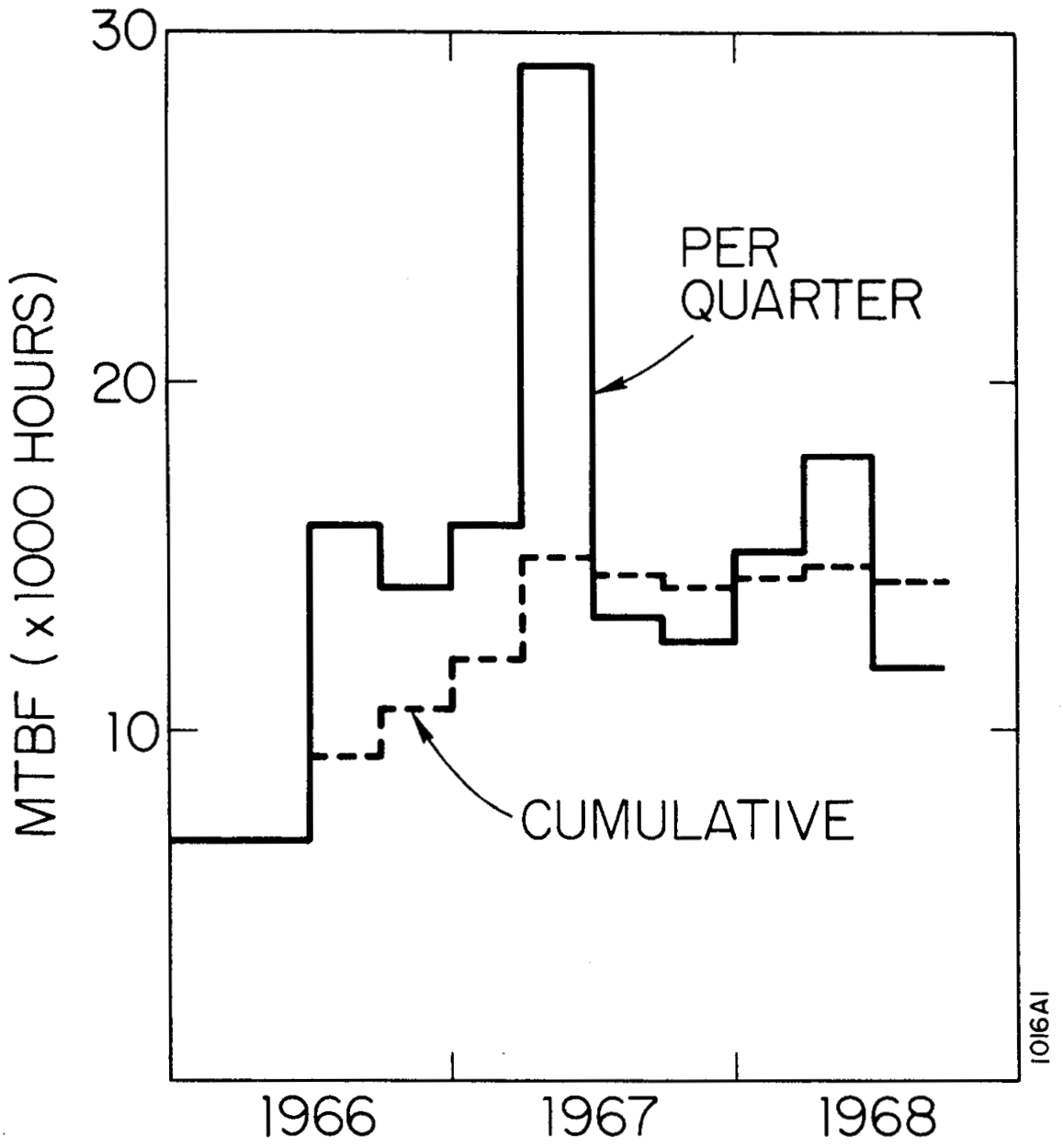


FIG. 5a--Mean time between failures, excluding Sperry tubes.

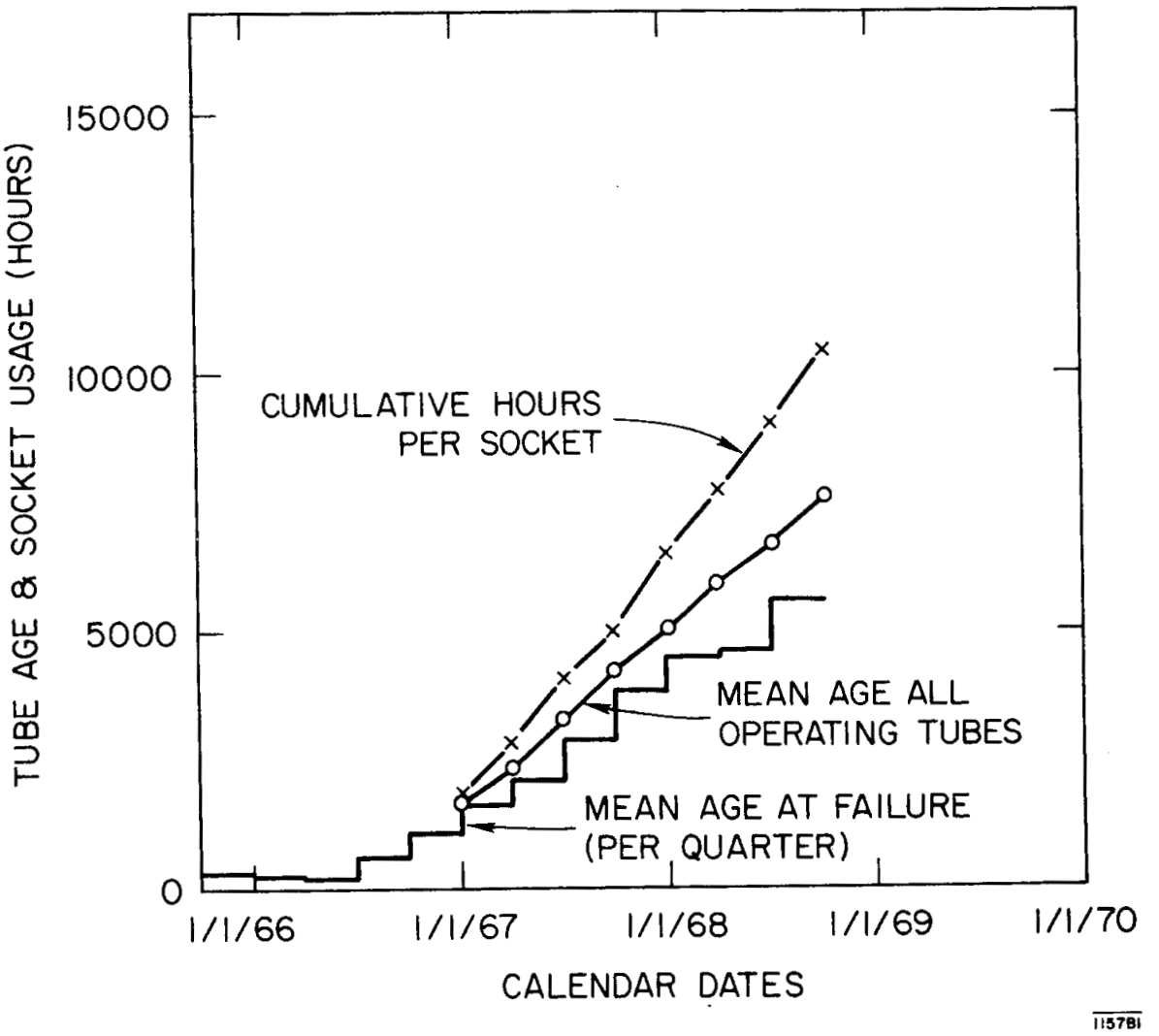


FIG. 5b--Operating tube performance.

