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UC-28
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TWO-MILE ACCELERATOR PROJECT

1 April to 30 June 1969

Quarterly Status Report

STANFORD LINEAR ACCELERATOR CENTER

STANFORD UNIVERSITY

Stanford, California

PREPARED FOR THE U. S. ATOMIC ENERGY COMMISSION

UNDER CONTRACT NO. AT(04-3)-400 AND CONTRACT NO. AT(04-3)-515

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ABSTRACT

A status report on the Stanford Linear Accelerator Project covering the period April 1, 1969 to June 30, 1969 is presented. Topics included are accelerator and research area operations, accelerator and research area equipment development, and physics research equipment development.

Previous reports in this series of Quarterly Status Reports:

SLAC-1, 1 April - 30 June 1962.
SLAC-8, 1 July - 30 September 1962.
SLAC-10, 1 October - 30 December 1962.
SLAC-16, 1 January - 31 March 1963.
SLAC-18, 1 April - 30 June 1963.
SLAC-23, 1 July - 30 September 1963.
SLAC-27, 1 October - 31 December 1963.
SLAC-30, 1 January - 31 March 1964.
SLAC-32, 1 April - 30 June 1964.
SLAC-34, 1 July - 30 September 1964.
SLAC-42, 1 October - 31 December 1964.
SLAC-45, 1 January - 31 March 1965.
SLAC-48, 1 April - 30 June 1965.
SLAC-53, 1 July - 30 September 1965.
SLAC-59, 1 October - 31 December 1965.
SLAC-65, 1 January - 31 March 1966.
SLAC-69, 1 April - 30 June 1969.
SLAC-71, 1 July - 30 September 1966.
SLAC-73, 1 October - 31 December 1966.
SLAC-80, 1 January - 30 June 1967.
SLAC-85, 1 July - 30 September 1967.
SLAC-87, 1 October - 31 December 1967.
SLAC-89, 1 January - 31 March 1968.
SLAC-90, 1 April - 30 June 1968.
SLAC-93, 1 July - 30 September 1968.
SLAC-98, 1 October - 31 December 1968.
SLAC-105, 1 January - 31 March 1969.

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INTRODUCTION

This is the twenty-eight Quarterly Status Report of work under AEC Contract AT(04-3)-400 and the twenty-second 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 April 1, 1969 to June 30, 1969. 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 April 27, 1969, a beam energy of 21.5 GeV was achieved. Beam currents up to 55 milliamperes peak have been obtained.

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

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

I. ACCELERATOR OPERATIONS

A. Operating Hours

Manned Hours	<u>APR.</u>	<u>MAY</u>	<u>JUNE</u>	<u>QUARTER</u>
<u>Physics Beam Hours⁽¹⁾</u>				
Machine Physics	82	23	25	130
Particle Physics	<u>329</u>	<u>380</u>	<u>351</u>	<u>1,060</u>
Total Physics Beam Hours	411	403	376	1,190
<u>Non-Physics Hours</u>				
Scheduled Downtime	---	8	10	18
Unscheduled Downtime Due to				
Equipment Failure	13	20	13	46
All Other (Machine Tune-Up, etc.)	<u>48</u>	<u>41</u>	<u>73</u>	<u>162</u>
Total Non-Physics Hours	<u>61</u>	<u>69</u>	<u>96</u>	<u>226</u>
TOTAL MANNED HOURS	<u>472</u>	<u>472</u>	<u>472</u>	<u>1,416</u>

B. Experimental Hours⁽²⁾

1. Particle Physics

(3) Beam Line	Sched. Hrs. Electronic Experiments (a)	Electronic Experimental Hrs.		%	Actual Bubble Chamber Hours	Actual Test And Check-Out Hours	Total Experimental Hours	
		Actual Hours (b)	(4) Charged Hours				Actual Hours	Charged Hours
A	767	543	299	70.8	---	38	581	337
B _N	234	187	212	80.0	---	297	484	509
B _C	---	---	---	---	---	---	---	---
B _S	584	517	717	88.5	---	282	799	999
C	5	3	5	60.0	703	345	1,051	1,053
Total	1,590	1,250	1,233	78.6	703	962	2,915	2,898
							259	259
TOTAL EXPERIMENTAL HOURS							3,174	3,157

2. Machine Physics

- (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. 1 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		3,764
Hours charged during the quarter		1,233
New hours approved during the quarter		<u>534</u>
Approved hours remaining at end of quarter		3,065

2. <u>Bubble Chamber Experiments</u>	<u>40" BC</u>	<u>82" BC</u>
Approved pictures at beginning of quarter	920 K	2,165 K
Pictures taken during the quarter	---	1,610 K
New pictures approved during the quarter	<u>---</u>	<u>1,103 K</u>
Approved pictures remaining at end of quarter	920 K	1,658 K

D. <u>Beam Intensity</u>	<u>April</u>	<u>May</u>	<u>June</u>	<u>Quarter</u>
Peak	47.0mA	40.0mA	30.0mA	47.0mA
Average	7.0 μ A	6.2 μ A	2.9 μ A	5.4 μ A

E. <u>Klystron Experience</u>				
Total Klystron Hours	111,348	111,250	112,339	334,937
Number of Klystron Failures	8	2	7	17

F. <u>Data Analysis</u>				
Spark Chamber Events Measured	19,541	16,179	29,741	65,461
Bubble Chamber Events Measured	9,217	9,843	6,385	25,445

G. Computer Operations

Manned Hours

Computation Hours

SLAC Facility Group	93	87	77	257
User Group	<u>462</u>	<u>468</u>	<u>454</u>	<u>1,384</u>
Total Computation Hours	555	555	531	1,641

Non-Computation Hours

Scheduled Maintenance	94	78	88	260
Scheduled Modifications	25	43	28	96
Unscheduled Downtime and Reruns	15	23	66	104
Idle Time	7	9	6	22
Utility Failure	<u>16</u>	<u>--</u>	<u>1</u>	<u>17</u>
Total Non-Computation Hours	<u>157</u>	<u>153</u>	<u>189</u>	<u>499</u>
TOTAL MANNED HOURS	<u>712</u>	<u>708</u>	<u>720</u>	<u>2,140</u>

H. Special Operating Features

1. Positrons

No positron experiments were run during the quarter.

2. Beam Knockout

The beam knockout was used for a total of 695 hours during the quarter, including 24 hours of check-out. It was operated at both 10 and 40 MHz.

3. Power Supplies

The 3.4 MW power supply was run for a total of 881 hours, all with the 82" bubble chamber.

The 5.8 MW power supply was run for 287 hours with the 54" spark chamber and for 10 hours with the two meter spark chamber.

The motor generator facility was out of action for most of April and all of May due to transformer trouble. During June and part of April it was run for a total of 328 hours, including 14 hours of check-out, with the 54" spark chamber.

Repair of the primary transformer on the 5.0 MW power supply continued during the quarter. The power supply was not used.

II. RESEARCH AREA OPERATIONS AND DEVELOPMENT

A. General Beam Switchyard and Research Area Activities

Primary activity in the Research Area and Beam Switchyard during the period consisted of support of scheduled experiments, installation of equipment for future experiments, and maintenance. The major installation activities centered on:

The installation of a polarized target in End Station A in preparation for E-29* was completed. The target was operated with approximately 32% polarization during tests. The experiment ran during the entire period.

The move of the streamer chamber facilities from their location in the A-beam line to the new location in the C-beam area used major effort during April. The large building, the magnet, and the streamer chamber were moved early in May. In its new location the streamer chamber will be able to share the beam with the 82" bubble chamber with its low repetition rate and will no longer compete directly with spectrometer experiments for beam time.

The installation of the modification to the μ -beam line and the installation of Experiment E-38 was completed and the experiment has started.

Installation work in preparation for experiment E-41 continued throughout the period. Building 403 was moved from beam path 2 to beam path 11 where it will house a hydrogen target and detection apparatus. The large 40-D48 magnet was moved from beam path 2 to 11 as well. A large Cerenkov counter was installed downstream of the 11-D-6 magnet in this experiment. Air conditioning is being installed in the building to help insure the stability of the spark chamber being used in the experiment. Work continues on the improvement of the beam transport system and the setup of experimental equipment to be used in this experiment. Included in the work is installation of a computer link from the IBM 1800 located at the experiment to the laboratory IBM 360.

Equipment for E-43 in the beam switchyard was installed, checked out, and run in May. A light source for alignment purposes was placed in Sector 19 of the accelerator during a shutdown period. The light was visible at the detection station in the beam switchyard.

Work on the shielding block cave inside End Station B for E-44 continued. Eighteen feet of the north wall of the cave was moved 30 inches north. Earthquake bracing was installed. The 72-D36 magnet was installed and magnet

*See Table 1 for titles of numbered experiments.

measurements were made. Installation of a new hydrogen target, hook-up by the experimenter of main spark chamber and counters, and interfacing the experimental equipment to an IBM 1800 computer associated with the experiment were completed.

The calibration of the cosmic ray counter by NASA personnel from Goddard Space Flight Center in Beam Path 10 was completed (Experiment D-7). Considerable general effort was used in the support of this activity.

Preparation for tests of a large sodium iodide crystal by Dr. R. Hofstadter of HEPL in a parasitic experiment in End Station A was begun. The arrangement consists of a large shielded cave, constructed from general purpose concrete shielding blocks, which will enclose an 18-D-72 sweeping magnet and the crystal under test. Cabling is being installed for readout of the detector in the End Station A Counting House.

Rework of End Station C in the C-beam in order to establish a K_0 beam for the streamer chamber Experiment E-48 has been initiated.

Work on the installation of the new 1500 kVA substation for general house power at the eastern end of the Research Area continues. Installation of a 2500 kVA transformer and power supply shelter for powering beam transport magnets is proceeding south of End Station B. During the period several improvements have been completed in the low conductivity water system for the Research Area in order to meet the continuously increasing heat and flow load being placed on the system.

B. Power Supply Activities

Most power supply equipment is now operating reliably and with satisfactory regulation. Continued engineering improvement in the operation of power supplies in critical areas is underway.

We continue to experience difficulty in attaining reliable operation of the large magnet power supplies. Fortunately, these problems have not interfered with operations. In April, a failure occurred in the auto-transformer used for starting the motor generator set; repairs were completed in June. The 5.8 MW power supply, now operational, was put into service in place of the MG set, to energize the spark chamber magnet. Delivery of the rebuilt transformer for the 5.0 MW supply is now overdue, but is expected by mid-July. Some necessary maintenance and modifications of the 3.4 MW power supply are being held up pending completion of the 5.0 MW power supply project.

A 1500A/100V power supply was borrowed from Berkeley and installed to operate the polarized target magnet for E-29.

A plug type patch panel was installed for use with the pulsed steering magnets in Sector 30 of the accelerator. This will allow quick interchangeability between any of several available power supplies and five magnets.

Four power supplies rated at 150 kW each were tested and delivered. Six new 400 kW power supplies were delivered in May and are undergoing tests.

Pulse-to-pulse instability of the main pulsed switching power supplies has always been a problem, which has now become critical in view of the stringent requirements for Experiment E-29. Parts have been ordered so that improvements which were worked out on a prototype can be made, and some temporary measures were also being investigated. Completion of all improvements will be done over a period of a few months.

New reversing switch mounting assemblies were being installed in four of the eight spectrometer power supplies, for the July 9 run. The change is being made to eliminate some troublesome reversing switch failures that have occurred in the past. The remaining four power supplies will be similarly improved during the August shut-down.

C. Research Area Control Center Improvements

A considerable amount of work has been done in the Data Assembly Building since the December/January shut-down. At that time, operations were shifted from the old console to the west side of the new dual console. For the past several months, the west console equipment has been evaluated and modifications have been made where necessary. At the same time, a start was made on installation of equipment in the east console. At present, the spectrum monitor system has been duplicated and within the next few months, video displays, profile monitor controls and magnet display and control panels will be installed.

Improvements have been made in the sensitivity of the microwave position monitors P-12 and P-13 in the A-beam line. This has become necessary because of the low beam currents (10-20 microamps) required by Experiment 29. In the new configuration the output of the position cavity is mixed with a local oscillator and the resulting 30 megahertz signal is amplified in an I. F. strip with a gain of 90 db. This approach has resulted in useful steering signals

at currents of 10-20 microamps compared to the previous values of approximately 100-150 microamps.

D. Liquid Hydrogen Target Group Activities

Two targets, E-29 and E-37, were in operation in April. These targets were both shut down April 6, 1969 and removed from their installations in End Stations A and C, respectively. The E-29 check-out target was installed in End Station A on April 6th and operated successfully until its removal on April 14th. No other targets were in operation during the period. The design of the target for E-40 was delayed due to changes resulting from a review with the physicists. New physics criteria were established. Work on the design continues. A prototype target cannister was fabricated and tested. Excessive window deformation was observed.

The heat exchanger for E-41 was completed and pressure tested. The refrigerator was received and is being tested. The target motion mechanism is in design.

A Target Advisory Committee review of the target for E-49 was held in May. This target will be reviewed again as soon as more details of the design are worked out. The bids for 4.5" submerged LH₂ fans used on E-44 were opened in May.

The destructive test of the E-44 target cell was conducted during May. Test results were as predicted.

The 15,000 gal. LH₂ tank was warmed up in May. Preliminary results from an SRI analysis of the residual gases indicate that approximately 10 liters of solid air were in the tank. It is believed that this air enters the tank during the transfer operation. A filter is being installed on the inlet side similar to the ones on the withdrawal side, in an effort to trap the air before it enters the tank.

E. Beam Switchyard Beam Line Improvements

Design and detail drafting of the new high-power slit for the B-beam were nearly completed during the period and a final project review can be held soon. This slit will allow transmission of the full Stage I beam power of 600 kW and has enough reserve capacity to safely dissipate future power up to 1 MW. An investigation to improve the reliability of the high-Z slit jaws was started. The goal is a design of a set of composite jaws which allow quick removal and replacement of the section of peak power deposition in case it is thermally damaged by the beam.

A modification program is underway to increase safety and reliability of the beam stoppers used in the Beam Switchyard. The stoppers are uncooled power absorbers designed to absorb only a few beam pulses and protected by an ionization chamber. If the radiation sensing instrument fails and the beam is accidentally deposited in the stopper, the stopper will fail due to melting and a hazardous condition may arise. A more direct and fail-safe method to detect such a condition and shut off the beam has been developed which consists of a device that responds to thermal radiation emitted by the stopper when bombarded by the beam. The temperature sensitive part of the device consists of a thin (about 2 mm thick) diaphragm of low-melting alloy ($T_{\text{melt}} \approx 60^{\circ}\text{C}$) which covers the end of a 1 cm diameter tube that connects the vacuum system with the atmosphere outside. When the diaphragm bursts it lets the beam transport system up to air and shuts the beam off. All stoppers will be equipped with such devices in the near future.

Two additional beam ports were added to the Tune-Up Dump design. One of these, on the north side of the Central Beam port, can be used for the proposed Storage Ring beam transport system. The other one is located symmetrically to the south of the Central Beam and represents at this time only a spare. Fabrication on the Tune-Up Dump will continue as soon as manpower is available in the fabrication shops.

A dual beam video position monitor for the B-beam that was designed earlier in the year is well along in mechanical fabrication.

Finally, a new intercepting beam pickup device was designed, fabricated and installed for testing during the next operating cycle. It is of the SEM type and the central conductor is copper to obtain a stronger signal than was possible with previous models. The pickup will be used as a timing device for time-of-flight experiments using the chopped beam mode of operation of the accelerator. It is hoped that the source of ringing and other noises which have been observed on previous pickups can be either identified or eliminated.