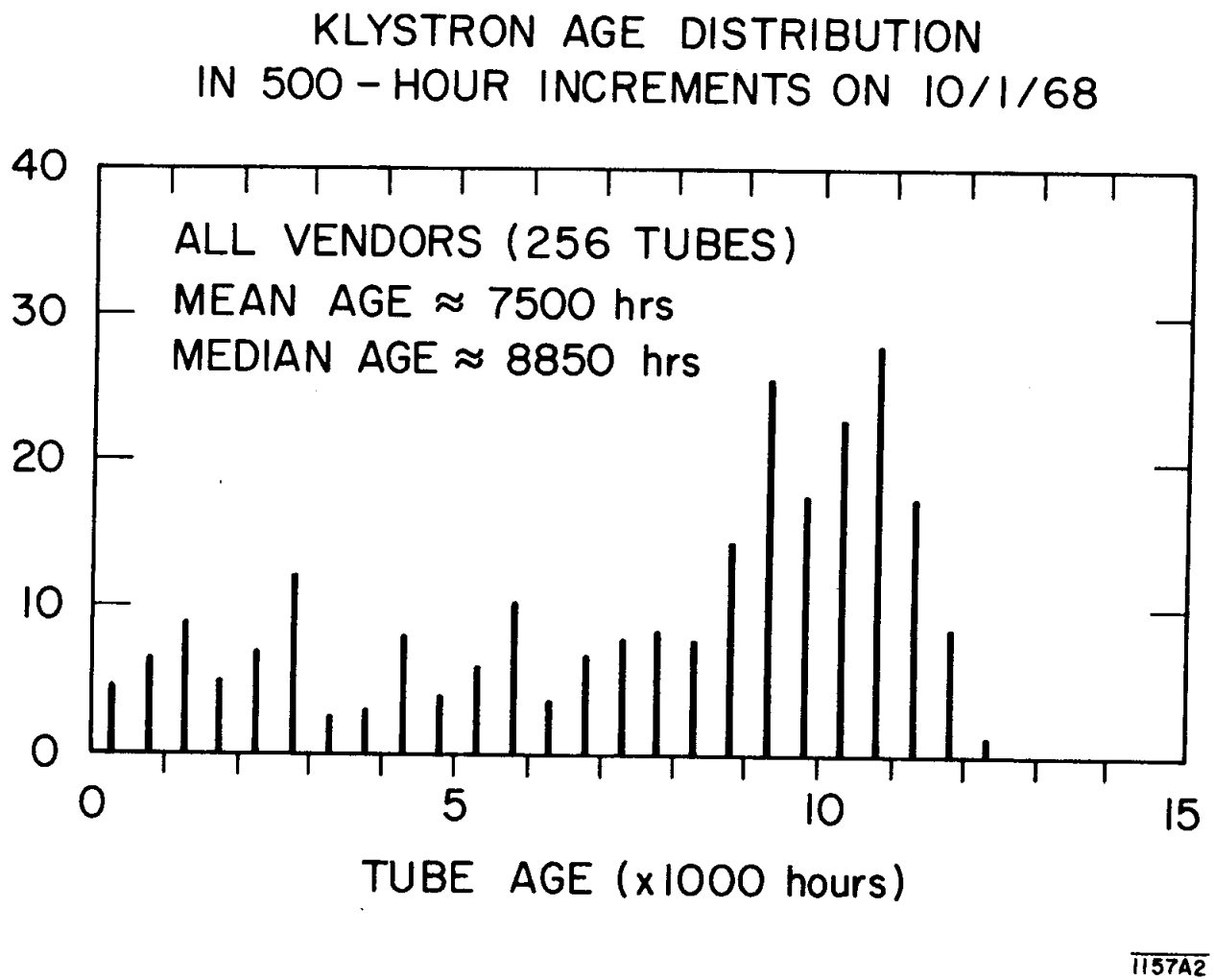
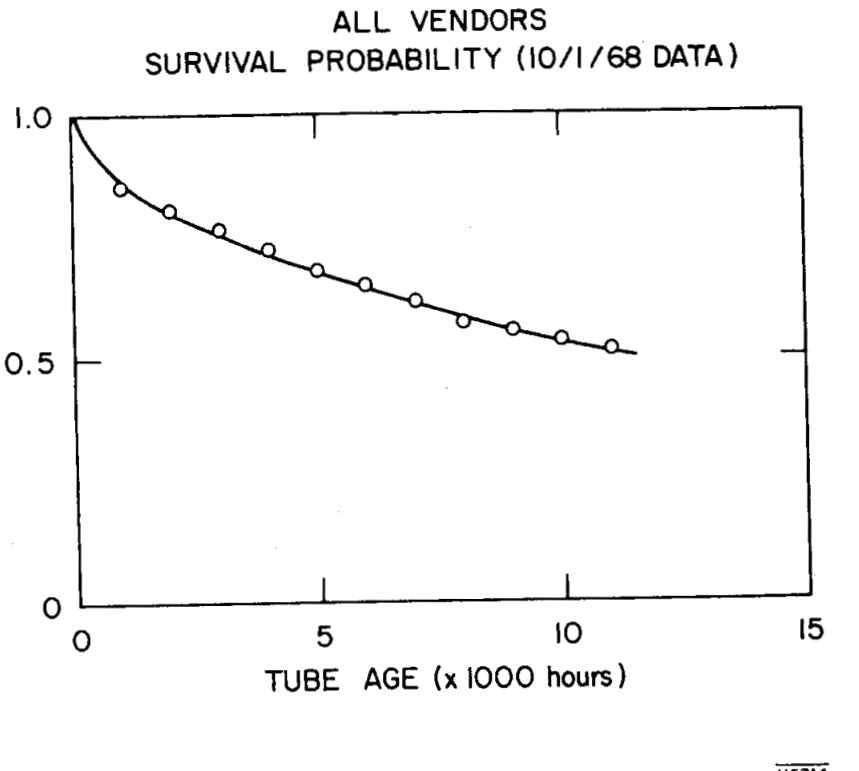


FIG. 6--High power klystron age distribution.



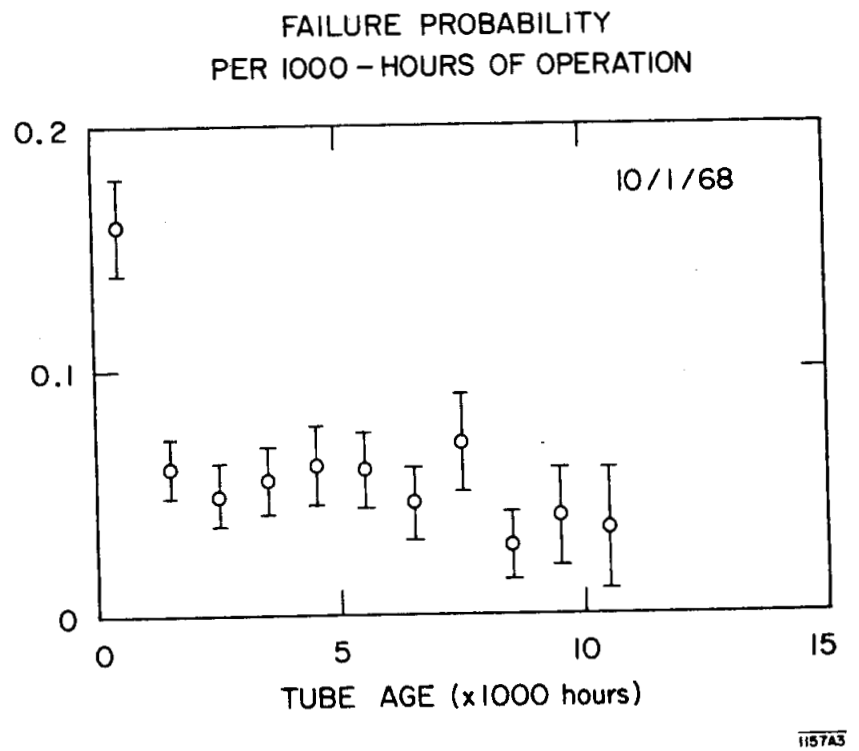


FIG. 7--High power klystron survival and failure.

2. High Power Klystron Maintenance

Figure 8 gives the operating experience per quarter since the beginning of operation. It is particularly interesting to note that the ratio of tube replacements to tube failures stays substantially constant at between 2 to 2-1/2 replacements per failure. Preventive maintenance operations were restricted during the quarter by the large number of high energy runs which severely limited the number of tubes available on which maintenance could be performed. However, surveys of klystron radiation were performed and the lead shielding had to be readjusted on approximately 30 tubes to maintain the radiation level to acceptable limits. During the klystron maintenance, the crew also spent considerable time with the Accelerator Physics Department in attempting to resolve the gain per section and the effect of dimpling in the first sector.

3. Driver Amplifier Klystrons

One SLAC and 8 Eimac driver amplifier klystrons failed during the quarter. The mean age at failure was 5280 hours for Eimac, and 1350 hours for the one SLAC tube which failed because of low power output. The tube age distribution of the driver amplifiers is shown in Fig. 9, and the operating experience for driver amplifiers is given in Fig. 10.

4. Main Booster Klystrons

No problems were experienced with the main booster klystron operation. Arc detectors have been installed in the output and penultimate cavities. They are functioning in both stations.

5. Vacuum System

No major changes occurred in the accelerator vacuum system. The average pressure at the sector main manifold gauges was 1.1×10^{-8} Torr with klystrons off, and 1.9×10^{-8} Torr with klystrons operating.

No argon gas bursts were recorded during the quarter. Operation of several pumps at 7 kV, repair of a few small air leaks, and installation of two ion pumps with the D-I type elements seems to have the problem solved, at least temporarily.

There have been no significant problems with either ion gauge failures (2 for the quarter), or valve failures. Ion gauge controllers appear to experience minor failures at the rate of approximately 5 per month with no significant increase over the past year.

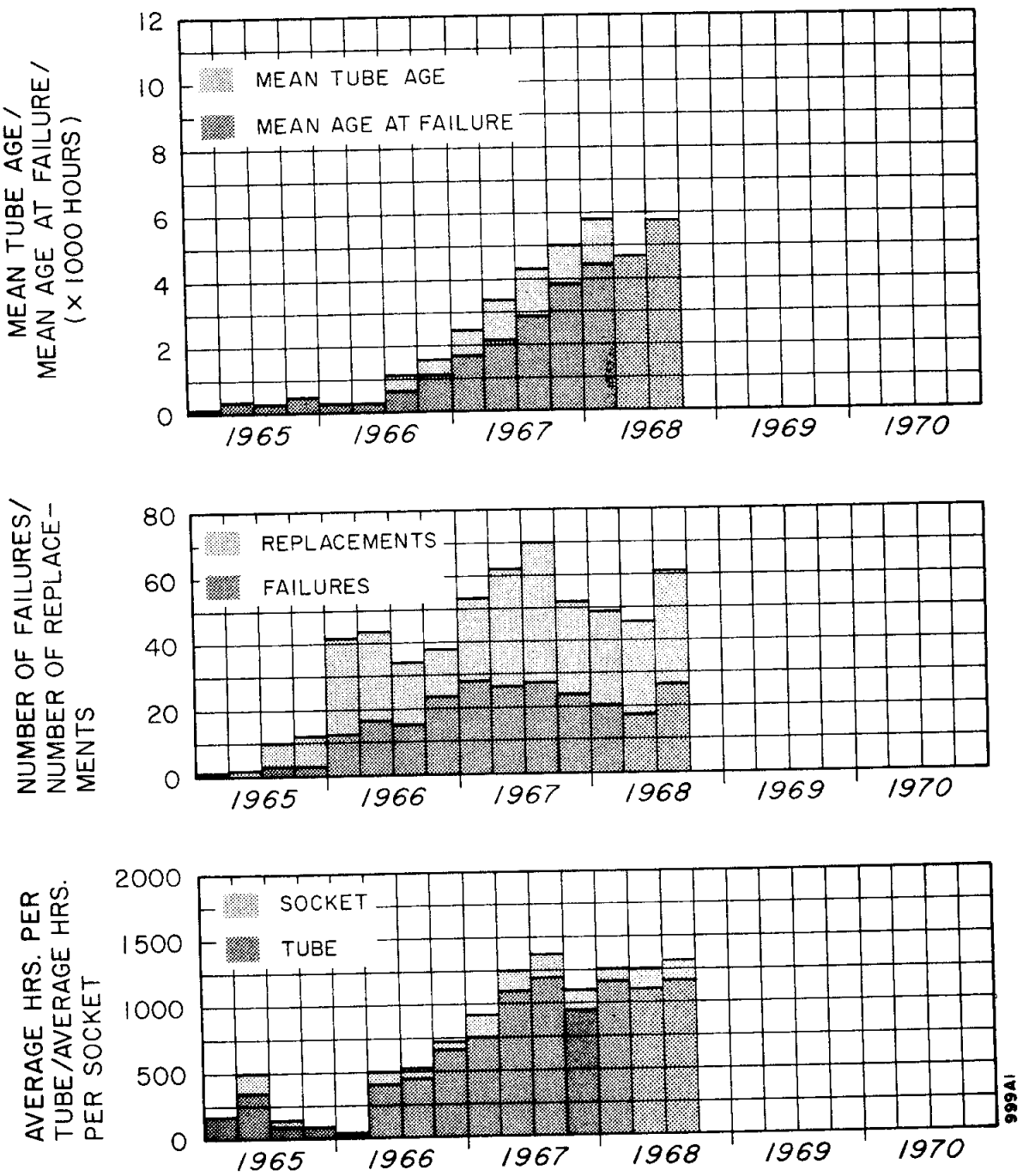


FIG. 8--High power klystron quarterly operating experience.