F. Bubble Chamber Operations and Development

Modifications and repairs on the 40" chamber body were essentially completed. The major repair was the replacement of the broken bellows that had cracked in three places. Modifications were made to the expansion piston and its associated cooling circuitry. Plumbing changes necessary to the chamber

modifications and future Ne-H₂ operations were also completed. In addition, a small hydrogen bubble chamber is being developed to fit into the 40" chamber in conjunction with the Ne-H₂ development program. The chamber is to be cooled and operated in October.

The 82" chamber performed its initial deuterium operations in April. The chamber was expanded 1,329,540 times and 586,726 pictures were taken; 51,073 pictures were for R-4 check-out of the polarized photon beam (laser beam), and 535,653 pictures were for BC-17. The higher pressures involved in deuterium operation caused some breakdowns in the pulsing system and a development program has been initiated to solve these problems. At the end of the month the chamber was re-filled with hydrogen for Experiment BC-11.

In May the chamber was expanded 1,338,670 times, bringing the total number of expansions past 10 million. 506,607 pictures were taken for BC-11, completing that experiment.

The chamber expanded 992,809 times in June taking 267,383 pictures for BC-21 and 305,215 pictures for BC-20 and completing those two experiments. The chamber had expanded 3.4 million times since its cool-down in March, 1969, and the dirt accumulated from this many pulses made the chamber unusable for BC-14 and 15 without a warm-up and clean-up cycle. This cycle has been completed and the chamber will cool down and do the BC-14 and 15 experiments in July, using the new 35 mm camera.

At the end of June, the picture totals for the fiscal year were 3,407,696 for the 82" chamber, 1,742,816 for the 40" chamber, making a total of 5,150,512.

G. Spectrometer Operation and Development

The 20 GeV spectrometer in End Station A was prepared for experiment E-29 and was in use for that experiment during the period. A rotating hodoscope was completed and has been installed in the spectrometer and appears to be operating properly. The polarized proton target which was designed and fabricated by the Lawrence Radiation Laboratory group collaborating on the experiment was installed and has operated with satisfactory 32% polarization. The target is a complicated device consisting of several components, including a large magnet, a 500 liter helium dewar, two 310 CFM Kinney pumps, 5000 CFM Rootes pump, and electronic equipment for achieving and measuring the polarization in the target.

Design work continued on three detector carriages which are to be used in Experiments E-21c, E-42, and E-50. Construction on these carriages was initiated during June.

Electronics for the test of the sodium iodide crystal by HEPL previously discussed were installed in the new area of the Counting House.

H. Summary of C-Beam Activity

The principal activity during this period was completion of BC-11, with a run of 0.5×10^6 pictures. At the same time it became clear that control of the beam (and the accelerator) has become sufficiently systematic through evolution and improvement of the instrumentation for use of the system by outside groups to be considered practical.

Over the past year a number of changes have been made in the π/k beam and in each case the need for better performance to produce K^- beams has been borne in mind. Also, as a result of accelerator improvements during the same period an electron beam of 40 mA peak at 19 GeV can be obtained now with no greater difficulty than previously encountered with 30 mA, 18 GeV beam.

In view of the improved conditions we re-evaluated the capability of the system and found that a well-separated beam of 5 to 6 K^- per pulse can be delivered to the 82" bubble chamber. This intensity is only half the canonical minimum for normal bubble chamber experiments but may still be useful in special cases. An electron beam equivalent to 50 mA and 20 GeV would satisfy all normal requirements.

The first steps to install the streamer chamber in the C-beam area were taken--installation of the building and magnet. Design of the neutral K-beam for the streamer chamber is complete and installation has begun. Operation of this new beam will be compatible with simultaneous operation of the charged π/k beam.

Two bubble chamber runs were completed during this period: BC-20 and BC-21. In addition, tests of a balloon-borne "experiment" were carried out simultaneously in the secondary e^+ beam for a NASA group from Goddard Space Flight Center, under the direction of Dr. Johnathan Ormes.

Another shower counter test was performed in connection with Experiment E-44 using the π/k beam after conclusion of the bubble chamber runs.

Developmental work on the beam for Experiment E-41 continued.

I. Description and Status of Approved Experiments

Figure 1 is a Research Area plan drawing showing the location of the various experiments. Table 1 is a list of presently approved high energy physics experiments. The right-hand column of Table 1 gives the status and activity of each experiment during the period.

During the 10-11 June 1969 meeting of the Program Advisory Committee, Experiments E-53, BC-25, BC-26 and BC-27 were approved and Experiments BC-5 and E-38 were granted extensions.

Information on the status of certain experiments and descriptions of the newly approved experiments follow:

E-31a — Measurement of the Magnitude of η_{00}

A successful run was completed during the April operating cycle. About 90 rolls of film were taken — 25 using a copper regenerator at various positions, one with a piece of interacting material in the beam, and 65 on the free decay of the K_L^0 . The regenerator and interaction film will be used to evaluate errors in the data analysis, while the free decay rolls are data.

E-38 — μ^+e^- Scattering

This experiment measures the μ^+e^- elastic scattering cross section, near the kinematic limit for this process. During the period installation was completed and preliminary tests conducted. A new optical design for the muon beam was tried successfully. All of the counters and electronics were installed and tested. A few hundred events were obtained from a thick (20 gm/cm^2) carbon target. Approximately 8000 events were obtained at 12 GeV/c and 4000 at 10 GeV/c incident muon energy using a thin target. Some minor amount of check-out and calibration running still remains to be completed during the July running period.

E-43 — Velocity of Light Experiment

This experiment compares directly the velocity of light of optical frequencies and synchrotron radiation to the velocity of approximately 7 GeV gammas produced by bremsstrahlung. During the June cycle initial tests on the experimental equipment were completed. Visible light and gammas from sources located at the one-half point of the two-mile accelerator were observed at the detector located in the Beam Switchyard C-beam. Data on timing and various checks and improvement of the experimental equipment and procedures are planned for future runs.

E-29 — Search for T-Violation in Enelastic e-p Scattering

This experiment has been running in End Station A for about two cycles. The check-out of the beam polarized target and electronics have been completed and data were accumulated for the experiment during the last cycle. The experiment consists of inelastically scattering electrons from a target containing polarized protons. The scattered electron is detected and its momentum is measured. In the one-photon approximation, any difference in the rate of scattering when the sense of the target polarization normal to the scattering plane is reversed would be evidence for T-Violation in electromagnetic interaction. During the cycle data were obtained for the incident electron energies of 15 and 18 GeV. Data have been obtained at q^2 equal to 0.3, 0.6, 1.0 for missing masses of 0.94, 1.236, 1.512, 1.688, and 2.0 GeV. Approximately four to six hours per day are used for replacing and/or annealing the target to repair the radiation damage. Good electron scattering events are observed at the rate of 4 to 5×10^6 events/day. Also, calibration data on using a carbon target are made daily. The experiment will continue to run for two cycles.

E-53 — Survey of Photon and π^0 Yields

In a test to determine the photon background for a measurement of inelastic Compton scattering (SLAC Proposal No. 51), a shower counter was used to find photon yields at few angles and energies. Relative to previously measured charged pion yields, the number of photons was found to be anomalously large, especially at large angles and high secondary energies. Since the flux of gamma rays is an order of magnitude more than expected, the inelastic Compton scattering experiment would not work in the form originally proposed, but it is now of interest to understand the source of these abundant photons. It was proposed, therefore, to use an array of shower counters to determine whether these are single photons or whether they come from π^0 decay, and by utilizing the counters singly or in coincidence to find single photon and π^0 yields as a function of incident gamma energy and the energy and angle of the outgoing photon or π^0 .

BC-25 — Proposal to Study Pomeranchon, Meson, and Baryon Exchanges

This is a proposal to make a systematic, high statistics, investigation of nucleon diffractive dissociation. It is also planned to use the same experimental equipment to study certain selected quasi-two and three body reactions which are expected to be described by simple meson and baryon exchanges.

For this, 1.6×10^7 expansions of the hydrogen-filled SLAC 40" chamber operated in a triggered mode were requested. Through selective triggering this number of expansions is expected to generate 8×10^5 pictures and 2.4×10^5 measured events. Both π^+ and π^- as incident particles will be used. This not only increases the number of final states available, but also checks that diffraction dissociation initiated by π^+ and π^- do indeed behave similarly.

BC-26 — Determination of Quantum Numbers for Resonances in the R, S, T, and U Region Using π^+ + d Interactions at 12 BeV

The primary purpose of this experiment is to clarify the situations concerning resonances in the mass region 1.5 GeV to 2.5 GeV. Several schemes for the classification of meson states have been proposed using, for example, the quark model of boson resonances or a baryon-antibaryon model. While these schemes have many features in common, they do begin to diverge for masses above 1.5 GeV. It is important that at least G parities become well known for these massive states. Also, many of the available slots in these schemes occur for T = 0 mesons, a state which is best observed in π^+ d interactions.

In addition to studying the general channel $\pi^+N \rightarrow P + (n\pi)^0$ it is also planned to investigate the following: The splitting of the A_2^0 , the $\rho(1650)$, the $\pi(1650)^0$, the $(1840)^0$, and the S, T, U regions. It is also planned to investigate coherent production on deuterium.

BC-27 — Study of the "A₂" Problem and Other Members of the $J^P = 2^+$ Nonet

This proposal is to study 10^6 pictures of 4.5 and 6 GeV/c π^- in the 82" hydrogen bubble chamber with a beam intensity of 20 particles per picture. The momentum spread must be less than $\pm 1/2\%$. The pictures will be searched for interactions causing the production and visible decay of neutral strange particles and it is estimated that there will be ~ 100 K events of this type. From these events it is hoped to find more of the properties of "A₂" $\rightarrow K\bar{K}$, the $K^*(1400) \rightarrow K^*(890) \pi$ (or ρK) and other boson resonances. Altogether about one year will be required to complete the experiment from the end of the exposure.

TABLE I

TABLE OF PROGRAMMED EXPERIMENTS

<u>Number</u>	<u>Title</u>	<u>Authors</u>	<u>Date Approved</u>	<u>Status</u>
E-14	Proposal for Testing of Quantum Electrodynamics by Photoproduction of Asymmetric Muon Pairs	<u>STANFORD</u> (Group A) W. Panofsky, D. H. Coward H. DeStaebler, J. Litt, A. Minten, L. W. Mo R. E. Taylor <u>MIT</u> J. I. Friedman, H. W. Kendall, L. VanSpeybroeck	11/18/66	d
E-21c	Proposal for Measurements on the Photoproduction of π^0 , η , ρ^0 , ω and ϕ Mesons at Small Momentum Transfer t and Photon Energies Up to 18 GeV and a Search for Mesons of Other Masses	<u>STANFORD</u> R. Anderson, D. Gustavson, J. Johnson, R. Prepost, D. Ritson <u>N. E. UNIV.</u> R. Weinstein, M. Gettner <u>CAL TECH</u> R. L. Walker, G. Jones, D. Kreinick, A. V. Tollestrup	3/11/67	d
E-29	Search for T-Violation in Inelastic ep Scattering	<u>U. C. BERKELEY</u> O. Chamberlain, G. Shapiro, H. Steiner, H. Weisberg, C. Morehouse, T. Powell, P. Robrish, S. Rock, S. Shannon <u>STANFORD</u> R. Taylor, L. Mo, E. Bloom, J. Litt <u>MIT</u> H. Kendall, J. Friedman	12/16/67	a
E-31	Measurement of the Magnitude of η_{00} and its Phase Relative to η_{+-}	<u>STANFORD</u> D. Dorfan, M. Schwartz, W. Wojcicki	11/6/67	a, h

Table of Programmed Experiments (cont'd) - 2

<u>Number</u>	<u>Title</u>	<u>Authors</u>	<u>Date Approved</u>	<u>Status</u>
E-34	Electron-Deuteron Quasi-Elastic Scattering	<u>STANFORD</u> E. Bloom, D. Coward, H. DeStaebler, J. Dress, J. Litt, R. E. Taylor <u>MIT</u> J. Friedman, G. C. Hartmann H. W. Kendall <u>CAL TECH</u> B. C. Barish	7/2/68	d
E-37	Measurement of the Total Photoabsorption Cross Section for Hadron Final States	<u>UCSB</u> D. Caldwell, V. Elings, W. Hesse (Student), R. Morrison, F. Murphy <u>STANFORD</u> D. Yount	5/11/68	h
E-38	Proposal to Stanford Linear Accelerator Center for an Experiment on $\mu^+ e^-$ Scattering	<u>UNIV. OF WASHINGTON</u> S. Neddermeyer, N. Scribner, P. Kotzer, G. Eilenberg, T. Koss	8/5/68	c, b
E-40	High Statistics Study of the Production of Charged ρ^\pm Mesons, Neutral ρ^0 Mesons, f^0 Mesons and Nucleon Isobars By Pions	<u>SLAC</u> J. Cox, B. Dieterle, W. Kaune, M. Perl, J. Pratt, J. Tenenbaum, W. Toner, T. Zipf	8/5/68	d
E-41	Rho Production by Pions — A Test of Vector Dominance	<u>SLAC</u> F. Bulos, W. Busza, G. Fischer, E. Kluge, R. R. Larsen, D. W. G. S. Leith, B. Richter, H. Williams <u>IBM</u> M. Beniston	8/5/68	c, b
E-42	Photon-Proton Scattering at Forward Angles	<u>SLAC</u> A. Boyarski, F. Bulos, W. Busza, R. Diebold, S. Ecklund, G. Fischer, H. Lynch, B. Richter	3/22/69	d
E-43	Velocity of Light Experiment	<u>UCSD</u> G. Masek	12/14/68	c, b

Table of Programmed Experiments (cont'd) - 3

<u>Number</u>	<u>Title</u>	<u>Authors</u>	<u>Date Approved</u>	<u>Status</u>
E-44	Coherent Regeneration from Hydrogen	<u>UCLA</u> D. Drickey, H. Ticho D. Stork, C. Buchanan, D. Rudnick, P. Shephard <u>SLAC</u> E. Dally, E. Seppi, <u>JOHNS HOPKINS</u> L. Ettlinger R. Zdanis <u>CERN</u> P. Innocenti	2/8/69	c
E-45	Proposal for the Measurement of π^+ Photoproduction with Polarized Photons at SLAC	<u>MIT</u> D. Luckey, L. S. Osborne, R. Schwitters <u>SLAC</u> A. Boyarski, R. Diebold, S. Ecklund, B. Richter	12/14/68	d
E-47	π^+ Photoproduction with a Polarized Target	<u>LRL</u> O. Chamberlain, C. Morehouse, T. Powell, P. Robrish, S. Rock, S. Shannon, G. Shapiro, H. Weidsberg <u>SLAC</u> A. Boyarski, R. Diebold, S. Ecklund, Y. Murata, B. Richter	2/8/69	d
E-48	Proposal to Measure the ξ Parameter in the Decay $K_L^0 \rightarrow \pi\mu\nu$	<u>BNL</u> D. Hill, R. Palmer, M. Skitt, N. Samios <u>SLAC</u> D. Fries, F. Liu, R. Mozley, A. Odian, J. Park, W. Swanson, F. Villa.	2/8/69	c
E-49	Inelastic Electron Scattering from D ₂	<u>SLAC</u> L. Cottrell, D. Coward, H. DeStaebler, C. Jordan, R. Taylor <u>MIT</u> J. Friedman, H. Kendall	2/8/69	d
E-50a	Compton Scattering at High Energies From Hydrogen	<u>SLAC</u> R. Anderson, D. Gustavson, J. Johnson, I. Overman, D. Ritson, B. Wiik <u>HARVARD UNIV.</u> J. Walker <u>NORTHEASTERN UNIV.</u> R. Weinstein	3/22/69	d

Table of Programmed Experiments (cont'd) - 4

<u>Number</u>	<u>Title</u>	<u>Authors</u>	<u>Date Approved</u>	<u>Status</u>
E-53	Survey of Photon and π^0 Yields	<u>U. C. SANTA BARBARA</u> D. Caldwell, V. Elings, D. Fancher, A. Greenberg, G. Jahn, A. Kaushal, B. Kendall, R. Morrison, F. Murphy, S. Tyler, B. Worster	6/11/69	d
BC-6	Proposal to SLAC for Study of the One Pion Exchange Contribution to γ -Nucleon Scattering (in 40-inch Deuterium Bubble Chamber)	<u>OAK RIDGE</u> H. O. Cohn, <u>R. D. McCulloch</u> <u>UNIV. OF TENNESSEE</u> G. T. Condo, W. M. Bugg	9/28/68	d
BC-10	A Proposal to Investigate K_{2p}^0 Interactions with the 40-Inch HBC	<u>STANFORD</u> 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	d
BC-11	A Proposal for a Bubble Chamber Experiment with the Polarized Laser Induced Photon Beam	Spokesman: Gunter Wolf	5/11/68	a, h
BC-14	Proposal for 7.5 and 13 GeV/c, π^+ and π^- Exposures in the SLAC 82" HBC	<u>MIT</u> 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	<u>UNIV. OF ROCHESTER</u> T. Ferbel, W. Katz, P. Slattery, S. Stone, H. Yuta	9/28/68	d
BC-17	A Search for $1^+ K^*$ Mixing Effects by Coherent Production on Deuterium at 12 GeV/c	<u>LRL BERKELEY</u> D. G. Coyne, A. Firestone, G. Goldhaber, J. A. Kadyk, G. H. Trilling	9/28/68	h

Table of Programmed Experiments (cont'd) - 5

<u>Number</u>	<u>Title</u>	<u>Authors</u>	<u>Date Approved</u>	<u>Status</u>
BC-18	A Proposal for a 4.25 BeV γ -Deuterium Experiment in the SLAC 40" Bubble Chamber	<u>WEIZMANN INSTITUTE</u> 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	<u>TEL AVIV UNIV.</u> G. Alexander, I. Bar-Nir, A. Brandstetter, S. Dagan J. Gunhaus, A. Levy, Y. Oren	9/28/68	d
BC-20	Exposure of the 82" Deuterium Chamber to a Beam of π^+ Mesons at 13.4 GeV/c	<u>PURDUE UNIV.</u> D. H. Miller	3/22/69	d
BC-21	Study of π^- -D Interactions at 12 GeV/c in the 82" Bubble Chamber	<u>U. C. - RIVERSIDE</u> D. Davison, W. Jackson, U. Mehanti, R. Rice, Y. Williamson, Y. Oh, R. Bacastow, W. Barkas, S. Fung, E. Hart, A. Kernan, R. Poe	3/22/69	d
BC-25	Proposal to Study Pomeranchon, Meson, and Baryon Exchanges by Triggering the SLAC 40" Bubble Chamber on Fast Forward Particles	<u>CAL TECH</u> B. Barish, W. Ford, R. Gomez, C. Peck, J. Pine, F. Sciulli, B. Sherwood, A. Tollestrup, G. Zweig	6/18/69	d
BC-26	Determination of Quantum Numbers for Resonances in the R, S, T, and U Region Using $\pi^+ + d$ Interactions at 12 BeV	<u>DUKE UNIV.</u> M. Binkley, D. Carpenter, L. Fortney, C. Rose, E. Fowler, J. Elliott J. Golson, V. Joshi, J. Kronenfeld, T. Snow, W. Yeager	6/11/69	d
BC-27	Study of the "A ₂ " Problem and Other Members of the $J^P = 2^+$ Nonet	<u>BROOKHAVEN NAT. LAB.</u> D. Crennell, U. Karshon, K. Lai, R. Kinsey, J. O'Neill, W. Sims, J. Scarr	6/11/69	d
D-7	Calibration of Cosmic Ray Space Flight Detector (Shower Counter)	<u>GODDARD SPACE FLIGHT CENTER</u> J. Ormes	4/7/69	c, h

Table of Programmed Experiments (cont'd) - 6

<u>Number</u>	<u>Title</u>	<u>Authors</u>	<u>Date Approved</u>	<u>Status</u>
ND-4 D-4	Tests of Sodium Iodide and Other Total Absorption Counters	<u>HEPL</u> E. B. Hughes, R. Hofstadter, I. Sick, W. Lakin, L. Madansky	5/8/68	g, i
NT-6	Fast Cycling Bubble Chamber Development	<u>SLAC</u> H. Barney, R. Blumberg, A. Rogers, S. St. Lorant	12/15/68	c, g
NFD	A Proposed Study of High Energy, Cosmic Ray Muons at Sea Level	<u>U. C. BERKELEY</u> S. M. Flatte, M. L. Stevenson <u>SLAC</u> W. Toner, T. Zipf	8/23/68	c, j
N-5	Sodium Iodide Counter Test	<u>HEPL</u> R. Hofstadter, E. B. Hughes	6/2/69	c

- a. Experiment is in data collection phase and was a prime user of accelerator time during the period.
- b. Experiment is in initial check-out phase and used accelerator time for check-out purposes.
- c. Experiment was being setup in the research yard during the period.
- d. Experiment was inactive in the research yard during the period.
- e. Bubble chamber beam is under construction and check-out.
- f. Experiment ready for future scheduled run.
- g. Used parasite beam time during the period.
- h. Experiment completed.
- i. Special test run performed.
- j. In data collection phase--did not use accelerator beam.

III. ACCELERATOR IMPROVEMENTS

Work continued during the quarter on fabrication of a gun modulator for the off-axis injector. The dc magnet was designed and fabrication was begun. This injector, when installed, will improve the operation of simultaneous beams with radically different intensities and will improve the reliability of the accelerator by acting as a back-up in case of malfunction of the main injector.

Computer control of klystron replacement in the accelerator became operational in June and operators are being trained in its use. As a by-product of the replacement function, the computer has been programmed to record klystron and modulator recycles, each time a variable voltage substation goes off or comes on, and each time rf drive is lost or recovered. This information has been very useful in klystron and modulator maintenance.

The planned modification of four sectors to provide pulse-to-pulse steering progressed satisfactorily during the quarter. After successful testing of the prototype power supply three additional units were nearing completion as the quarter ended. Installation is scheduled for August.

The pulse-to-pulse focusing for the four sectors mentioned above was delayed by problems with the quadrupole core. The contract was amended to secure laminations from the vendor, these to be built into cores by SLAC. The first two magnets were built by SLAC during June and will be installed and tested with a previously built power supply in August.

In a continuation of beam break-up studies, three sectors of the accelerator were blind-tuned in June. The sectors were dimpled in a previously determined pattern without removal from the accelerator. Three more sectors will be similarly tuned in August. A small cathode gun was installed during the last week of June and tests will be conducted at start-up in July to determine if the beam break-up threshold is related to cathode diameter.

Studies continued on the concept of using a fixed "wheel" for delivering interlaced positrons and electrons. Instead of building a new "wheel," it was decided to use the existing one, properly interlocked. An interlock system was installed during June and tests will be conducted in July and August prior to using the "wheel" for delivering positrons to Experiments BC-6, BC-18, and BC-19 using the 40" bubble chamber in September.

IV. RESEARCH DIVISION DEVELOPMENT

A. Physical Electronics

1. Semiconductor Secondary Emitter

The measurements of photo and secondary emission, which were carried out in May 1969, have been the object of careful examination. Secondary emission results predicted by a two-valley model for electron transport in GaAs show secondary yields of over 1000 at primary energies just above 20 keV and yields of about 50 for minimum ionizing particles. Such high results were not obtained in the first measurements of May.

It has become clear that photoemission yields corresponding to the optimum surface treatments of vacuum-cleaved GaAs have not been obtained either. Our first results were one order of magnitude below published optimum results. From the time dependence of photoemission yield in the measurements it is apparent that we did not have a sufficiently good vacuum to insure good results. Therefore, the tube has been opened, better conductance between the vacuum pumps and the body of the tube has been provided, and the tube is now undergoing a careful long bake in order to obtain pressures as close to 10^{-11} torr as possible.

A short paper has been submitted to Applied Physics Letters, covering the theoretical derivation of the secondary yield for GaAs, and indicating the areas of work in which that material will be very interesting, after the surfaces can be reliably controlled.

2. Glass Semiconductors

Evaporation of batch 002 (containing Si and Ge) proved to be difficult, insofar as the glass dissociates, spatters, and leaves a residue even after being heated to temperatures above its original melting point. The situation was not improved by the use of a covered evaporation boat. Flash heating of the sample appears to be desirable, and this approach will be taken in the coming quarter. No problems were encountered in depositing batch 003 which contains only As, Se and Te.

Evaporation masks with 1-mil slots have been designed for small area (1 mil square) devices. The masks have been made by two techniques: photo-resist and electron beam machining. The first approach was only partially

successful, but it is probable that it could be fully successful if additional development work was performed on the problem. Several masks were also produced by cutting the 1-mil slots in an electron beam milling machine procured from government surplus. Devices have been made with these masks, and are presently being tested. An electron beam gun has been assembled to pulse devices with 10-kV electrons.

3. High Vacuum Developments

Bakeout testing continued on a new Al to SS flange pair using a standard Cu gasket. Results at this time, with somewhat over 400 thermal cycles from 20°C to 220°C, showed two leaks, both less than 10^{-7} std cc/sec. They were closed with moderate tightening of the flange bolts, and sustained repeated bakeouts. This test is being continued.

Due to the small cross section of the ISR vacuum chamber and resulting low gas conductance, a distributed sputter ion pump is being investigated. The pump consists of two Ti plates and a 304 SS anode structure 1-1/2 inches by 1-1/2 inches by 48 inches, and would be placed in the vacuum chamber at the bending magnets and use their magnetic field to confine the discharge. This method would place the pump at the source of desorbed gases.

The first test results of this method of pumping seem encouraging, at least from a vacuum standpoint. Speeds of 125 l/sec have been measured.

Further tests are now in progress using a smaller anode radius and it is hoped this structure will increase the pumping speed to more than 300 l/sec.

B. Magnet Research

1. Supercritical Helium

Measurements are progressing at a slow pace in determining the correlation between heat transfer, pressure, and flow rate. We are now attempting to acquire either an orifice or a Venturi meter to measure the flow of supercritical helium through the test setup in order to be able to obtain three independent variables: temperature, flow, and pressure.

2. 2-Meter Wire Chamber Magnet Model ($2 \times 3 \times 2$ m³), 18 kG

The latest specifications on the performance of this magnet require that the homogeneity of $\int B dl$ be within 1% over the median plane, as well as over 80% of the rest of the experimental area. A magnet of this size will

require a substantial amount of measurement, modification, and shimming, which, due to the odd shape of the magnet, are not predictable from mere two-dimensional computer calculations. Therefore, the method of trial and error has been adopted. After each correction, the field in the gap is measured and the shimming modified.

In the original plans, the use of superconducting screens had been foreseen to correct for the fringing field effects. However, we are attempting to reduce the size of these screens by using adequate shimming methods such that only small final corrections need be done with the superconducting screen. The shimming procedure is similar to methods used in cyclotron-type magnets.

From the required magnet strength of 30 kGm, we chose the field strength of 18 kG and the effective length of 2 meters. Presently $\int B dl$ varies over the median plane by about 2%. Further improvements are being made.

3. Proposed 40-Inch Bubble Chamber Magnet

The previous calculations have been based on a surface heat flux stability of $.54 \text{ W/cm}^2$ and an operating current of 2800 A. It was generally felt that for a magnet which would operate over thousands of hours, the surface heat flux was somewhat high, and the above was considered a border value. Fortunately, we have been able to modify the magnet configuration and the conductor size and shape in such a way that the nucleate boiling heat flux is reduced to approximately $.40 \text{ W/cm}^2$, corresponding to an operational current of 2500 A. The magnet is completely stabilized for dc operation. We have used intrinsically stabilized conductor with 7-mil filament size, using approximately 225 filaments in the conductor ($0.385'' \times 0.25''$). The hoop stresses on the conductor could be confined to 15,000 psi by using pre-tensioned stainless steel tape wound bifilar with the composite conductor. The field homogeneity of the magnet is $\pm 2\%$, within the useful chamber region. The field generated in the usual chamber area is 70 kG. With these data, the final proposal for the conversion of the bubble chamber was worked out during this quarter.

4. Storage Ring Magnets

Preliminary calculations for an H-type magnet with shimmed poles have been made. However, the results, using a modified NUTCRACKER program, are not satisfactory, and further work in this area is indicated.

5. Computer Programs

(a) NUTCRACKER Program. Several improvements have been made:

- (1) The acceleration convergence method has been incorporated, using continuously optimized ω values. This method reduces computation by a factor of 2.2.
- (2) The computer will printout the required data in areas of interest, and no longer over the whole magnet including iron.
- (3) Field plots are now printed out.

(b) Coil Program, is being modified in such a form that the axial-symmetric system, where coils fill only a part of the circumference, can be calculated.

(c) Bar Program. The program to calculate two-dimensional coil configurations with variable current densities and any shape has been completed and is now available for general use.

6. Thermal Conductivity of Multi-Crystal Pure Niobium

A survey of the literature has shown that measurements of thermal conductivity performed by various workers (with different experimental setups, different impurities, and different conditions such as cold work, annealing temperatures, etc.) show a scatter of two orders of magnitude at a temperature of 2°K.

As thermal conductivity is of great interest in the performance of microwave cavities for linear accelerators, a test program has been initiated to measure the thermal conductivity of pure multi-crystal niobium bars at temperatures from 1°K to 4.2°K. In addition, the effect of geometry--specifically the rod diameter--on thermal conductivity, the effect of annealing, cold work, impurities, crystal boundaries, and other unknown parameters, will be checked systematically. Since the thermometry of such a problem is quite delicate, we are presently engaged in calibrating new sets of carbon and germanium resistors which should allow a reproducibility of better than one millidegree and an accuracy of 10 millidegrees over the entire duration of the test.

C. Conventional Data Analysis Activities

1. Maintenance

The second magnetic tape unit for the SPV-B measuring machine was installed during the week of June 23.

NRI #6 was placed on-line in mid-June and operated about 2 weeks. Operator comments seem favorable. The machine is down at the moment to correct a couple of bugs, one of which is a rather elusive intermittent, twice-a-day type.

Hummingbird III mechanical parts are near completion. Assembly is beginning. Still waiting for long delivery items: sprockets, encoders, cylinders. Electronic parts due latter part of July.

70 mm thin film (.003 thick) test runs were made on 4 different types of scanning and measuring machines. Conclusion: Film is unsatisfactory without considerable changes. The film buckles at most rollers and does not guide well through the SPV-A pinch type capstan. Further test runs on virgin film are to be made during July.

The Spiral Reader has been changed to SLAC 40" HBC 70mm film format. Magnification changed to 3x; new projection lens, lamp box, and platen installed.