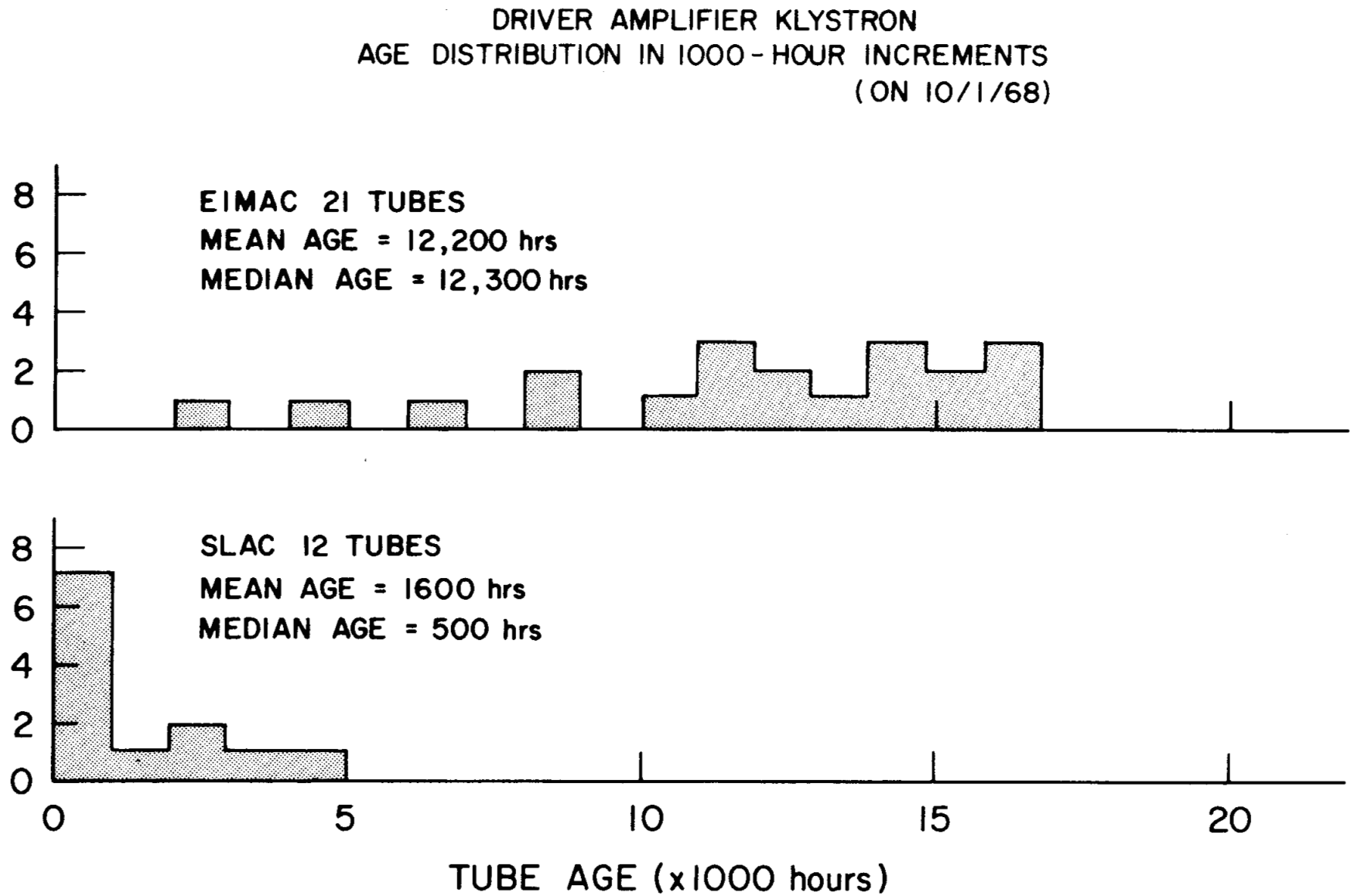


FIG. 9--Driver klystron age distribution.

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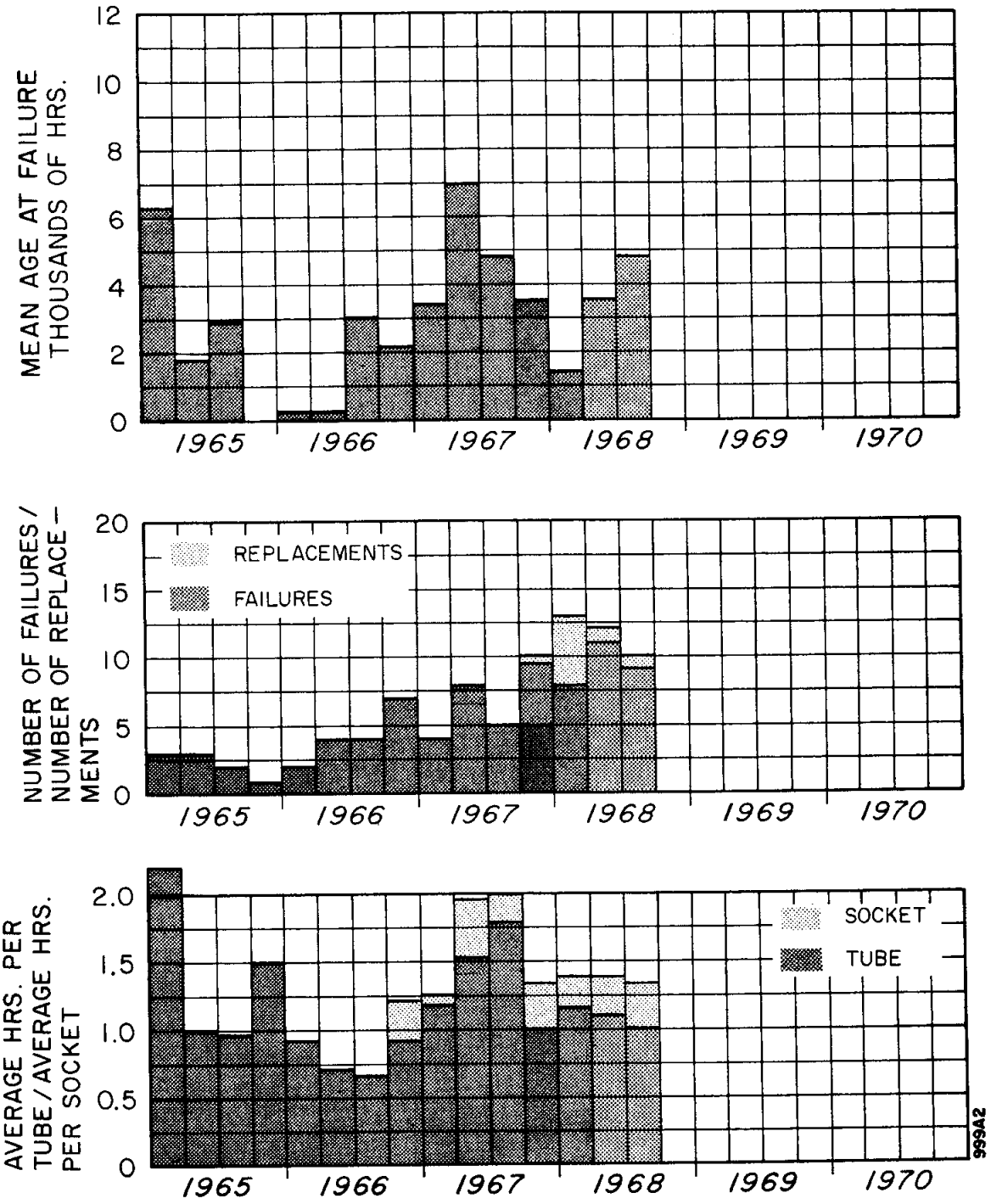

FIG. 10--Driver klystron quarterly operating experience.

Causes of Failure

Again during the quarter approximately 40% of all operating failures were window failures; in fact, all RCA failures were caused by window problems. The next highest cause of failure (approximately 30%) was cathode arcing and/or overcurrent. Litton was the only manufacturer to experience this type of failure at this time. The other 30% of the failures were distributed between output pulse breakup, high voltage seal failures, and loss of vacuum or gassiness in the tube.

Effect of Operating Levels

We have continued operation of 4 sectors at approximately 245 kV operation. Although the number of trouble reports has been substantially the same for the higher voltage sectors, it appears that the number of failures is definitely affected by the operating level. Table IV gives the MTBF observed in the 4 sectors running at 245 kV since this level was initiated. It can be seen that although for the past two quarters the difference in MTBF seemed to be well within the probable error due to statistical difference, the average overall statistics lead one to believe that the MTBF at 245 kV will be approximately half of that expected at 235 kV. A check indicates that the MTBF during the two quarters preceeding the operation at 245 kV for sectors 17 through 20 was within 10% of the value obtained for the rest of the sectors. Hence, there appears to be a real difference in failure rates as the operating level is increased. However, it appears desirable to continue this investigation of effect of operating level on tube life (and eventually tube cost). Hence, the operating level of 8 additional sectors has been raised to 245 kV during the month of September.

TABLE IV

Date	Failures		MTBF	
	17-20	Others	@245 kV	@235 kV or Less
7/1 -- 9/30/67	6	19	7,200	15,000
10/1 --12/31/67	7	14	4,900	16,300
1/1 -- 3/31/68	3	17	13,500	15,800
4/1 -- 6/30/68	3	14	13,300	19,000
7/1 -- 9/30/68	7	19	5,900	14,400
7/1/67- 9/30/68	26	83	7,700	16,000

VII. MECHANICAL ENGINEERING

A. ACCELERATOR ENGINEERING AND MAINTENANCE

1. Accelerator Maintenance

A dimpling tool for detuning three accelerator section cavities was designed and fabricated. Accelerator Physics Department personnel were assisted in detuning Sector 1 during the two week long shutdown. The Accelerator Physics Department was also assisted with cleaning, refacing, and straightening drive line flanges in Sectors 4 through 10.

The critical components of the keybanks, which are a part of the personnel protection system, were redesigned and parts were fabricated. The rework of keybanks was initiated and by the end of the third quarter, eleven keybanks had been reworked and replaced.

2. Positron Source

The wand positron source was operated during the quarter for a one week-long positron run. The new electric motor drive, which had been installed during the previous quarter operated satisfactorily. A small vacuum leak appeared when the wand traversed the beam line more than five times per second. The leak is believed to be at a water-line-to-bulkhead weld where a vacuum leak had been repaired last year, and is stress dependent.

Redesign of the wand support, actuation, and insertion systems was begun and is nearing completion. The new wand system will be fabricated and installed during the next quarter.

During the last positron run in which the wheel target was used, it was noted that the wheel trolling speed was lower than it was when first installed and that the speed was varying. The vacuum load compensating system was found to be binding. It was disassembled, cleaned, reassembled and lubricated. The wheel ran satisfactorily after that.

While the positron source vacuum system was up to air for the above repair, the wheel and wand targets were examined with a borescope. The wand target appeared to have two pits in its downbeam face. The target still appears to be usable, but will be replaced next quarter since the entire wand system is to be replaced. The wheel target exhibited a typical etched ring on the beam circle. There also appeared to be a few shallow radial cracks. It is estimated that the wheel target will easily last through another two-week-long high-power run.

A radiation hardened TV camera installation was made at the profile monitor just down beam of the positron source. The TV camera is now shielded by one inch of lead. It is estimated that the shielding will increase the time between camera repairs by four-fold.

Radiation damage to electrical wiring insulation just down beam of the positron source resulted in short circuits in the fast valve and profile monitor status circuits. The wiring was replaced with glass fiber insulated wire.

B. PRECISION ALIGNMENT ACTIVITIES

The alignment team made a survey of the accelerator and klystron gallery. The comparison of the level survey with previous surveys indicates a definite settling of the klystron gallery and a fairly stable condition in the accelerator housing with the exception of the fill area at Sectors 12 and 13. An examination of the results indicates good correlation between the level survey and the laser alignment.

The origin of the readings was the deep bench mark (DBM -1 + 96) at the far west end of the accelerator housing. The survey was run from west to east along the klystron gallery and tied into the accelerator housing by a vertical tape measurement of Sector 30. The tape was suspended in the man-way penetration with a 10 lb. tension weight. Before taking readings, the tape was allowed to come up to the thermal equilibrium of the penetration. The average tape temperature was approximately 90° F. The tape measurements were temperature corrected and the elevations in the housing reflect this corrected value. The vertical measurement tied the klystron gallery to the accelerator deep bench mark, DBM 100 + 00. The survey then returned to Sector 1 and again made a vertical measurement and tied back into rivet 1 in Sector 1 in the klystron gallery.

Figure 11 is a plot of relative movement of the klystron gallery and accelerator housing. The klystron gallery data was plotted with the original USC and GS survey as base line and the two SLAC surveys are relative to this data. The origin of all measurements is the DBM -1 + 96. This point has been assumed constant since installation. The accelerator housing has two independent plots. The solid line indicates the SLAC level survey and the intermittent line is a plot of the gross adjustments made to the accelerator laser targets. That is, if the targets had not been adjusted, their positions would be as indicated in the graph.

Other Precision Alignment Team activities were as follows:

1. Installation and alignment of E-37 transport system.

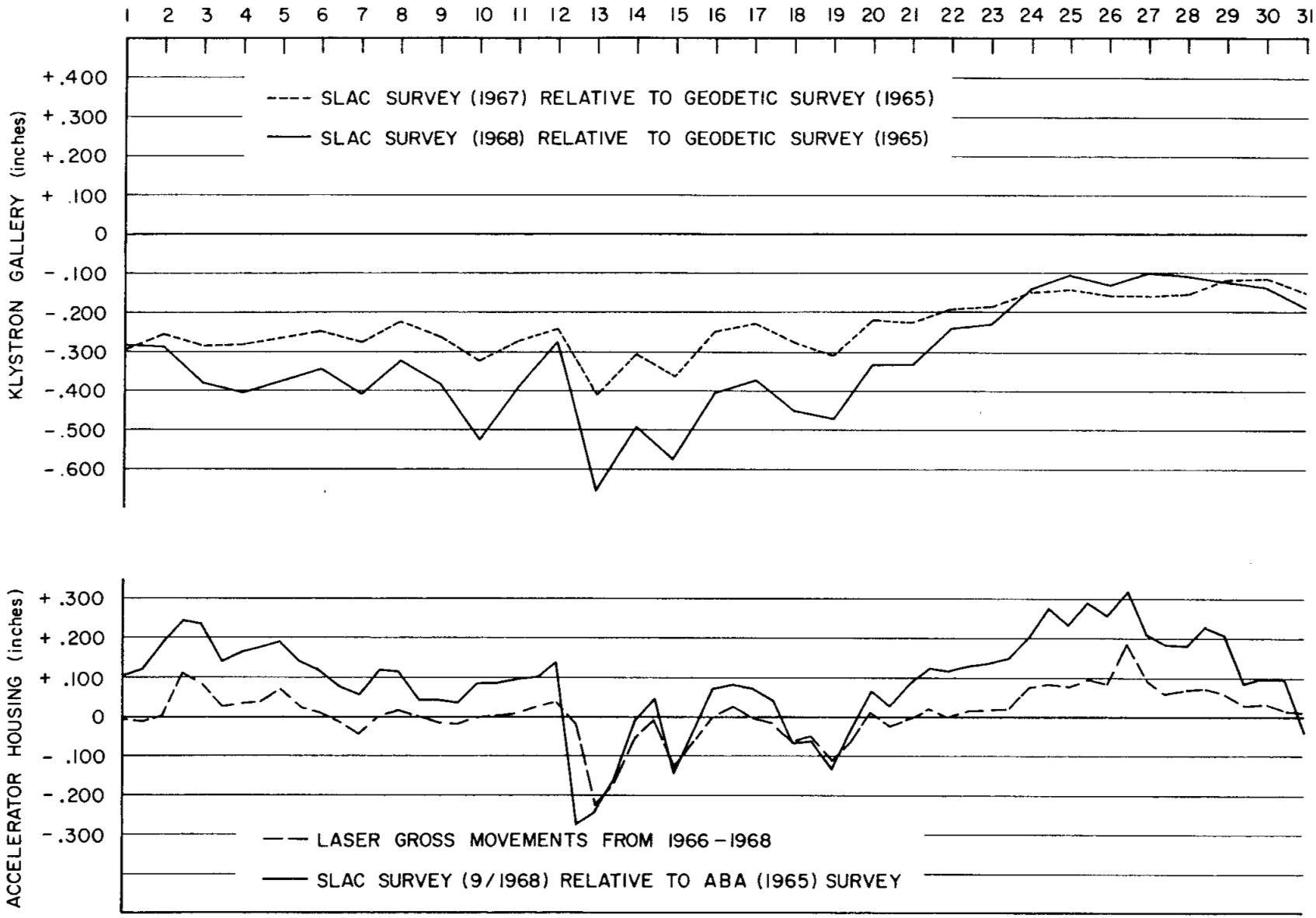

FIG. 11--Relative movement of klystron gallery and accelerator housing.

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2. Numerous alignment changes in central K beam and laser beam (alignment of laser and optical system).
3. Hydrogen Bubble Chamber 40-inch pre-and post-run fiducial mapping.
4. Assembled, quality-controlled and installed E-32 spark chambers and aligned the experimental setup.
5. End Station A - setup from spectrometer to streamer chamber run, resurveyed 20 BeV spectrometer completely.
6. Streamer Chamber - complete streamer chamber post-run fiducial survey and checking of counter and magnet location.
7. BSY - targeted and quality-controlled SL-31 (with new jaws) and aligned in BSY.
8. Accelerator - 1/4 point alignment of girders continued.

C. GENERAL ENGINEERING

Studies of converting large magnets to aluminum coils and consequent cost savings were continued. No corrosion problems have been seen in two years of service of an aluminum conductor magnet in a copper-stainless steel water system. Computer model studies on flux termination schemes (mirrors) for large magnets were continued. The Berkeley magnet design program "TRIM" was converted to run at SLAC to facilitate magnet design efforts. A development program on (1) a practical weld and cut off flange and tooling, and (2) a rechargeable (in situ) indium flange was initiated.

1. Group A Engineering Support

General experimental beam setup for the 20 and 8 BeV spectrometers continued. On the 20 BeV shielding hut a position sensor was installed that referenced the hut to magnets Q201 - Q204 and the θ (momentum) hodoscope. New pointing wire defining a radial line by means of Q201 - Q204 was installed on the 20 BeV spectrometer. To facilitate the measurement of torsion in the 20 BeV frame, a wire pendulum with position readout sensors was installed at the 78-foot and 43-foot bulkheads.

The 1.6 BeV spectrometer drive was modified to accept an irreversible Winsmith gearbox. This solved the problem of rollback on the spectrometer in the stopped position.