2. Programming

Data Expediting. Procedures and statistics for Time Card, 360 NRI data reduction programs being continued. Training in error-recovery techniques being continued.

NRI System. Diagnostic software for EMR 6020 components still being negotiated. Implementation of EMR 6020 tape operating system waiting for diagnostics. Technical support for scanning and EMR maintenance personnel continuing.

Programming Maintenance and Development. SPV-B output routines for Experiment 13 being coded. The NRI data reduction program redevelopment

continuing. Drivers which will test the BUCAPS geometry routines on the 360 have been coded and compiled. Training in BUCAPS, EMR 6020 assembly language and IBM 360 PL/I and JCL continuing.

3. Scanning and Measuring Operations

Measuring totals for the month of April are as follows:

NRI (5 machines)	14,510 events measured in 1601.16 hours
Vanguard (3 machines)	1609 events measured in 282.50 hours
SPVB (2 machines)	2185 events measured in 252.00 hours
Hummingbird	15,000 events measured in 280 hours.

In May there were 57.8 scanners who worked 53.04 man months. 406,800 frames were scanned during the month and 40,415 events were measured on 12 measuring machines. This can be compared to July, 1968, in which 22,774 events were measured by 54 scanners on ten measuring machines. At that time, seven experiments were being scanned and measured in CDA; currently, there are nine experiments not counting the cosmic ray experiment which will soon begin. The Hummingbird, an automatic measuring machine capable of producing ten times the amount of measurements as a conventional machine, is being used in production work, and 15,877 events were measured on it this month.

In June, 390,000 frames were scanned in 2700 hours and 26,600 events were measured in 2600 hours. The Hummingbird measuring machine was down all month and did not contribute any events. The NRI system is currently producing about 4000 events per week. It is anticipated that if all goes well, the Sprial Reader will begin production measuring within a few weeks. The total man-months worked dropped to about 50 this month.

D. Computation Group Activities

1. Computational Graph Theory

The basis of a formal theory of heuristic search has been developed. The model has been tested over the domain of fifteen puzzle problems. The basic results of work in this area appeared in SLAC Report No. 104, "Bi-directional and Heuristic Search in Path Problems," by Ira Pohl, (May 1969). Most exciting are the theorems showing the importance of appropriately weighting the heuristic term in the search function.

2. Compiler Implementation Language (CIL)

The language is defined in SLAC Report No. 102 (March 1969). The compiler for CIL (except for the part which translates code generation statements)

is essentially programmed in CIL itself. This work proceeded in parallel with the language design and gave us some practical experience with the language.

The problem now is to get the CIL compiler (which is written in CIL) into machine language. We are programming a "quick and dirty" compiler in PL/1 to translate a restricted version of CIL into OS/360 assembly language, relying heavily on macros. With this we can translate our CIL compiler into machine language and bootstrap our way up.

E. Rapid Cycle Bubble Chamber

The two-inch version of the rapid cycling bubble chamber has been moved into the research yard and has run successfully in parasite beam 12 at 45, 60, 72, and 90 expansions per second.

The chamber is basically a two-inch diameter multiconvolution bellows with a depth of two inches immersed in a liquid hydrogen cooling bath. The back of the bellows is welded to a stainless steel spherical mirror which provides dark field illumination. The chamber is photographed at nearly one-to-one magnification and has very limited depth of field, hence, the track reflections in the mirror are no problem.

The chamber is expanded by an electromagnetic linear actuator connected to the rear of the chamber with a drive rod. A capacitor is discharged into the armature of the actuator to expand the chamber.

The light delay was varied from one-quarter to one-and-one-half milliseconds with respect to the beam, and apparent bubble diameters from ~70 to ~150 microns were obtained. With light delays less than one millisecond, the chamber falls into near resonance and the pressure in the chamber varies nearly sinusoidally. This mode of operation requires finer temperature and pressure adjustment for stability than does the pulsed mode but it requires much less driving power and the pressure overshoot still completely extinguishes the tracks.

A four-inch diameter by three-inch deep chamber subassembly replaced the two-inch version in May. This chamber is basically the same as the two-inch except that the window and valve flange and the mirror are made of copper for better cooling. The new chamber also has a large ratio of diameter-to-height and hence should have a higher resonant frequency. The chamber has been operated and produced good pictures at 45 and 90 cps.

V. PLANT ENGINEERING

During the quarter several projects were completed and the facilities placed in use. Included in this category are: Enclosing of the Heavy Assembly Building Welding Shop; installation of foundation and utilities at the new location of the streamer chamber building; modifications to the Crafts Building heating and ventilation system; and relocation of three large temporary buildings from the shops area to the research area and BSY storage yard.

Relocation of the front entryway incident to the widening of Sand Hill Road was completed and the new facility placed in service for SLAC traffic on June 16, 1969. Landscaping improvements and a permanent information booth at the new site are in the planning stage.

Bids have been received and a contract will be awarded shortly for the relocation of SLAC's Library within the Central Laboratory. For convenience of scheduling, construction on this project will be held up until late summer.

Other projects are in various stages of progress, as follows:

- (1) Electronics Building Air Conditioning - bid opening scheduled for July 8, 1969.
- (2) Enclosing of Room 109B at Cryogenics Laboratory - construction underway.
- (3) Enclosing of Fabrication Building Cleaning Shop - contract awarded.
- (4) South Staging Yard Low Voltage Distribution - construction underway.
- (5) Additions to the LCW cooling and pumping capacity in the research yard - field work and procurement underway.
- (6) Craft Building Dust Collector System - installation contract awarded.
- (7) Magnet Shelter for K⁰ Beam - construction underway.
- (8) Modifications to Radioactive Water Service in End Station B Target Room - in design.
- (9) Enclosing of Pulse Tank Maintenance Area - out for bids.

An engineering study for the conversion of the SLAC two-mile machine to a superconducting accelerator was continued. Scoping and cost estimating for a proposed storage ring to be sited in the north portion of the research yard was completed.

The program of plant utility operation and minor modifications to buildings as a general service to SLAC was continued. The highest peak electrical demand to date was registered on June 20, 1969 at 51.65 megawatts.

VI. KLYSTRON STUDIES

A. Development

1. Summary

The RCA development program to deliver tubes capable of operation at 270 kV with 30 MW minimum power output is beginning to bear fruit.

The work at Litton to eliminate the problems encountered during the past year is still continuing.

SLAC has been testing some cathodes for preliminary design of the CW amplifier needed for the proposed superconducting accelerator.

2. High Power Klystrons

Litton Subcontract. As mentioned above the efforts of Litton to eliminate the problems which have plagued their production during the past year appear to be getting under control, and during the month of June, six Litton tubes were acceptable. If the number of acceptable tubes continues at this rate or better one could consider that the worst Litton problems are behind us and the availability of Litton tubes for use in the gallery should again increase.

As indicated last quarter, the majority of acceptable Litton tubes has been new tubes. This is not to indicate that there are no rejectable new tubes nor does it imply that there are no further problems with the Litton tubes delivered last quarter. As in the past we have experienced some serious tube magnet interchangeability problems, and instabilities do show up even in the new tubes, but not to the same extent in general as those which are present on rebuilt tubes.

RCA Subcontract. The program set up by RCA to improve their tube efficiency and operating level is showing signs of success. During the quarter RCA submitted 7 tubes designed for operation at 270 kV. All 7 were accepted, although 1 was accepted for operation at 250 kV only because of a gun oscillation which begins at approximately 260 kV beam voltage. Of the other 6 tubes 3 gave a power output of 30 MW or higher at 270 kV, the other 3 were somewhat below 30 MW. In addition, RCA delivered twelve 21-MW tubes during the quarter.

Although the results of the development program for 30-MW tubes are very encouraging RCA realizes that some additional work is needed to insure a better yield. RCA has been able to accomplish these results in spite of

various delays experienced due to test component failures. In addition, these tubes which have been delivered up to now have to be operated in a magnetic field somewhat higher than the standard RCA permanent magnet. It is hoped that during the next quarter additional improvements in the RCA tube design will result in achievement of the full specification in the RCA standard magnet field.

SLAC. The oscillation problem observed in SLAC tubes has not been fully resolved yet. The first attempts at solution by suppressing unwanted modes in the third cavity have not been successful. Additional cold testing of the whole tube body is continuing to ascertain the source and eliminate the oscillation problem.

In anticipation of additional 270-kV-operation tubes, a new collector has been designed and tested. The aim of the redesign was to increase the water flow at the same pressure drop experienced in the present tube. The first results are encouraging with the total pressure drop of 10 to 12 psi at 10 gpm compared to approximately 30 psi at 10 gpm in our present design. The cooling efficiency of this collector appears excellent, and it gave us no indication of either cavitation or boiling even with a reduced flow of 6 gpm and a dissipation of 85 kW in the collector.

3. Klystron for Superconducting Accelerator

The first 2 diodes have been built and tested in preparation for this program; one with an oxide-coated cathode, the other with a dispenser cathode. Both have shown good characteristics from an overall gun design standpoint with a measured micro-perveance of 0.77 at 21 kV. The oxide cathode was removed from test after 420 hours of operation at 21 kV to enable testing of the dispenser cathode, which had accumulated 140 hours at the end of the quarter. There appears to be more tendency for arcing in the dispenser cathode than the oxide coated.

The first beam tester built developed a major leak in the anode nose during bake. The second beam tester has been successfully built and baked and the cathode has been converted. We expect to start testing the beam tester during the next month.

4. High Power Windows

Two (2) SLAC windows failed on SLAC tubes during initial tube tests because of operation at excessive temperatures. Based on limited data to

date it appears that the failures may be related to the smoothness of the surface of the new windows prior to coating. A new schedule of roughening the surface finish by wet blasting prior to coating seems to have improved the situation, and additional oxidation of the load side coating on the window by exposing it to air at reasonably high temperature also seems to improve the condition. Additional investigations on surface finish of old windows is being undertaken to assist in correlation between coating thickness, surface finish, and operating temperature.

Two (2) SLAC windows failed in operation. In one case it appears that a gas discharge may have caused removal of some of the coating and resulted in localized heating. The high temperature gradients would then have caused the window to crack. The second window was almost certainly lost by an external cause. A loose fragment of ceramic was found lying at the seal of this window; this ceramic chip was apparently a residue of a window which disintegrated when an RCA klystron failed on this station in September 1967.

5. Driver Amplifier Klystrons

One driver amplifier klystron failed in test from what appears to be a weak mechanical joint in the output window. A minor redesign of that assembly is being undertaken to avoid that problem in the future.

B. Operation and Maintenance

During the quarter we had 17 high power klystron failures for a total klystron operating time of 335,000 hours. There were 23 spares available for immediate installation and more than 50 additional spares without permanent magnets at the end of the quarter.

Driver amplifier klystrons operated approximately 48,500 hours (including test lab use). There were 2 failures.

There were no problems with the main booster klystrons.

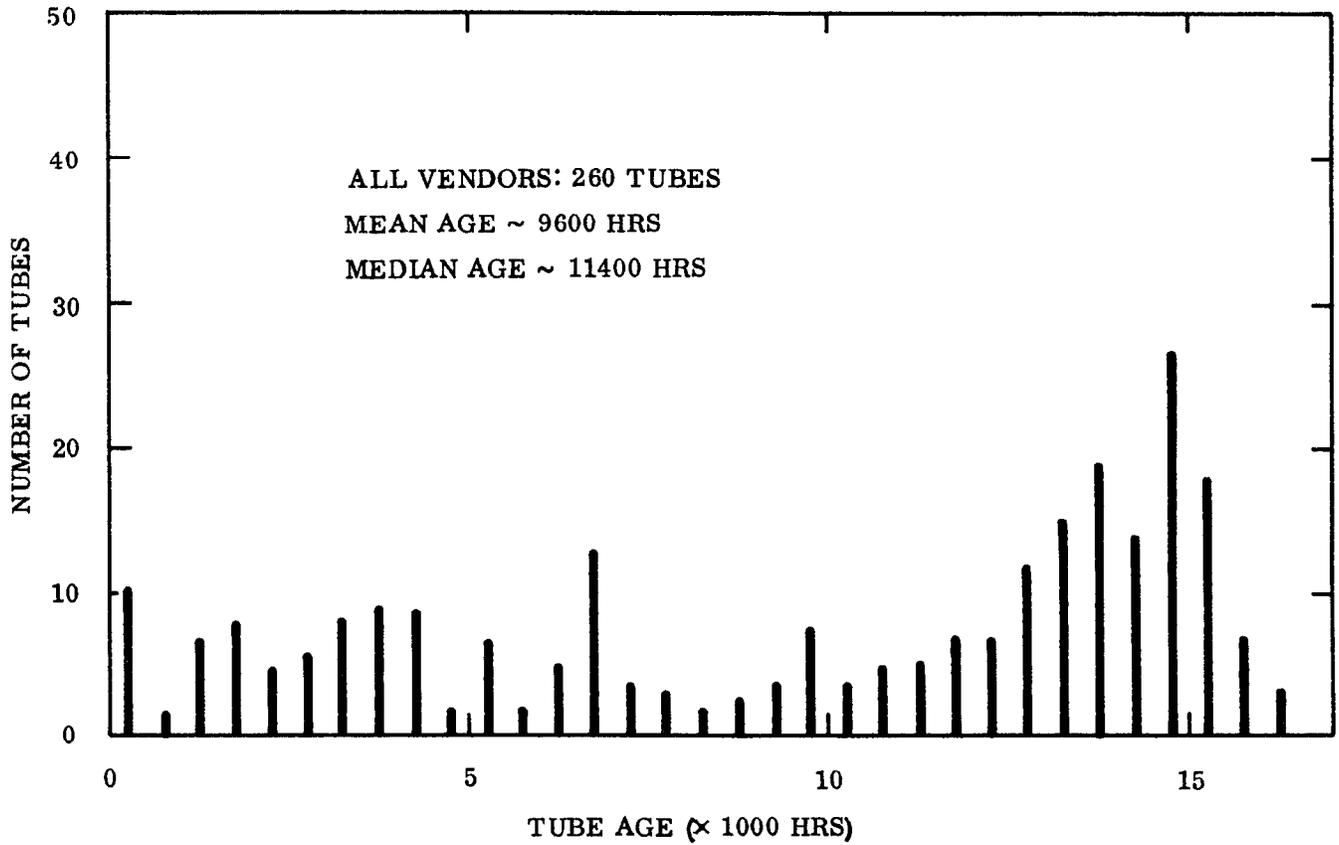
1. High Power Klystron Operation

Table II gives a summary of the usage and failures since the beginning of machine operation, updating Table II presented last quarter.

Figure 2 shows the tube age distribution for all operating tubes as of July 1, 1969.