Designs initiated were: new zinc sulfide roller screens to increase stability, accuracy, and ease of referencing the fiducials while the unit is under vacuum; and new vertical collimating slits for the 20 BeV spectrometer crossover point.

2. Group B Engineering Support

Engineering support for Group B's experimental program and experimental setups continues. Preliminary design work for Experiment 41 has started, and design of a large acceptance (40 × 100 inch window size) Cerenkov counter is underway. Several 40 × 100 inch rectangular windows have been tested to determine if such a window size is practical and to determine a safe thickness which is compatible with physics requirements. The maximum operating pressure will be 30 PSIG of Freon - 12. Initial window test results are as follows:

Material (aluminum)	Thickness	Pressure	Results
6061-T6	.040"	20 PSIG	Window fracture along edge
6061-T6	.080"	48 PSIG	Window failed between bolt holes
7075-T6	.060"	48 PSIG	No sign of failure

3. Group C Engineering Support

General experimental support for Group C continues. Initial engineering for proposal No. 41 was started which included design of beam transport magnets and power supplies, design and construction of a general manufacturing facility for large wire spark chambers, and the preliminary design of a gas purification system for the spark chambers.

4. Group D Engineering Support

Experimental support for the streamer chamber run in July was followed by post-run equipment verification and evaluation of operation, as well as consideration of where improvement was needed. Updating and modification of the cameras and optical systems are presently in progress. A program to increase the reliability of the data boxes has been initiated. The re-design of the magnet mapping apparatus is in progress for the scheduled mapping later this fall.

Future work will involve modification of vacuum loops, new camera support for Hi-Z chambers, and design studies to switch from the present 1200-foot film reel to a 2400-foot reel, and conducting film and chemical tests on the film processor.

In preparation for the proposed streamer chamber move to the central beam, studies were conducted on the movement of the large streamer chamber magnet, auxiliary equipment and the streamer chamber building itself.

A new design of the streamer chamber cells is being contemplated.

5. Bubble Chamber Group Engineering Support

Design work continued on the proposal for the conversion of the 40-inch bubble chamber to a high field superconducting chamber. Design of a new 35 mm camera for the 80-inch bubble chamber was started. The deuterium storage system design for the experimental yard continued and fabrication of the vessels were started. Preliminary development work on an electro-static fluid valve was carried out.

6. CDA Engineering Support

New film drives were installed on 11 SP5 scanning machines and a prototype single frame advance was designed and built for the SP5. Two Vanguard scanning machines were modified to include a standard grid projector, a film projection lamp box, a film transport and a stage drive. Fabrication of two SP6 scanning machines was started and is about 80% complete. Mechanical debugging continued on the Spiral Reader. The following items were designed and fabricated for the Spiral Reader: film storage vacuum loops, 70 mm SLAC 40-inch HBC film format platen, a 70 mm film projection lamp box, and Argonne 35 mm format platen assembly was re-designed and built, and a prototype auto fiducial system was also designed and built. Three large monitoring projectors (IMP) used for pre-scanning and end station use were designed and built. In addition, a major portion of time was involved in updating, modifying and maintaining the measuring and scanning machines.

7. Applied Electronics Engineering Support

A half size section of the storage ring rectangular vacuum chamber was procured to test the feasibility of extruding it by the die and mandrel method to obtain a model from which metallurgical samples could be taken and on which vacuum environment studies and welding tests could be made. Only Kaiser was willing to attempt the extrusion. Two 15-inch lengths were obtained. An 8-inch section has been installed into an ultra high vacuum system. Connection to the aluminum was made with stainless steel flanges and .005" aluminum foil gaskets. This seal was reliable through a 220°C bake. The ultimate pressure after a 3 day 220°C bake was 2×10^{-10} Torr. Assuming no serious contributions from virtual leaks, this yielded a gas desorption rate for the aluminum surface of 3×10^{-12} Torr liters/sec/cm^2. The residual gas analysis was similar to that of a stainless steel vacuum system. Further work will be to determine the residual gas effects and pumpdown performance after letup to dry nitrogen and air.

VIII. ACCELERATOR PHYSICS

A fairly comprehensive summary of many Accelerator Physics activities during this reporting period can be found in a paper presented at the 1968 Proton Linear Accelerator Conference, Brookhaven National Laboratory, May 1968.* This paper highlights such topics as overall operating experience, beam breakup threshold improvements, main drive line failure, positron source developments, RF separator operational results and others. Further details are found below.

A. INJECTION SYSTEM

1. Electron Gun

In February of this year, the gun which had been on the accelerator since September 1965, failed from a heater short caused by heater sag. This gun was replaced with a gun of almost the same design, the principal difference being between internal corona shielding which now permits reliable operation at up to 80 kV dc. Future guns will have heaters made of a larger diameter non-sag tungsten wire to reduce the probability of heater shorts. A new spare gun was assembled and converted. This spare has a number of design improvements incorporated in it, including a redesigned heater and heater support structure, an alumina vacuum envelope with improved tolerance to temperature cycling and a stronger internal insulating support structure with improved shielding against corona and vacuum deposition.

Three new air-actuated gun thin valves have been fabricated. Design refinements have been made which appear to have solved the problem of mechanical binding experienced with the two original gun valves. The valve which was on the gun that failed in February has been modified and the valve presently installed on the accelerator will be modified when that gun is changed.

Measurements of the HEPL gun emittance were completed early this year. It was found that appreciable reduction in the emittance could be achieved by removing the intercepting mesh grid, and reducing the cathode diameter.

2. New Gun Modulator

The new gun modulator was installed at the West End and put into operation in June 1968. It has operated satisfactorily to date with only minor breakdowns. Modifications and improvements are still being made. A set of spare P. C. cards

*R. H. Helm, G. A. Loew, R. H. Miller, and R. B. Neal, "Recent Developments at SLAC", SLAC PUB-420, May 1968.

is on hand for most of the electronics, and a new spare pulser and bias supply are constructed and currently undergoing tests.

The six channel height control capability is in continual use. Ease of servicing the modulator makes the need to switch back to the old Manson modulator in case of a fault exceedingly remote. Therefore, the old Manson modulator will shortly be moved out of its West End location.

3. Beam Chopper Systems and Fast Pulsers

A second RF chopper system was installed on the machine. This system uses long non-resonant deflection plates downstream of the 10-foot injector accelerator section and can chop the beam at any frequency from 5 to 20 MHz. Currently, it is frequency-locked to the fourth subharmonic of 38.667 MHz to provide a 50 nanosecond spacing between electron bunches in the machine. Both chopper systems operate in this mode, the 39.887 MHz system providing single electron bunches at a 12.5 nanosecond spacing and the fourth subharmonic system eliminating three of every four bunches to provide a single bunch beam with a periodicity of 50 nanoseconds.

A new short-pulse pulser to drive the gun grid was ordered from Edgerton, Germeshausen and Grier, Inc., Goleta, California with delivery scheduled for January 1969. This pulser will operate in conjunction with the new gun modulator, and will be able to pulse the gun grid in a periodic series of short pulses approximately 2 nanoseconds in width. The spacing of these pulses can be changed on a pulse-to-pulse basis in the machine. The system will replace the second set of beam chopping plates, and will permit the single bunch spacing of the pulse train to be changed on a pulse-to-pulse basis, thus accommodating more than one experimenter.

B. DRIVE SYSTEM

1. Master Oscillator

The master oscillators have performed within specifications since installation over two years ago. Only periodic maintenance has been required to keep the units in satisfactory operating condition.

2. Main Boosters

The two main booster amplifiers have been undergoing a gradual improvement program. To date, both units have had arc detectors installed in the output and penultimate klystron cavity. Periodic maintenance has helped in reducing the incidence of machine downtime due to main booster failures.

3. Sub-Boosters

During the last three quarters, 11 Eimac and 2 SLAC klystron tubes have failed. At the end of the last three quarters, 12 SLAC sub-booster klystrons were in use and six spares available.

The sub-booster modulators have been performing well. Routine maintenance by the maintenance group has reduced failures during operation to an acceptable minimum. No improvement programs were initiated during this period.

4. Main and Subdrive Lines

The main drive line system and associated coax transfer switch were involved in catastrophic failure on April 16, 1968. During the early hours of Shift 1, an unknown failure caused a high VSWR to occur near the end of Sector 6. This high VSWR produced an arc which burned an anchor insulator and bullet, and as a result, propagated upstream and burned a hole through the wall of the nearest expansion section. Several other upstream sections of coaxial line were damaged by the traveling arc.

The damaged sections of line were replaced and all the flanges in Sector 6 were refaced and reassembled by the morning of April 18. Operation of the accelerator was attempted but the beam continued to be unstable because of drive line instabilities. As a consequence, beam operation had to be suspended and a major overhaul of the main drive line was undertaken. Between April 18-19 and April 30, many items were repaired, checked, replaced, cleaned, and then reassembled. A list of tasks performed during the 10-day repair cycle is given below.

a. The thermal insulation was removed from the drive line package in Sectors 1 through 14, and in Sector 30. All 30 drift sections were also exposed.
b. All coaxial flanges were refaced in Sectors 1 through 14, and in Sector 30.
c. New anchor bullets and insulators were installed in Sectors 1 and 2.
d. All expansion sections were removed and cleaned, inspected and reinstalled.
e. The Sector 1 and 30 lines were exchanged.
f. All inner conductors were checked and adjusted for proper length.
g. The line was reassembled and tested in single and multiple sector blocks.

h. The entire system was reassembled and subsequently turned on.

i. The water temperature stabilizing lines were re-epoxied to the main drive line in Sectors 1 through 14 and in Sector 30.

j. During the following month, the insulation was reinstalled and covered. When all the insulation had been replaced the main drive line appeared to operate as well as it had originally, upon installation.

After operation of the accelerator had resumed, a review between SLAC personnel and engineers from Dielectric Engineering Products Inc., the manufacturer of the line, indicated that while the drive line was operating at the moment, it was still in need of a more careful and exhaustive maintenance and cleanup program.