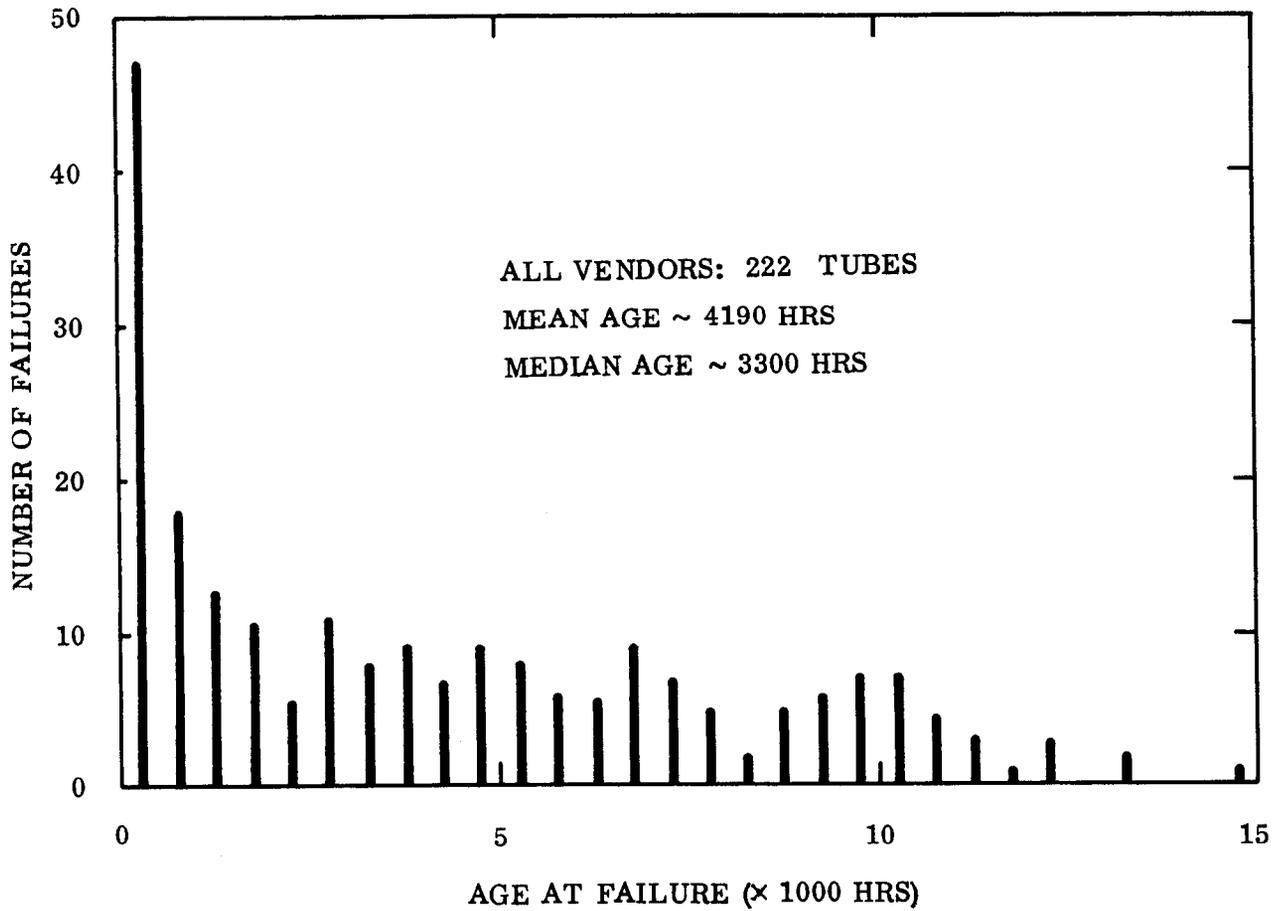
The mean age of all tubes is 9600 hours, the median age 11,400.

Figure 3 gives the age distribution of all failures through July 1, 1969, indicating the mean age at failure 4190 hours and median age at failure 3300.



1422A2

FIG. 2--Age distribution for all operating tubes, July 1, 1969.



1422A3

FIG. 3--Age distribution of all failures in 500-hour increments through July 1, 1969.

The data shown in Figures 2 and 3 have been used to compute the failure probability and survival probability for all tubes. The results are shown in Figure 4.

Figure 5 shows the mean time between failures (MTBF) (cumulative), mean age at failure (per quarter), mean age of all operating tubes, and cumulative hours per socket since the beginning of operation.

2. Effect of Operating Level

At the beginning of the quarter the operating level was raised from approximately 235 kV to approximately 245 kV on all sectors except 0, 1, 2, 21 and 22. A survey of one-half of the tubes operating at 245 kV indicates that the mean of the peak of the power output of the stations operating at this level is 21 MW. In spite of this increase in operating level the MTBF for the quarter is well above the cumulative MTBF.

One can also begin to look at the effect of operation at 265 kV (first 7 stations of Sector 21, and beam separator klystron). There has been a total of 4 failures. In addition, 2 tubes were removed for excessive over-current faults and are no longer operable at 270 kV but are completely satisfactory for operation at 250 kV.

Three of the failures were SLAC tubes, 1 at 900 hours, 2 at 1800 hours approximately. One was an RCA tube at slightly under 400 hours of operation. Two SLAC tubes failed for excessive arcing and 1 by window failure. The RCA tube failed for instability. An examination indicated that the output gap had been badly eroded by the beam.

Based on the small total sample, it appears that the probability of early failure is somewhat higher than indicated in Figure 4 for all tubes under all operating conditions and it is also probable that the MTBF under these operating conditions will be approximately one-half of what is experienced in the rest of the gallery. We will be carefully monitoring operation at the higher level to guide in the determination of improvements needed to obtain the same operating life as has been experienced up to 245 kV.

3. High Power Klystron Maintenance

Operating experience of high power klystrons through the end of the quarter is shown in Figure 6. There were 54 replacements which indicates a slight increase in the ratio of replacements to failures to 3.2. However, during this quarter there were proportionately more replacements because of

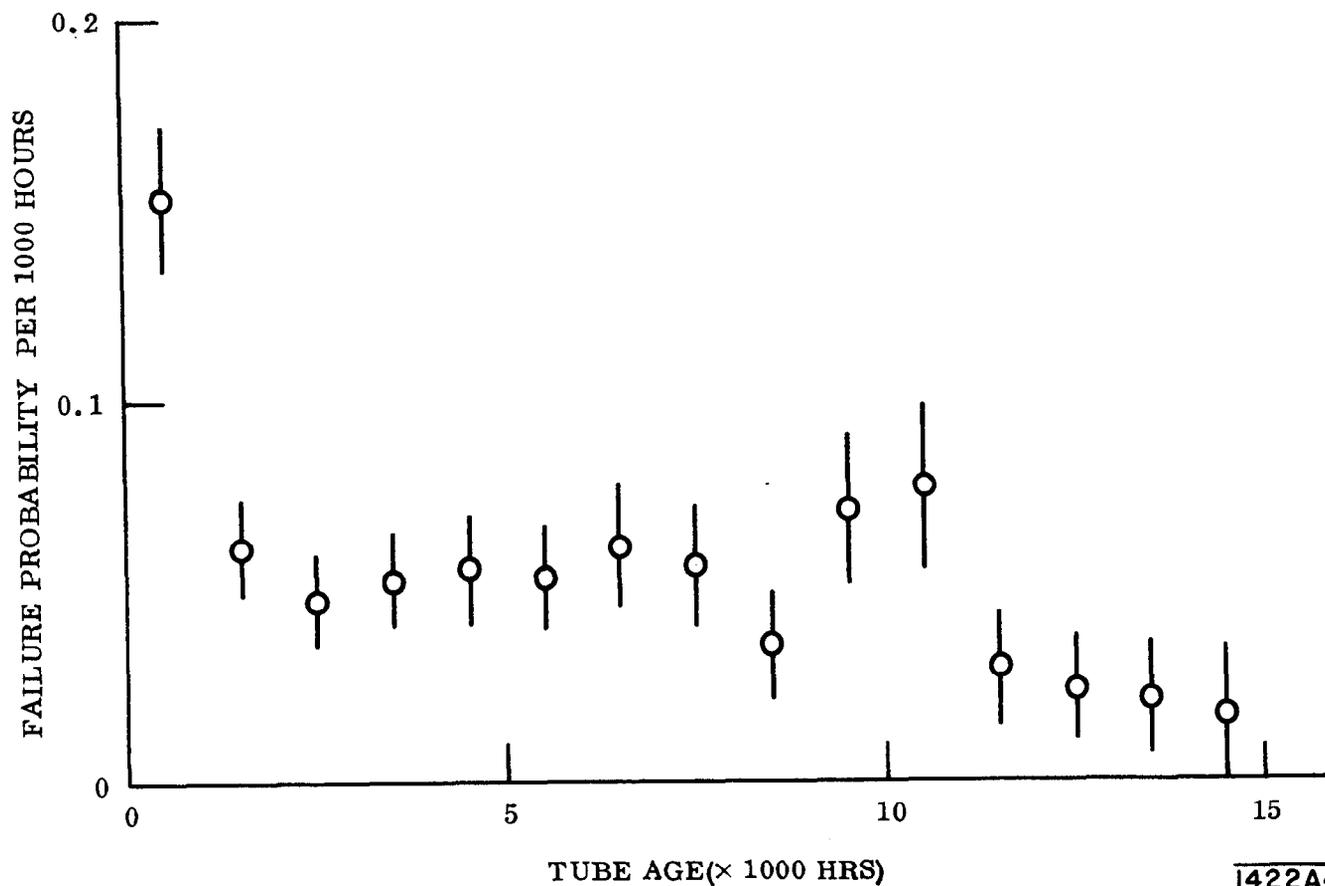
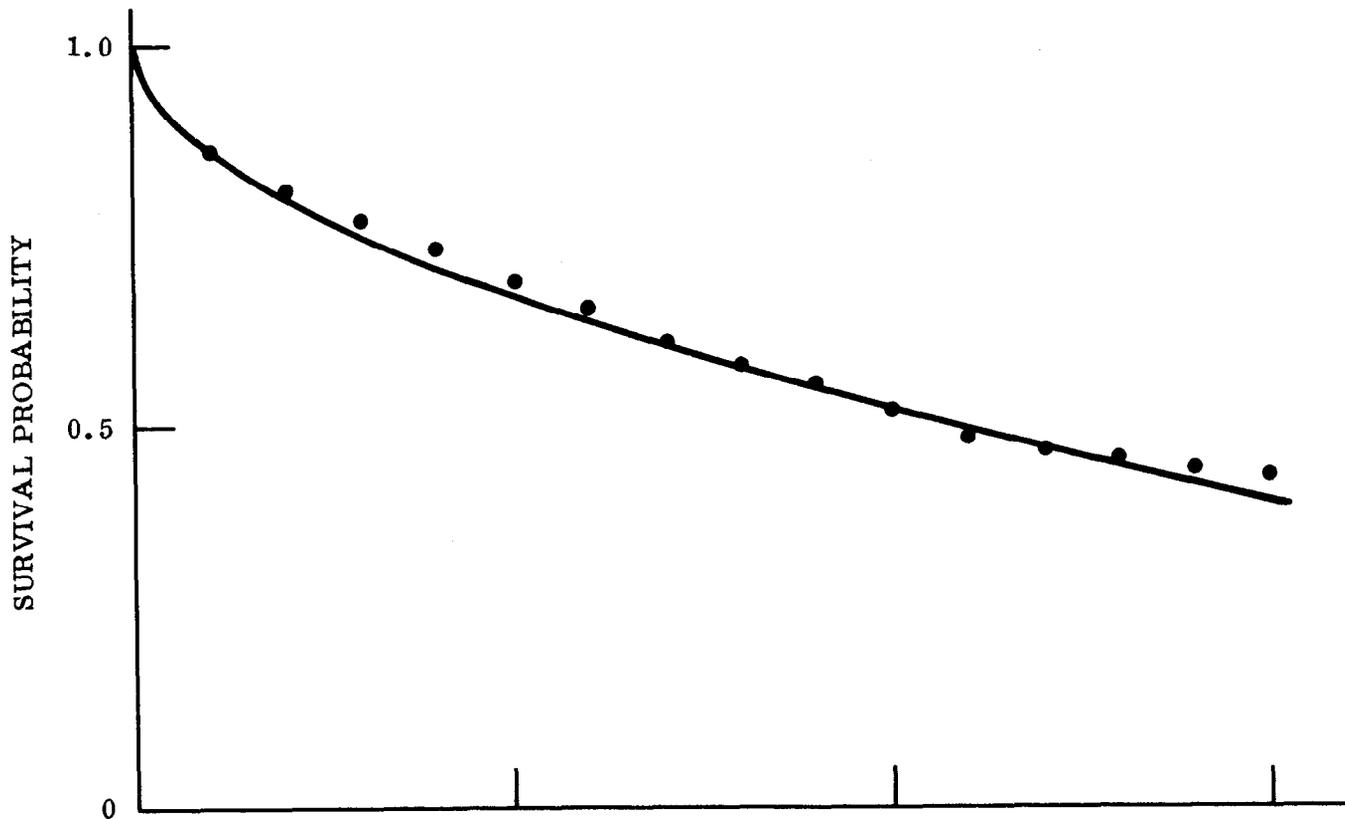
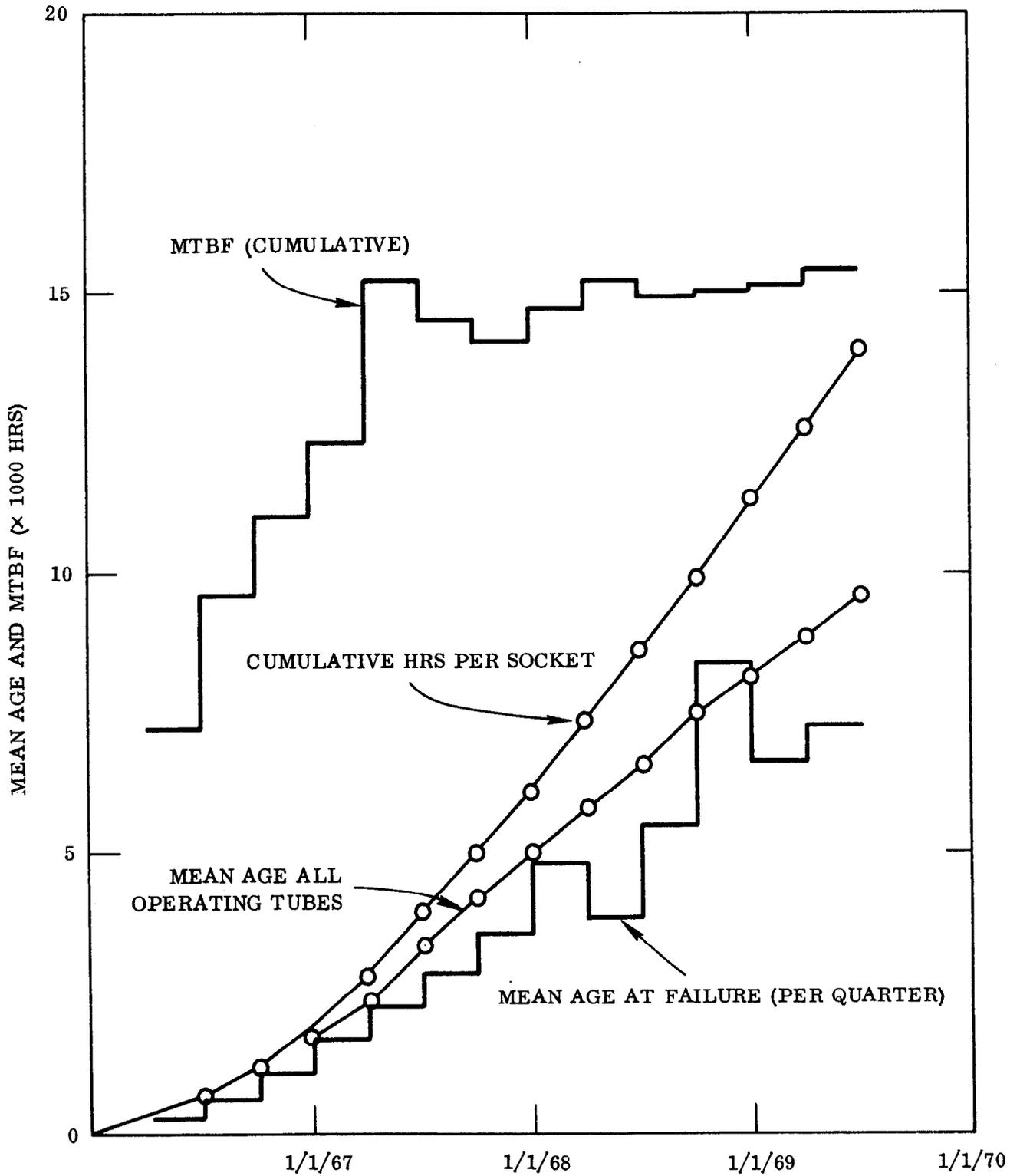


FIG. 4--Survival and failure probability for all tubes, July 1, 1969.

1422A4



1422A5

FIG. 5--Cumulative MTBF, mean age at failure per quarter, mean age of operating tubes, and cumulative hours per socket for all operating tubes, July 1, 1969.

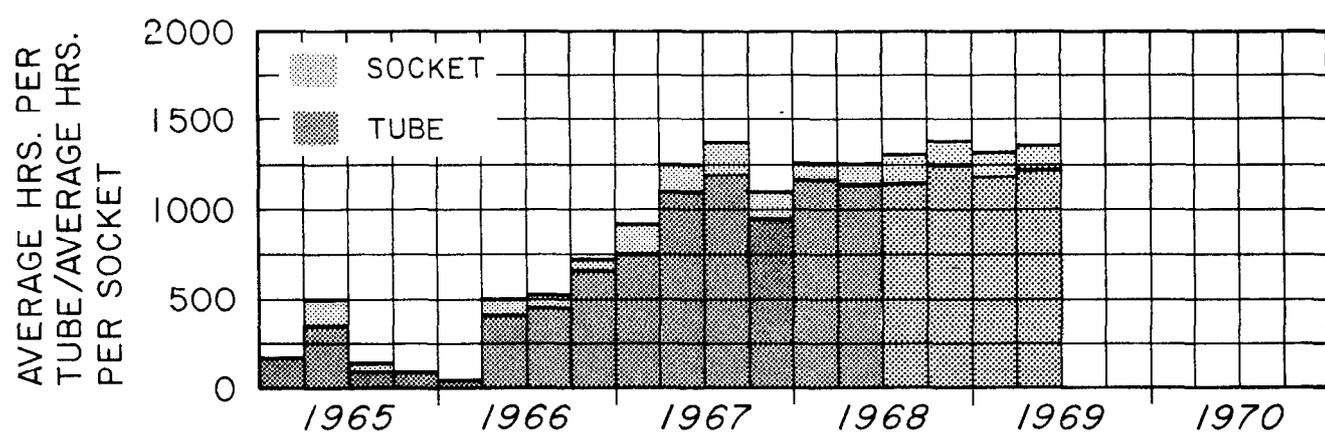
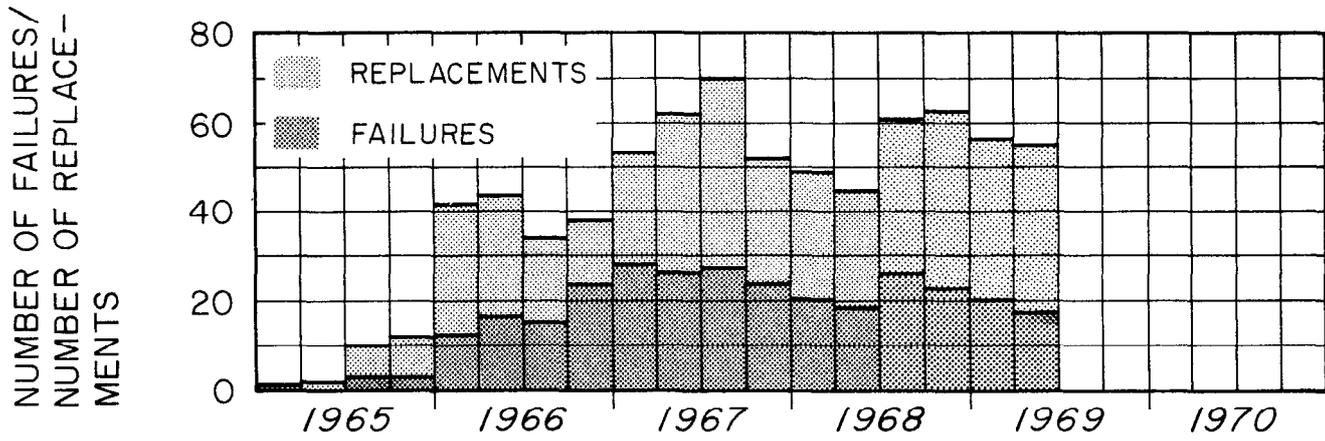
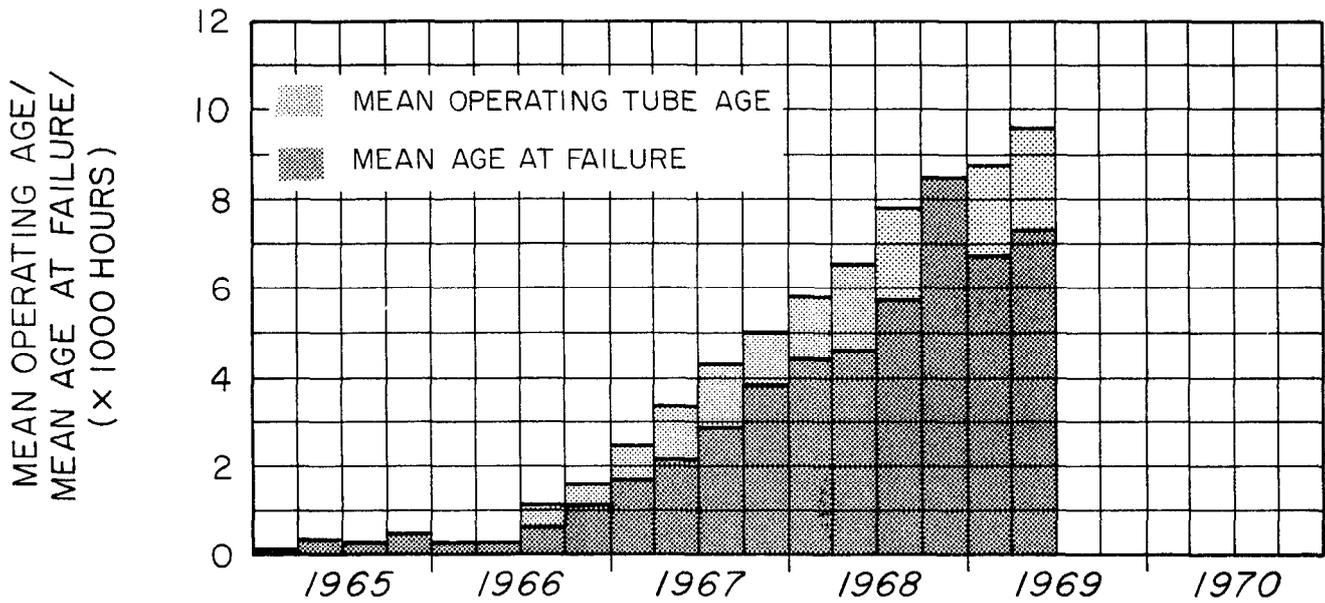


FIG. 6--Operating experience of high-power klystrons to July 1, 1969.

1969A1

suspected tube problems (over-current faults, window problems, etc.). Actual tube failures were well below the replacements due to suspected tube failure.

The present accelerator operation schedule makes it more difficult to maintain a high power klystron preventive maintenance program at the optimum desired level of once every 500 hours. During the quarter the stations were checked at the rate of approximately once every 700 hours of operation.

4. Driver Amplifier Klystrons

The maintenance of driver amplifier klystrons is continuing, and as indicated some of the problems initially attributed to the klystrons may in fact have originated in other areas of the drive system. As reported last quarter a maintenance program for the sub-drive line has been undertaken by Accelerator Electronics Maintenance Department, and Sectors 29 and 30 have been completed. However, a survey of drive power and attenuator studies throughout the gallery indicated that changes in the drive power to individual klystrons could occur without any changes being made in either driver amplifier output or manual attenuator setting. Changes of drive power in excess of 10% caused by supposedly passive devices in the drive system were found in approximately 10% of the stations.

Figure 7 shows the tube age distribution of all driver amplifiers, and Figure 8 gives the operating experience for these tubes.

5. Vacuum System

There were no problems in the gallery vacuum system during the quarter.

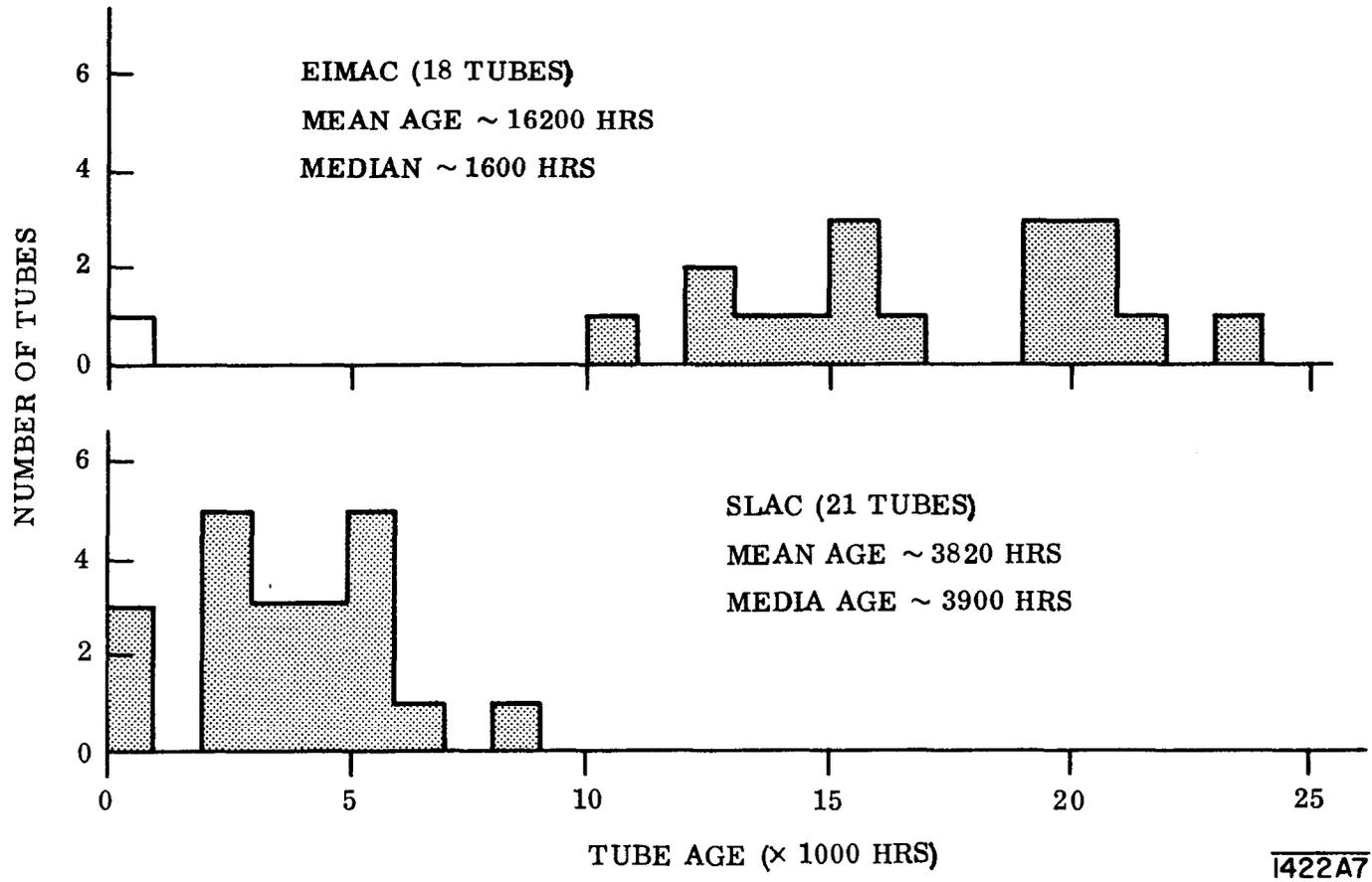


FIG. 7--Tube age distribution of all driver amplifier tubes in 1000-hour increments to July 1, 1969.

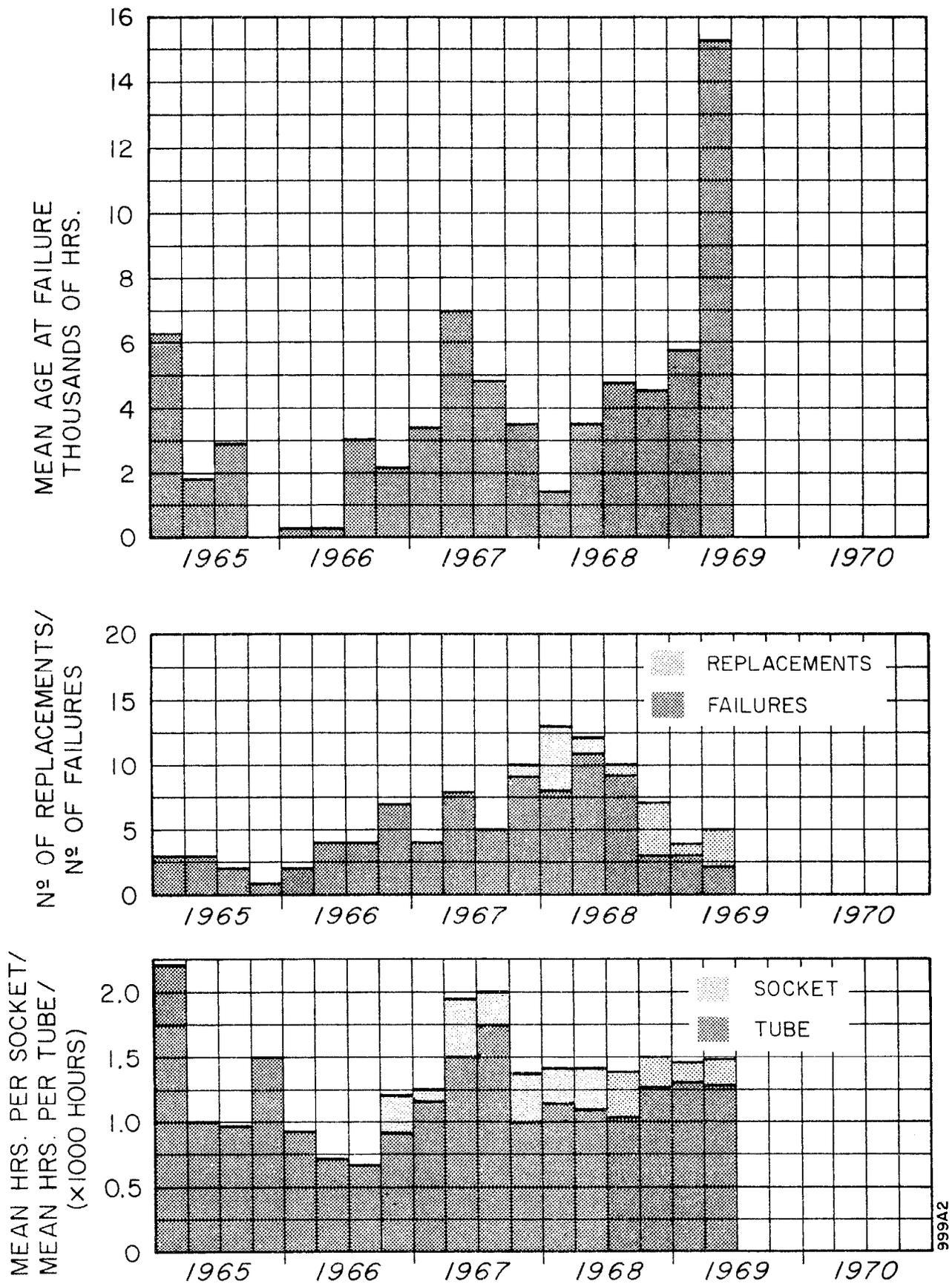


FIG. 8--Operating experience for all driver amplifier tubes to July 1, 1969.