It was decided that during the next machine shut down week, May 20 to 28th, insulators, bullets and flanges in Sectors 1 and 2 would be reworked and the output power of the main boosters would be reduced from 17.5 kW to approximately 8.5-9 kW. The exact power level was determined by the output required to permit the directional couplers to deliver the proper power to the varactors. As part of the power reduction program, the main drive line couplers were all moved up-stream by 4 sectors. In addition, 4 new couplers were obtained for the last four sectors (Sectors 27, 28, 29 and 30). The purpose of this swap was to lower the drive line power at the beginning of the accelerator in order to increase the reliability of the line, the transfer switch and the main boosters.

Work during the shutdown progressed so rapidly that Sector 3 was also repaired. RF tests on the three repaired sectors showed a marked improvement. The improvement in VSWR was large enough to suggest that further improvements would be obtained by reworking the remainder of the sectors.

During the two-week shutdown of August 19 through 31, Sectors 4 through 10 were disassembled and flanges checked, straightened, refaced and reassembled. The resulting improvements were again notable and the repair of further sectors is scheduled for future shutdown weeks.

As a result of problems encountered prior to and during the months of April, May and August, the coax switching arrangement for the main boosters and main drive line was rebuilt. A "patch panel" type of assembly was installed which will facilitate the interchange of transfer switches as well as the use of "U" links if the switches should fail.

During the weekend of September 27-30, the main drive line directional couplers supplying Sectors 27, 28, 29 and 30 were replaced with conventional

commercial couplers in order to improve isolation and operation. The previous couplers had inadequate isolation and changed coupling when the load presented by the varactors changed. These changes in turn created phase changes in the varactor multipliers. The problem appears to have been eliminated with the installation of the new couplers.

The subdrive line system operated without incident throughout the 9 month period. One directional coupler was exchanged in Sector 1 in conjunction with a pulsed phase closure modification. The exchange of the coax transfer switch for a manual waveguide switch was accomplished on a temporary basis, pending arrival of a suitable motorized waveguide switch. The new waveguide switch has arrived but has not been modified to match the control circuits. This program should be complete by the end of the calendar year. The reason for the change is that the coax switch was unable to handle the RF power without periodic failures in its spring loaded contacts. The temporary manual waveguide switch has operated for the last 9 months without incident.

5. Varactor Frequency Multipliers

The varactor frequency multipliers performed well during the last 9 months.

6. RF Separator

The RF separator has been used in conjunction with the 82-inch bubble chamber since its installation in January of this year. After minor faults were corrected in the drive system, no other problems have been encountered. A gradual updating and improvement program is underway. This program will include a new driver amplifier similar to the sub-boosters used in the accelerator so that maintenance, reliability and availability of klystrons and spare parts may be assured. An improved amplifier for the 476 MHz power (which drives the varactor multiplier) is also planned for installation in the near future.

7. Pulsed Phase Closure

During the last quarter, 3 programmable pulsed phase shifters have been installed in the injector area. These units will provide independent phase closure for 3 different accelerator beams. The pulsed portion of the system is identical to that used in the positron and π (180^{o}) phase shifters in the sub-booster modulator cabinets. The main difference in this installation is that the circulator is used to switch a remotely controllable phase shifter into or out of the drive path to the injector klystrons.

C. PHASING SYSTEM

Modifications to the accelerator automatic phasing system which were planned as part of the accelerator improvements program have now been completed. As a result, the scope of system-control available to CCR operators has been considerably widened.

Programmers and CCR control panels have been modified to give "Phase/Don't Phase" and "Automatic Advance/Hold" options, which permit any klystron on the machine to be rephased without disturbing its neighbors. Used in conjunction with the video information transmitted to CCR, these controls allow the power and phase stability of any klystron to be monitored. A numeric display tells the operator which klystron is being observed.

A circuit which detects the presence of an adequate beam for phasing purposes has been developed and tested. For each pulse, this circuit monitors the sum of the video signals across the thermionic diode loads. This new signal is proportional to the square of the beam current. When the pulse current drops below 1 mA, or the number of pulses per second falls significantly below 60 on the first time-slot, all phasing actions are inhibited.

The phasing program is resumed automatically when a 60 pps beam of 1 mA or greater is restored in the section being phased. It is planned to install these beam presence detectors in every sector, so that many sectors may be phased at once without the danger of mis-phasing when the beam is lost because of RF steering. An improved wobbler-driver circuit with greater noise-immunity and less current drain has been proved in months of machine operating time in a few sectors. The circuit will be built onto the same card as the beam presence detector.

D. BEAM POSITION MONITORS

The in-line beam position monitors have continued to function adequately, although calibrations have drifted because of changes in characteristics of the thermionic diode detectors and the video amplifiers. Changes in the CCR beam "zero displacement" display have always been a major inconvenience to the machine operators, requiring them to steer to a fiducial line of grease-pencil dots on the face of the display oscilloscope - a line which had to be redrawn every time the beam current was significantly changed.

The difficulty has been removed by the installation of a remote-zeroing system, operated from the CCR console. The potentiometers which balance the

video outputs of the thermionic diodes are now adjusted by electric motors which can be driven by the pulse trains which are normally applied to the beam-steering power supplies in each sector. Pressing the "beam zeroing" button in CCR now performs two functions: RF signals from the horizontal and vertical beam-position cavities are disconnected, so that equal RF powers from the beam intensity cavities are applied to each pairof thermionic diode detectors, and CCR control channels are switched from the steering supply motors to the balancing motors. CCR steering switches may then be used to null the displayed zero errors.

As the result of an additional modification, the normalizing video signal is now derived from the sum of the position diode video signals. This simplification releases one diode per unit, considerably improving the ratio of spares on-hand to diodes in service.

By revising the specified current operating range of the monitors, it has been possible to double the levels of the normalizing video signals and quadruple the position signals. This has doubled both the sensitivity and the minimum discernible position signals of the CCR display. The system now saturates at 60 mA beam current. However, this affects only the displacement calibration at higher currents; the system will still guide the operator in setting up a centrally-steered beam.

E. BEAM BREAKUP

1. Computer Predictions for BBU Improvement by Dimpling

A series of computer experiments was carried out to investigate various schemes of detuning accelerator sections in the HEM_{11} mode. The computer program used is described elsewhere.*,†

In all of the computed cases, it was assumed that the focusing system was set at near optimum, i.e., betatron wavelengths of approximately 1.5 sectors in the alternating singlet regions (Sectors 1 through 6) and approximately 4 sectors in the rest of the machine. Uniform acceleration, from 35 MeV at the beginning of Sector 1 up to 18 GeV at the end of the machine, was assumed. In each case, the beam current was determined at which the growth of the transverse beam modulation, starting from an initial arbitrary signal at the beginning of the machine, was

* R. B. Neal, ed., "The Stanford Two-Mile Accelerator" (W. A. Benjamin, Inc., New York, 1968), Chapter 7.

† R. H. Helm and G. A. Loew, "Beam Breakup", in "Linear Accelerators" (North-Holland Publishing Co., Amsterdam, to be published 1969).

sufficient to just produce pulse shortening at the end of the machine at 1.6 μsec. A nominal experimental value of the BBU threshold, ~40 mA in the absence of detuning, served as a calibration for the threshold amplification required.

Figure 12 shows the effect of detuning several initial sectors as a function of frequency. Note that the computed improvement factor levels off for Δf greater than about 4 MHz, and is roughly symmetrical about $\Delta f = 0$.

Figures 13 and 14 show the effects of several detuning schedules. Several conclusions may be drawn:

a. Typically, there is an optimum number of detuned sectors; detuning a greater-than-optimum fraction of the machine causes the BBU amplification at the detuned frequency to dominate.

b. Detuning several different parts of the machine at different frequencies is better than using only one detuned group (e.g., compare curves C, D, E and F to A and B).

c. An alternating scheme such as 4-2-4-2-4-2 ...or 4-2-0-4-2-0... may be slightly better than dividing the detuned regions into blocks (e.g., compare curves E and F to C and D).

2. Experimental Results

The program of experimental work began with a search for the optimum method of detuning the HEM_{11} resonance in accelerator sections. Extensive cold tests performed on a 10-foot section fitted with tuning screws in the horizontal, vertical and 45^{o} planes in the first twelve cavities showed that the resonance observed on the machine develops maximum fields in the 4th cavity of each section. The fields fall to low levels in cavities 1 and 7. The mode may be readily detuned up to 4 MHz by distorting cavities 3, 4 and 5, at a cost of approximately 27 degrees phase shift in the TM_{01} mode at 2856 MHz. The VSWR at 2856 MHz may be held to its initial level by "symmetrically" distorting the three cavities, introducing the greatest phase-shift in cavity 4 and equal phase shifts (about 8^{o}) in cavities 3 and 5.

Cold tests confirmed that the HEM_{11} mode resonated with slightly different frequencies and Q's in the horizontal and vertical planes, because of the asymmetry introduced by the input coupler. In further cold tests on reject accelerator sections, cavity distortion was introduced by the same 'dimpling' technique as was used to originally tune the accelerator. It was determined that dimpling in the 45^{o} planes was preferred, as this detuned both polarizations of the HEM_{11} mode about equally.

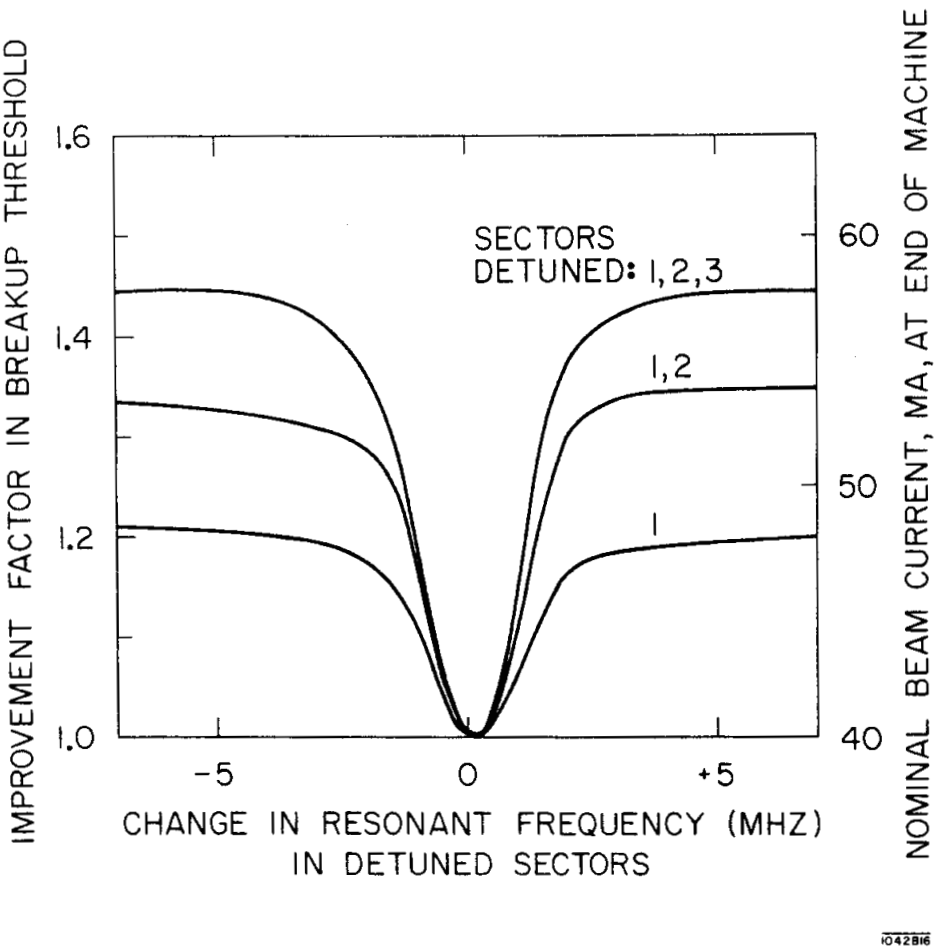

FIG. 12--Improvement factor in beam breakup threshold as a function of change in resonant frequency.

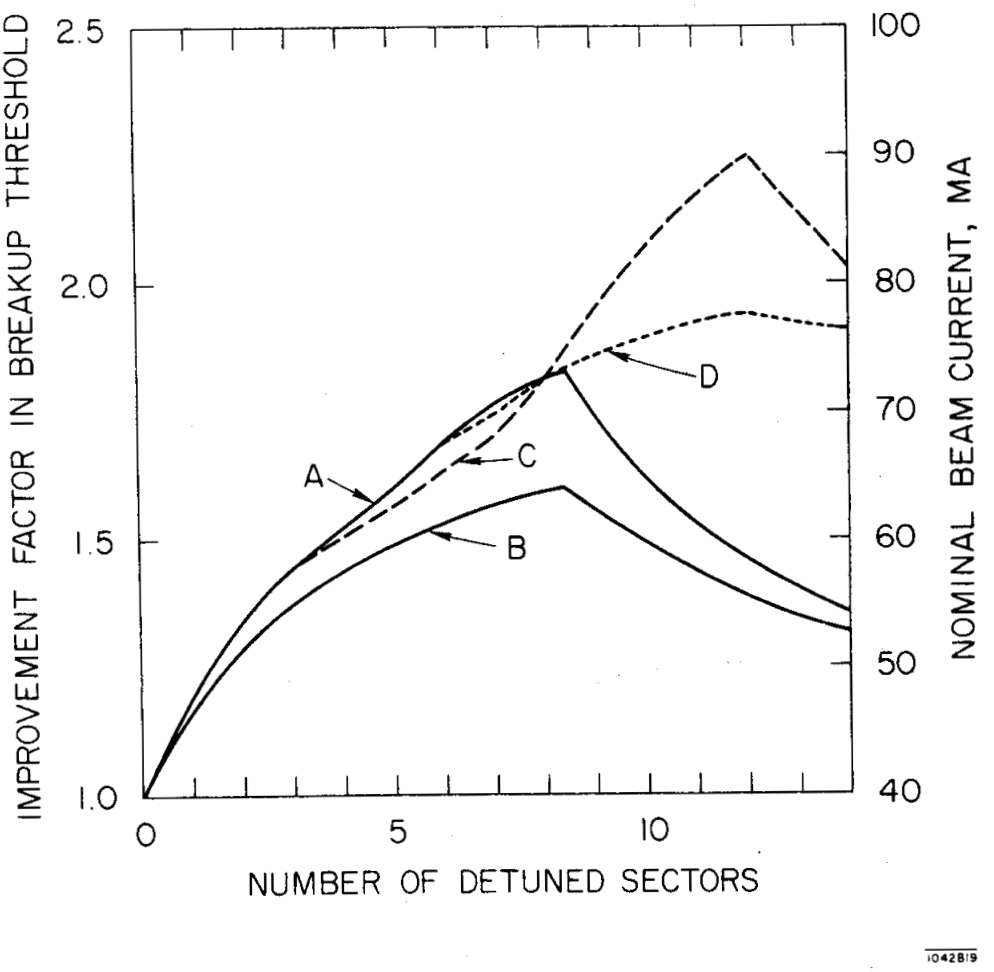

FIG. 13--Improvement factor in beam breakup threshold as a function of number of detuned sections, for various detuning schedules. Detuning schedules:

A: $\Delta f = +4$ MHz in all detuned sectors
B: $\Delta f = +2$ MHz in all detuned sectors
C: $\Delta f = +4$ MHz in sectors 1, 2, 3;
$\Delta f = +2$ MHz in remaining detuned sectors
D: $\Delta f = +4$ MHz in sectors 1 through 6;
$\Delta f = +2$ MHz in remaining detuned sectors.

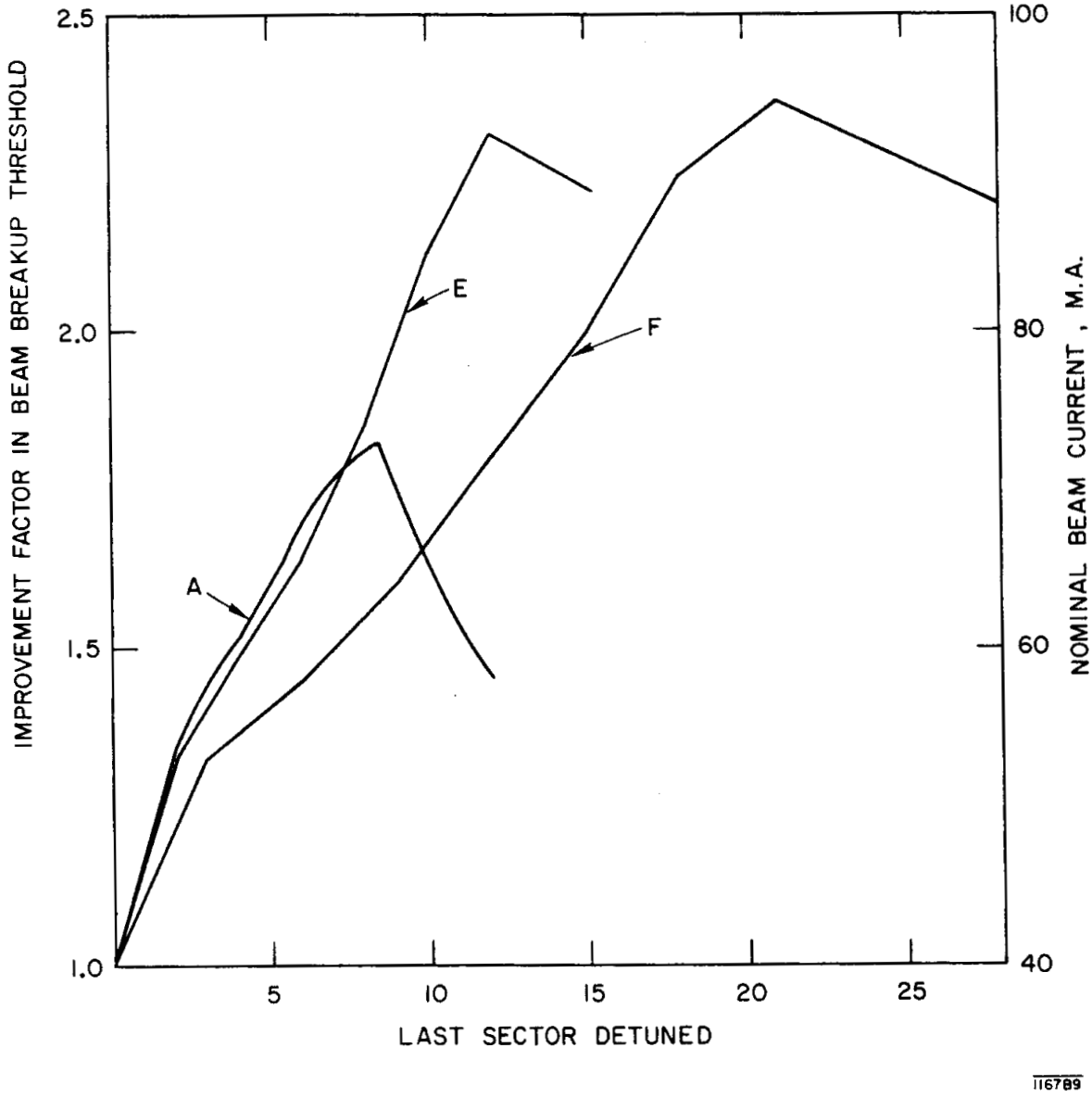

FIG. 14--Improvement factor in beam breakup threshold for several detuning schedules. Detuning schedules:

A: $\Delta f = +4$ MHz
E: $\Delta f = +4$ MHz in sectors 1, 3, 5;
$\Delta f = +2$ MHz in sectors 2, 4, 6
F: $\Delta f = +4$ MHz in sectors 1, 4, 7;
$\Delta f = +2$ MHz in sectors 2, 5, 8;
$\Delta f = 0$ in sectors 3, 6, 9.