999A2

TABLE II
KLYSTRON MTBF

Dates	PER QUARTER				CUMULATIVE			
	Operating Hours	Failures Number	Failures Mean Age	MTBF	Operating Hours	Failures Number	Failures Mean Age	MTBF
To 6/30/66					129,400	19	260	7,200
To 9/30/66	111,000	8	610	14,000	240,400	27	360	9,000
To 12/31/66	154,000	11	1,100	14,000	394,400	38	575	10,300
To 3/31/67	207,000	13	1,490	15,900	601,400	51	810	11,800
To 6/30/67	287,000	9	2,490	32,000	888,400	60	1,060	14,800
To 9/30/67	330,500	25	2,860	13,300	1,218,900	85	1,590	14,500
To 12/31/67	263,000	21	3,520	12,500	1,481,900	106	1,980	14,100
To 3/31/68	309,500	17	4,800	18,200	1,791,400	123	2,360	14,700
To 6/30/68	306,000	15	3,820	20,400	2,097,400	138	2,520	15,200
To 9/30/68	314,200	24	5,500	13,100	2,411,600	162	2,960	14,900
To 12/31/68	349,800	23	8,350	15,200	2,761,400	185	3,630	15,000
To 3/31/69	328,600	20	6,610	16,400	3,090,000	205	3,930	15,100
To 6/30/69	335,000	17	7,280	19,700	3,425,000	222	4,190	15,400

VII. INSTRUMENTATION AND CONTROL GROUP

(January - June 1969)

Summary

The PDP9 computer was installed in the fall of 1968. A 10^6 disk was installed in February 1969. Interface hardware was installed to read status and control the accelerator by January 1969. Status can now be read from Sectors 0 thru 30. Data Assembly Building (DAB) status will be available soon. Four analog signals from each sector can now be digitized and read by the computer. Pattern switch positions can also be read into memory. Four I/O handlers have been written (Interrupt, Teletype Printer and Keyboard, Status, and Pattern). These have formed the basis for the following test and user programs: Klystron Replacement, Quadrupole Setting, and Status Logging. Diagnostic programs have been written to test and help trouble shoot the interface hardware. Methods are under study to computer operate sector controls in parallel.

General

The Central Control Room (CCR) computer is a general purpose machine which will assist the accelerator operators in a variety of tasks. The hope is to provide eventually a system which will perform any function that is required by the operator. This is in contrast to a system that uses a computer or several computers each doing a specialized task.

Initial hardware efforts will interface the computer to all available information and controls, and software will provide useful operational routines on demand. Operational programming efforts to date have yielded specific routines such as klystron replacement and quadrupole setting to test the interface and basic operating routines. User programs have been written which format and print out operational data on modulators, klystrons, and other accelerator components.

Hardware

Status monitoring information from Sector 0 has recently been connected to the computer input. A program is now being prepared to monitor the security of the machine-protection tone-loop system. This system has been instrumented manually but due to its complexity, faults have been only casually verified. The computer is in a position to relate cause and effect since status

is now available from all thirty sectors and the injector. Status from DAB will be added soon thus allowing the computer to log security data from the research area. Status-monitoring frame synchronization had to be supplied to Sector 0 and to DAB and the bit-synchronization circuitry was modified for greater reliability.

The remote control switching interface from the computer was modified so that a sector and a control channel can be selected and either a "control command" signal initiated and/or a "read analog" signal initiated. For example, a quadrupole in a sector can be controlled and read simultaneously. The computer interface interrupts No. 3 switched sector panel in CCR and takes priority over the other two switched panels while the computer issues a command. Four analog signals are now available to the computer; they are: Quadrupole, beam loading, linear Q gain, and De Quing (VVS reference) voltage. All quadrupoles can be read and adjusted except the one at BAS I.

We have experienced some difficulty with a form A, form B reed relay used in a form C configuration in the control interface. These units have been replaced with a true form C in the most critical circuits. A new selector has been built and installed so that control signals sent to the sector could be separated from control signals which select analog signals, thereby reducing the frequency of unnecessary relay actuation.

The computer can now operate all remote controls which belong to the sector relay tree system. Controls now inaccessible to the computer include injector and DAB equipment and the steering dipole current controls.

The DS01 (computer input multiplexer) now has three words of input. Words 1 and 2 are status signals from Sector zero to DAB. Word 3 strobes in pattern switch information and the digitized value of a selected analog signal. A 64-position scanner has been constructed which operates at 360 pps (2.78 ms per position). Scanner lines from 1 to 47 strobe in pattern switch positions, line 60 strobes in a selected "digitized" analog signal, and 61 thru 64 will strobe in channel and sector information from the three switched sector panels.

Pushbuttons have been installed on the control console to permit the accelerator operators to initiate specific routines in the computer. The buttons are connected to the DEC-supplied "pulse input detector" interface.

Software

The programming effort has been divided into two tasks; (1) to write system programs; (2) to write user programs. The operating system software include I/O routines such as: interrupt handlers, teletype printers and keyboard handlers, status handlers, and pattern handlers. The interrupt handler is a subroutine which recognizes and modifies the basic program at a 360 pps rate as well as reacting to teletype keyboard and printer flags. The status handler checks all status information for synchronization and validity. The pattern handler formats the pattern switch data. These routines are the basis for a klystron replacement test program and a quadrupole setting program which is just now being written to read and store the values and reset all quads to the previous value on a closed loop basis.

Users programs have been written to run compatibly with the system programs. A status logging program now stores klystron and modulator recycles for a period of 8 hours and then provides a printed format using the status collected by the operating system. Printouts are provided at 0800, 1600, and 2400 hours and totals are accumulated for a 24 hour period. An immediate printout occurs when a Variable Voltage substation goes on or off, or if rf drive goes on or off in any sector. Programming efforts now are aimed at printing out all this data if a major status change occurs, i.e., power dip, main booster goes off, or personnel protection system opens. The operator, upon request, can obtain the pattern switch printout, number of klystrons on standby or klystrons off, the energy per station, and number of klystrons on each beam.

Diagnostic programs have been written to check and help maintain the hardware interface. They include programs to check the 360 pps synch, a remote control--status monitoring loop test, an analog readout test, and a pulse input detector test. Several of these tests have options so that portions of a system can be checked or looped continuously. The analog test program has options to change the number of samples taken, the number of steps per sector, and the type of analog being read, and several time delays.

Future

The computer can now read most CCR pattern switch settings including the Sector 27 and 28 toggle and the high-low-off beam rate switches. It is planned to provide pattern controls that can be operated by the computer as

well as the operators. The first step will probably add pulse-to-pulse computer control of Sector 27 and 28 patterns. This will provide part of the system to implement pulse-to-pulse klystron replacement.

The sector relay tree remote control system limits the accessibility of controls to one at a time in any one sector, and three at a time in all sectors. Modifications are under study which would circumvent this limitation. One arrangement would provide a sector memory which allows the computer to issue a command to a sector and move on to a new sector as soon as an acknowledgement is received. A second method under study would provide mechanical latching of several controls in a sector so that the computer could be making several changes in parallel. These systems are aimed particularly at quadrupole adjustments which at present are tedious manually and time-consuming for the computer.

A fast analog system is being designed which will use the Log Q transmission system. This system is required to interface pulsed quadrupole and steering analogs to the computer.

A number of local CCR status signals will be connected to the computer to avoid conflicts between operator requests and computer-issued commands.

VIII. COUNTING ELECTRONICS GROUP

(January - June 1969)

A. General

The Group activities are separable into two areas: about two-thirds of the people in the group are on direct assignment to Research Division groups or to other Technical Division groups, working on group-related development projects; the remaining one-third constitute a central group which supports a variety of general-interest development projects, in addition to group or project services such as management of the Electronics Pool (HEEP), Electronics Stores coordination, etc. In the case of the central group, engineering support is often provided on a part-time basis to both in-house and outside experimental user groups.

B. Group A Support

1. Experiment E-29

The "Helmholtz Coils" and their associated electronics were modified to handle 150 amps in either axis and thus provide a 1.5 inch \times 1.5 inch raster at the pivot in End Station A.

2. General

Counting Electronics is providing assistance with fabricating and testing a proportional wire chamber. A chamber with variable wire spacing is being built to determine optimum spacing for hodoscope applications. Special winding fixtures are being built.

C. Groups B and C Support

1. Experiment E-41

In addition to general supporting activities such as the control room and rack layout, power requirements, and the high voltage power distribution system involved in the Counting House move from B-beam to C-beam, the following new equipment has been designed, built, and tested:

- (a) A 640 digit oscilloscope display system for the Science Accessories Corporation blind scalers which provides a numeric display of all scalers simultaneously and a controller which allows these scalers to be multiplexed with the A/D converter into the IBM 1800 under data channel operation.

- (b) A general control system to control multiplexing the above equipment, spark chamber scalars, buffer storage latches, scope display and the 360 link into the 1800.
- (c) A set of three Scanner Control Units.
- (d) A Fixed Word Generator - 2 units at 4 words each.
- (e) Two sets of modules for a 64-channel Strobed Latch Unit plus associated scanners and level shifters and a single bin plus power supply.
- (f) A Sync Fan-In and TTL to IBM Voltage Level Converter.
- (g) A Ready-Select IBM to TTL Level Converter.
- (h) A NIM to TTL Event Fan-Out.
- (i) Two 4-Word External Scanners.
- (j) A Scanner Control to SAC Magnetostrictive Readout Interface Adaptor.

In addition, the Buffer Storage Junction Box Unit and the LRL Monitor Unit were modified extensively.

Incorporation of the equipment listed above makes it possible to multiplex data generated by thumbwheels, hodoscopes, and spark chamber equipment into a single data input channel of the IBM 1800 computer.

The Scanner Control Units contain timing and control logic for preclearing the equipment under control, for multiplexing the data, and for displaying any selected word of information on the data bus.

The Fixed Word Generator provides a means for generating data from thumbwheels. An internal scanner controlled by the Scanner Control Unit strobes each word in sequence onto the data bus.

The 64-channel Strobed Latch Units were described in the October-December 1968 Quarterly Report (SLAC-98).

2. Experiment BC-10

The complete interface for the PDP-9 has been built and is being tested. The design allows interchangeability of device controllers with those used with the IBM 1800. The following sections have been tested and are working.

- (a) The control panel utilizing the automatic priority interrupt system.
- (b) The scope display and TSI under program control.
- (c) The 40" HBC roll and frame indication under data channel operation which will be expanded to include the buffer storage latches.

The data channel controller and multiplexer which will allow the Hewlett-Packard 200 MHz linear ramp ADC to multiplex into the PDP-9 the time and height information from the scintillators mounted in the 40" HBC vacuum tank is being built and should be tested by September 1, 1969.

D. Group D Support

Experiment E-48

Electronics for the K^0 decay experiment in the streamer chamber was designed and is now under construction. It consists of interfacing 40 A/D converters which contain time and amplitude information from 20 scintillation counters to a PDP-9. The interface consists of a set of fixed data thumb-wheels, two multiplexers, three strobe generators, one indicator module. In addition, the selection and wiring of DEC cards for controlling the flow of information to the PDP-9 was diagramed.

Also designed and built was a sequence timing generator "Guiseppe" which is the equivalent of 10 EGG GG200 gate generators.

Interfacing for a scaler scanning system for TSI and LeCroy blind scalers, as well as for the phototube high voltage scanner, is under design.

E. Group G Support

Experiment E-54

1. The 7-bit ADC is being redesigned with the following features:
 - (a) CAMAC format for the digital data distribution within the bin;
 - (b) fast gate is independent of supply voltage variations;
 - (c) a very low temperature dependence;
 - (d) extended linear range, 2 to 190 counts;
 - (e) utilization of up-to-date IC's and hence less components at lower cost;
 - (f) synchronization of clock pulse, gaining 1/2 bit in accuracy.

The breadboard check-out has been completed, and the printed circuit mask is complete.

A new control unit for the above was also designed and tested.

2. Specifications were established for a 12-fold, nanosecond fan-out using MECL III. A prototype was made and performed to specification. Format: CAMAC.

3. Specifications were established for an eight-channel dual-coincidence Latch. A prototype has been built. Changes are required for more convenient handling of MECL and TTL logic levels. Format: CAMAC.

All MECL Circuits of paragraphs (2) and (3) operate from one non-floating 6-volt supply.

4. Data Logging: A system was designed to collect experimental data and apply them via the PDP-9 computer data channel. The system includes:
 - (a) PDP-9 Data Channel Interface.
 - (b) A 9-bit multiplexer sending the 9-bit code to chassis control stations.
 - (c) Control modules to (1) decode the MUX bits for unique addressing of modules (2) buffer data and address codes for redistribution.

Parts of the system have been checked. Construction awaits decisions on several details of the CAMAC board.

5. LeCroy ADC's - LRS 143A: Twenty-two units have to be modified to make the 8th bit (overflow) available for computer readout. The circuit was tested and a PC is being made by the Electronics Shop.

6. Spark Chamber with FET Readout: A 64-channel circuit was completed to allow efficient testing of the spark chamber. Each channel includes a FET switch, a diode limiter, a flip-flop with a light indicator and a comparator (one shared by two units). First tests indicate high failure rates of all components. Efforts are underway to improve the HV pulse shape and minimize reflections that are thought to be the principal cause of the failures.

F. Automatic Data Analysis (ADA) Support

Design of Hummingbird* III and redesign of Hummingbird II was initiated so that these two devices would be available for work on the μ -P experiment, the π - ρ experiment, and the Streamer Chamber experiment. The μ -P and π - ρ experiments will result in photographic images measuring 60×104 mm which will require division into picture elements as small as $15 \times 3.2\mu$. The Streamer Chamber experiment will result in photographic images 25×40 mm and will require division into picture elements $1.5 \times 10\mu$ or $6 \times 2.4\mu$ (at the operator's choice).

To meet these design goals in a timely and economical method it was decided to maintain the old Hummingbird system philosophy while increasing its speed through the use of more advanced semi-conductor devices. The new Hummingbird system will operate with a basic clock rate of 8 MHz as opposed to the old rate of 2 MHz. The added speed will be used to increase accuracy

* For description of Hummingbird system see: SLAC Report No. 82, "The Hummingbird Film Digitizer," (March 1968).

and resolution rather than to increase image rate. Maximum use of MSI* or third generation hardware is being used consistently with adequate maximum speed margins. The basic logic design will be completed and subsystem checks will be initiated in July.