A dimpling tool which could be clamped around an accelerator section and used to dimple cavities 3, 4 and 5 in the agreed pattern was constructed. After testing it on further sections in the laboratory, the tool was used to dimple Section 1-1C during May. Transmission phase-shift and input VSWR were monitored as the dimpling proceeded in small steps. The total phase shift introduced in cavities 3, 4 and 5 was - 29°. The input VSWR was 1.06 before dimpling, and 1.07 afterwards. The shift of BBU resonant frequency was + 4.28 MHz. After the dimpling was completed, the energy contribution of Section 1-1C was measured by several methods.

There appeared to be an energy loss of about 5%, but the measurements were not conclusive. The experiment was therefore repeated on 1-1B, taking careful "before and after" measurements of energy contribution as a function of klystron power and phase. Negligible change in energy contribution was observed. It was therefore planned to detune all of Sector 1 during the August shutdown.

After dimpling was completed, all waveguide feeds were checked and squeezed as necessary to regain the proper phase relationship between sections fed from the same klystron. The results of dimpling were measured during September. It was found that, under the standard conditions of energy, steering and focusing established for comparative beam breakup tests, the current through the accelerator to the switchyard had been increased from 40.0 mA to about 45 mA, an improvement of approximately 10%. The change in the energy contribution of Sector 1 due to phase shifts at 2856 MHz introduced by dimpling has proved to be less than the errors involved in making the measurement. However, a significant phase error was found and corrected in the waveguide feed from Klystron 8, and it is possible that the small energy gain from this correction just offset the loss due to dimpling.

The 10% improvement in BBU threshold fell short of the 19% improvement predicted by computation. Data obtained in the course of the Sector 1 dimpling program suggest reasons for this discrepancy: first, there was a rather large scatter in the resonance frequencies among the various 10-foot sections, which would decrease the coherence of the BBU amplification within the sector. Second, it appears that the resonance frequencies in Sector 1 may have been systematically different from those in the rest of the machine, possibly because Sector 1 consists largely of early production models in which the tuning procedure had not yet been standardized. (At present, there are insufficient data on sections beyond Sector 1 to definitely confirm the systematic frequency difference).

Further computer runs will be made to investigate these effects and to obtain revised predictions of improvements to be expected by dimpling of additional sectors.

F. MAGNETIC MEASUREMENTS

1. January of 1968 marked the beginning of operation of the newly modified rapid magnet mapper. The mechanical apparatus had been changed to contain three coils, one for each component; the entire 16-foot long beam had been remounted upon an I-beam for additional stability, and the cable retracting mechanism had been significantly improved. The electronic part of the system had been extensively modified to facilitate the logging of the three field components, the coordinate position in the measuring grid, and the magnet excitation current for each point measured. A computer program to read the magnetic tapes, and analyze and process the data for the user was being written and was ready by February. In January the mapper was used to make a 3-component map of magnet BR-1. Approximately 120,000 points were taken at three different currents. In February the mapper was used to map a Cosmotron magnet for Group D. Approximately 30,000 points were taken in a 1" × 1" × 1" grid. In September, the mapper was used to make a map of the magnet Leander for Group D. Again the grid size was 1" × 1" × 1". The mapper is now a highly reliable and very versatile system for measuring many large volume magnets at SLAC. The supporting computer programs for handling and processing data are operating well and preparations are underway to measure the Streamer Chamber magnet at two additional currents and to measure the new 100 D 40 magnet.

2. Two mappings of the 82-inch bubble chamber were made during the last three quarters, the first in February and the latest in August. All the measurements were made using a mechanical search coil moving device built for the 82-inch magnet when it was a 72-inch magnet at LRL. The data logging was done semi-automatically by a card punch, on-line with the mesurement device. This data logging system is now working very reliably and promises to be useful in the future for small measurement jobs, even though its speed is not as high as the rapid magnet mapper. (The rapid magnet mapper can take one 3-coordinate point per second and this system can take one 1-coordinate point in about five seconds.) With this system also, there is now a set of running computer programs to reduce the data, make function fits to it and plot significant characteristics of the data. In addition, the computer programs can generate output cards or tapes of the reduced data for the users.

3. The series of permanent magnets used as the laser beam dump magnets was gaussed, examined and measured. A series of tests was made to determine whether the permanent magnets were subject to magnetic change due to environmental conditions. No deterioration of magnetic characteristics was found. After measurements on the individual magnets were completed, a floating wire test was performed on the system of magnets as a whole.

4. The 3^{o} bending magnets in the A lane of the BSY were remeasured during a shutdown week. The measurements were performed with long coils to measure $\int_{-\infty}^{\infty} B \cdot d\ell$ of the magnets under specified conditions of magnet current. The measurements were in almost exact agreement with the original measurements in the A lane of the BSY.

5. A new long coil designed to measure directly the effective length of quadrupoles was built and tested extensively. The effective lengths of quadrupoles Q81 and Q82 of the 8 GeV Spectrometer were measured. The effective lengths as found are now being used in the running of the 8 GeV Spectrometer.

6. Several general purpose deflecting magnets (18D72's and 18D36's) were measured extensively and then modified by placement of steel shims in the magnet gap and remeasured.

7. Several BNL quadrupoles were studied to see if they could be used for pulsed accelerator focussing to supplement the QB doublets. Measurements have shown them to be suitable for use with only slight modifications and a design for magnets and power supplies is being prepared.

8. Numerous services and other small jobs were performed in addition to the larger jobs mentioned above.

G. KEYBANKS

The modification program of the keybanks has progressed to the point of installation of the first 11 units in the klystron gallery. This program has been the victim of several priority delays but is now nearing completion. Better reliability and ease of maintenance are the main improvements. Among other improvements is a special key shape which is not distributed to the public. Therefore, the possibility of a random key fitting the keybanks and doors is minimized. The keybanks themselves are now more tamper resistant and mechanically more reliable. The remainder of the units should be installed and spares completed during the next quarter.

H. SAD COMMITTEE

In early 1968, the laboratory established the SLAC Advanced Design (SAD) Committee. The primary goal of this committee is to develop criteria and plans for future developments of the SLAC accelerator. While the SAD Committee operates out of the Accelerator Physics Department, with G. A. Loew as head and W. B. Herrmannsfeldt as secretary, it draws on talent from all the SLAC departments which collaborate through their respective heads. For the time being, most of the SAD work is done on a part-time basis by staff members who have other prime responsibilities. Dr. Herrmannsfeldt is the only staff member for whom the SAD activity is the prime responsibility.

As initially formed, SAD had three types of Accelerators to consider:

1. Stage 1-1/2: an expansion of SLAC to higher energies by increasing the power and number of the conventional RF sources to the accelerator.
2. Superconducting Accelerator: an adaptation of the concepts then being developed at the Stanford University High Energy Physics Laboratory, HEPL, by which a very high-duty cycle accelerator could be made, using the new techniques of superconducting RF accelerator cavities.
3. ERA: The Electron Ring Accelerator, otherwise known as collective ion accelerator. This is a new technique now being developed in the USSR and more recently getting much attention from physicists at LRL, Berkeley.

So far, the organized activities of SAD have concentrated on the design and development of a superconducting accelerator. The reason for concentrating on the superconducting accelerator is that Stage 1-1/2 expansion is well understood already and, by contrast, ERA is still in a very speculative state. A set of tentative parameters for a superconducting accelerator were published,* specifying a 100 GeV maximum loaded energy at 48 μA peak with a duty cycle of 6%. Other parameters are discussed in the reference. A parallel effort, also coordinated by SAD, has been the study of RF superconducting materials. This work is reported below.

Under SAD auspices, a regular program of seminars on accelerator technology has been presented to the laboratory. All three types of accelerators have been discussed as prime topics of these talks.

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* R. B. Neal, "Sample Parameters of a Two-Mile Superconducting Accelerator", SLAC PUB-438, June 1968.

RF Superconducting Materials Research

An investigation of the RF properties of superconductors has been initiated as part of the SAD program. The presently-stated energy goal of a superconducting SLAC is 100 GeV, which necessitates an energy gradient of 10 MeV/foot in the accelerator structure. This is greater than has been achieved to date in any superconducting accelerator, either of the traveling-wave or standing-wave type. Field gradients are limited by the superconducting materials used in the accelerator circuit. Those materials which come closest to the design requirement are the pure metals, lead and niobium. Within the present state of the art, lead cavities are limited by field-emission loading effects to levels below 4 MEV/foot, and niobium cavities are limited by magnetic field penetration at gradients of about 5 MeV/foot in the traveling-wave mode of operation. In both cases however, sufficiently high Q-improvement factors have been obtained at superconducting temperatures to make them attractive for use in accelerators. Further improvments are expected for both lead and niobium.

For a two-mile accelerator to be economically feasible, it is likely that some deposition technique on a copper or aluminum substrate will have to be perfected. Deposition techniques for niobium and lead are therefore being studied. Equipment for sputtering niobium and other metals onto substrates at elevated temperatures has been constructed. Methods of coating lead surfaces with thin protective films of low-loss materials are being sought.

A search will also be made for inter-metallic compounds which might have suitable RF superconducting properties. It is possible that compounds of near perfect stoichiometry and crystal structure may yield high values of critical magnetic field.

Another material under study as a practical superconductor is technetium. While the values of critical temperature and critical magnetic field are intermediate between lead and niobium, it has the advantages over lead that it is a hard, oxidation resistant material, and the advantage over niobium that it can be electro-plated from an aqueous solution at room temperature. An attempt will be made to build and test a technetium-plated copper cavity.

Equipment to measure the very high Q's attainable in superconducting cavities in the frequency range from 2.8 GHz to 11.5 GHz has been assembled. Q's in excess of 10^9 have been measured in lead-plated TE_{011} cavities. Temperatures of 1.6°K have been achieved so far. Increased pumping capacity will allow temperatures down to 1.2°K to be reached.

Equipment for making magnetic susceptibility measurements on small rod samples of materials at low frequencies has been constructed and tested. These measurements will serve as a preliminary selection mechanism in the materials search.

Small-sample RF measurements will be done in a coaxial cavity resonant in the TE_{011} mode at approximately 11 GHz. The cylindrical cavity will be of lead-plated copper or solid niobium, and the removable center-center-conductor samples to be processed (by evaporation, sputtering, out-gassing, etc.) and then lowered, under vacuum, into the cavity for RF testing is being designed at present.