A television display system is also being developed to work in conjunction with the aforementioned experiments. This system employs a Datadisc magnetic storage disc on which is recorded one complete image plus any corrections entered via a light-pen. This system is necessary because of the time restrictions and low resolving powers of the IBM 2250 graphic display.

Coordination with the CDA group, which is responsible for design and fabrication of a three reel-pair film drive system for Hummingbird III, is a continuing effort. Maintenance of the old Hummingbird II system, which will be kept in operation until the new systems are available, has caused some concern in June due to CRT spot size growth, traced to amplifier drift and poor quality deflection coils. Some optical misalignment and photomultiplier problems were also encountered and corrected.

Plans and schedules were prepared indicating an anticipated hardware completion date of September 15 for the Hummingbird II and III systems.

G. Conventional Data Analysis (CDA) Support

Two incremental magnetic tape units were installed on two of the SP5-B image plane measuring machines. These two units replace a single unit which serviced both tables, but which was not working properly due to transient noise problems. By improving the reliability and serviceability of the machine as well as making the machine easier to operate, a fifty percent increase has been achieved in the measuring rates.

Work is progressing on replacing the electronics in the NRI computer-controlled measuring system. The design is 80% complete and work will soon begin on a prototype.

Extensive documentation work has been performed on the Spiral Reader. In addition, the film format including logic modifications has been changed from 3-strip 35 mm to single-strip 70 mm. The encoding system has been reconditioned and is now performing satisfactorily. The PM detector tube has been changed to an Amperex 1010 from an RCA 6199 to improve the S/N ratio. A Brenner detector has been added to the 35 mm film but at this time, it does

*Medium Scale Integration is interpreted to include devices having greater than one but less than 30 functions per chip.

not work satisfactorily due to problems associated with the placement of the marks on the film.

Electronics maintenance on all scanning and measuring machines is a continuing effort.

H. Spectrometer Facilities Group (SFG) Support

1. Spectrometer Controllers

Power Supply controllers used to control the spectrometer magnets are being redesigned. The present controllers are electromechanical in nature and cannot be activated without using the 9300 computer. The new controllers will be solid state and can be activated manually or by the 9300.

2. Computer Systems

Computer systems studies were made which evolved a plan for expanded capability in two phases. Phase I of this expansion will result in a system which will provide for time interlaced access from the 9300, 930, and two maintenance panels to all physics measurement devices. This system was conceived to permit greater use of the 930 which does not currently have access to the physics measurement devices. Furthermore, operating experience has revealed the desirability of having maintenance panels which can provide on-line maintenance and trouble shooting, functions which are not available in the present system. The Phase I system would also accommodate the use of an updated 930 as a second computer for parasitic experiments; however, the plans for the 930 are still under review.

To implement the Phase I system the following devices are needed: (1) four new EDC's (External Device Control), (2) a Phase I switcher (which time multiplexes the computers and maintenance panels), (3) an Alpha Decode Interface, (4) an Interrupt Router, and (5) Maintenance Panel. The design and development of the Phase I system is well along. The EDC is in packaging. The switcher is 90% designed. The Interrupt Router design is in its early stages. The interface is a small job involving a standard approach. The maintenance panel is about 75% designed.

The Phase II concept of computer facilities expansion is intended to provide a modularly expandable system capable of accommodating virtually any foreseeable Counting House data gathering requirements. The Phase II system would permit simultaneous access by any of four computers or maintenance

panels to the data gathering devices via the multiplexer system. Hence, two or more experiments could be run simultaneously without interference. Or, a visiting group could interface their own computer to an experiment by means of this system.

The Phase II system would require a new and more complicated Switcher, a new and again much more complicated Alpha Decoder, and new interfaces to the old multiplexers. This concept has been formally presented to SFG and interested physicists for review and comment but will not be implemented at this time.

As a final item, the present PIN multiplexer facilities in Counting House are utilized to near capacity. A new PIN multiplexer incorporating integrated circuits is under design. Several of these will be built as needed.

I. RAD Target Group Support

Updating of the LH_2 Target Control system has continued. The ESA Target Drive system has been changed from pneumatic to electrical. A new target position readout and control was introduced with the E-39 experiment for indicating Y axis (vertical) position of the target to an accuracy of 5 mm. The presentation is a digital number. The target is positioned by selection of a number associated with the target position desired and the target will automatically go to this position.

Three-dimensional movement and position readout was also introduced during this period with the addition of X (lateral) and Z (beam line) target positioning capability.

J. RAD Support

1. Video Position Monitors

A pulsed current source has been developed for calibrating all channels of the video position monitor. The current pulse is injected into the input of the X and Y preamp and into a special calibration winding on the intensity toroid. The calibrator will give the operator a quick check on overall VPM performance as well as a means of setting gain precisely.

A high-pass filter with adjustable cutoff will be mounted in the same chassis as the calibrator. The filter can be switched in at the operator's discretion and will result in a better signal-to-noise ratio at the expense of some pulse tilt.

Two new video position monitors are under construction and scheduled for installation about September 1. One unit is identical to all previous VPMs but

with a calibrator added. The other unit incorporates two complete position monitors in one housing.

2. Video Position Monitor Chopped Beam Performance

The video position monitor response to a chopped beam is a signal that is independent of beam position and related only to beam intensity. Various schemes to produce a position-dependent output have failed. These ideas were centered around improved input transformer shielding and better common-mode rejection.

No further work has been done during this period.

K. Magnetic Measurements Group Support

Based on a past history of malfunctions in the tape recorder in the Rapid Magnet Mapper, the addition of a tape alarm to the system which would indicate to the operator malfunction in the tape recorder was suggested. This alarm system has been implemented. In addition, portions of the logic and cabling in the system have been re-wired for improved reliability. Special maintenance problems are a continuing effort.

Preliminary work on the new Magnetic Measurements Computer System to measure magnets for the storage rings included the running of computer programs to demonstrate feasibility of spectrum analysis using the digital computer.

L. Video Intensity Monitor and Calibrator for End Station A

The design requirements have been modified and expanded.

The instrument will monitor four toroids simultaneously and produce an output pulse proportional to beam intensity. A preamp is located at the beam line near each toroid for good signal-to-noise performance. At the Counting House, the signals are fanned out to three remotely located monitor and calibration panels. Signals can be monitored from all panels simultaneously and calibration can be checked and adjusted from any panel. The calibrator is a pulsed current source with six discrete output levels, 0.1 mA, 0.3 mA, 3 mA, 10 mA and 30 mA. Calibrate pulses are accurate to 0.5%.

The instrument will be useful over a range of from 5 μ A to 50 mA peak beam current of electrons and from 5 μ A to 5 mA of positrons. A risetime of about 15 nsec will provide good pulse detail.

The system will be installed in early fall.

M. Count Rate Meter

Two additional units have been constructed since the prototype described in the last report. On one of these units, all 4 channels were equipped with a special 100 MHz pulse shaper and first decade using MECL II integrated circuits. All units are presently in operation in E-41 (π - ρ Experiment).

On two of the units, a small power pack for the Nixies failed due to excessive temperature. Addition of a cooling fan to all units appears to have cleared this problem.

N. Spark Gap Trigger Units

Two spark gap trigger units have been constructed and are presently being used in the field. These units have an avalanche transistor Marx generator front end, driving a triode which triggers the spark gap. The input threshold is - 250 mV, 50 ohms. The output pulse into 50 ohms has a risetime of 20 nsec, a jitter of ± 2 nsec at 12 kV, a maximum amplitude of 16 kV (limited by the output connector), and a delay from trigger input to half-amplitude output at 12 kV of 70 nsec. Maximum rate is 12 pps, limited by the pulse capacitor of 2×2700 pF.

Both units have been in field operation for about 5 weeks. One unit has more than 0.5 million shots with no perceptible problems or degradation. The second unit has replaced an earlier design and appears to have considerably improved delay and jitter characteristics.

O. End Station Charge Monitors

During this period considerable irregularities were noticed in the toroid #1 system in ESA. The digital accumulator portion of the system was fully tested and verified and a marginal plug-in card was discovered. A low error rate in the system continued and was eventually traced to noise on a marginal logic signal in the control system. A temporary fix was installed and the monitor has operated flawlessly since. This problem was probably the main cause of periodic difficulties over the past year or so. A new card, critical in the system, is being designed by one of our summer visitors, to further improve reliability.

In general, the two toroid systems in ESA continue to operate well. Agreement between the two instruments is usually within 0.2 or 0.3 percent.

In the ESB units, no major problems have been encountered; however, periodic checks of the amplifiers in the B target room show considerable transistor radiation damage, necessitating periodic replacement of the two amplifier transistors.

P. Centroid Time-Of-Flight System

No further work was carried out due to limited available manpower and pressure of other projects.

Q. High Speed Integrated Circuit Development

As a continuation of the work reported previously, a 90 MHz MECL II discriminator¹ has been finalized and tested. The prototype uses a wire-wrapped construction; the circuit is presently being re-designed in a printed configuration. The final design uses a tunnel diode ahead of the first IC, since it was found that the IC's could not produce the required accuracy of timing of the threshold crossing.

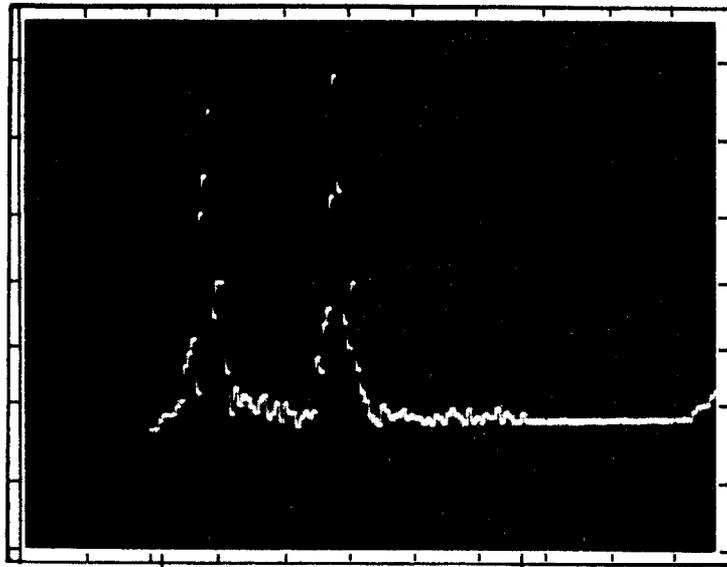
R. Proportional Wire Chamber Profile Monitor²

A proportional wire chamber profile monitor has been designed, and the first chamber plane installed in E-41. The system consists of two chambers, an X and a Y, with 2 mil diameter wire spaced 2 mm apart, 96 wires per plane; followed by an amplifier and scaler for each wire. The scalars are time-shared by multiplexing between the two planes. A control unit continuously scans the contents of the scalars, passes the signals through a D to A converter, and displays the output counts as a function of position on an oscilloscope. The system is presently operating with one plane and a simplified controller. The final control unit, presently in check-out, will be able to multiplex up to 8 chamber planes, and display them successively on a storage oscilloscope.

Figure 9 shows two successive accumulations with a 12 GeV/c meson beam at two different positions. (The accumulation periods are slightly different.) The single-channel 2 mm increments are clearly discernible. Figure 10 shows the results of an accumulation of test pulses passed through each individual wire-preamplifier-scaler channel. A broken chamber wire is easily identified on channel 95.

At the present time, the chamber uses a 90% Argon 10% CO₂ gas mixture which gives a total count efficiency of about 10% at -4200 volts bias, and 50% at -4700 volts. At the higher voltage, however, chamber breakdown is encountered. Further studies are in progress using different gas mixtures in order to better understand the chamber efficiency characteristics. A separate study is being carried out on the electrostatics of signal formation and amplifier pulse shaping.

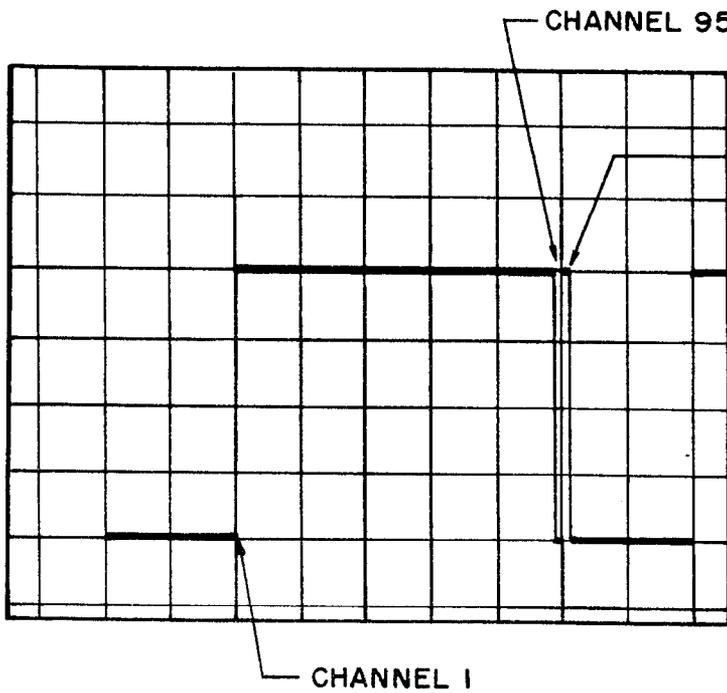
A second chamber is being readied for installation, and improvements in the preamplifier performance are being sought.



VERTICAL-20 COUNTS/CM
 HORIZONTAL-95x2MM
 TOTAL SPECTRUM WIDTH

CHANNEL 1 CHANNEL 96

FIGURE 9 - 12 GeV/c π - BEAM PROFILE



VERTICAL-20 COUNTS/CM
 HORIZONTAL - 95 x 2MM
 TOTAL SPECTRUM WIDTH

CHANNEL 1

FIGURE 10 - TEST PULSE PROFILE

S. Equipment Pool (HEEP)

1. General

In June approximately 30 quad 100 MHz discriminators and 30 4-fold coincidence modules were purchased. Module usage continues to run near 100%, with particular demand on discriminators and gate generators.

2. 7-Bit ADC's

A total of 60 units have been built for HEEP. About 40 of these are scheduled for the Group D Streamer Chamber Facility. Thirty units have been checked out and delivered, and the remaining 30 are awaiting check-out.

3. Scaler System Procurement

A survey of commercial scaler systems was made and an order was placed for a 30 channel, 100 MHz scaler system from LeCroy Research Systems, which employs a CRT for multi-channel display. The equipment has been received and after a period of debugging and periodic failures is now operating satisfactorily. The system is to be used by Group E, and in the near future will be interfaced to their PDP-8 computer.

4. Maintenance

Work on module maintenance and computer inventory records is a continuing effort. A large number of 100 MHz scaler repairs have been made in recent months. HEEP now provides service up to 9 pm on normal workdays during set-up and run schedules.

T. Electronics Stores Coordination

Electronics Stores procurement policy has been recently revised to take maximum advantage of the availability of mil spec components, and to avoid needless over-specification. This necessitates a thorough long-range overhaul of existing justification documents and the Preferred Electronics Components Handbook. Recent progress has been made in the areas of coaxial cable, capacitors, and inductors. The effort is continuing.

U. References

1. A. Barna and E. Cisneros, "Integrated-circuit discriminator with 10-nsec pulse pair resolution," Report No. SLAC-PUB-615, Stanford Linear Accelerator Center, Stanford University, Stanford, California (June 1969).
2. Memo from R. Larsen to B. Richter, "Proportional wire chamber profile monitor," (March 10, 1969).