SLAC-126
UC-28
(SR)

TWO-MILE ACCELERATOR PROJECT

1 April to 30 June 1970

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

September 1970

ABSTRACT

A status report on the Stanford Linear Accelerator Project covering the period April 1, 1970 to June 30, 1970 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.
SLAC-110,	1 April - 30 June 1969.
SLAC-112,	1 July - 30 September 1969.
SLAC-116,	1 October - 31 December 1969.
SLAC-120,	1 January - 31 March 1970.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

This is the thirty-second Quarterly Status Report of work under AEC Contract AT(04-3)-400 and the twenty-sixth 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, 1970 to June 30, 1970. Contract AT(04-3)-400 provides for the construction of the Stanford Linear Accelerator Center (SLAC), a laboratory that has as its chief instrument a two-mile-long electron accelerator. Construction of the Center began in July 1962. The principal beam parameters of the accelerator in its initial operating phase are a maximum beam energy of 20 GeV, and an average beam current of 30 microamperes (at 10% beam loading). The electron beam was first activated in May 1966. On April 27, 1969, a beam energy of 21.5 GeV was achieved. Beam currents up to 70 milliamperes peak have been obtained.

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

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

I. ACCELERATOR OPERATIONS

A. Operating Hours

Manned Hours	April	May	June	Quarter
Physics Beam Hours[1]	Accelerator was not operated.			
Machine Physics		38	30	68
Particle Physics		405	413	818
Total Physics Beam Hours				
Nonphysics Hours				
Scheduled Downtime (Maintenance, Startup)		24	24	48
Unscheduled Downtime (Equipment Failure, Tuneup, etc.)		117	45	162
Total Nonphysics Hours		141	69	210
TOTAL MANNED HOURS		584	512	1,096

B. Experimental Hours[2]

1. Particle Physics

(3) Beam Line	Sched. Hrs. Electronic Experiments (a)	Electronic Experimental Hrs.		%	Actual Bubble Chamber Hours	Test and Checkout Hours		Total Experimental Hours	
		Actual Hours (b)	(4) Charged Hours	$\left(\frac{b}{a}\right)$		Act. Hrs.	Chg. Hrs.	Actual Hours	Charged Hours
A	667	415	428	62.2	---	218	179	633	607
B_N	703	529	483	75.2	---	124	75	653	558
B_C	---	---	---	--	---	---	---	---	---
B_S	---	---	---	--	---	168	98	168	98
C	17	9	7	52.9	383	224	142	616	532
Total	1,387	953	918	68.7	383	734	494	2,070	1,795

	Actual Hours	Charged Hours
2. Machine Physics	76	76
TOTAL EXPERIMENTAL HOURS	2,146	1,871

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

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

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

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

C. Overall Experimental Program Status

1. Electronic Experiments

Approved research hours at beginning of quarter	3,867
Hours charged during the quarter	1,001
New hours approved during the quarter	820
Approved hours remaining at end of quarter	3,686

2. Bubble Chamber Experiments

	40" BC	82" BC
Approved pictures at beginning of quarter	856 K	2,886 K
Pictures taken during the quarter	---	653 K
New pictures approved during the quarter	(59 K)	550 K
Approved pictures remaining at end of quarter	797 K	2,783 K

D. Beam Intensity

	April	May	June	Quarter
Peak	---	65 mA	50 mA	65 mA
Average	---	9.0 μA	5.0 μA	7.0 μA

E. Klystron Experience

	April	May	June	Quarter
Total Klystron Hours	---	137,245	119,988	257,233
Number of Klystron Failures	---	12	6	18

F. Data Analysis

	April	May	June	Quarter
Spark Chamber Events Measured	23,308	22,759	26,654	72,721
Bubble Chamber Events Measured	20,600	28,064	16,687	65,351

G. Computer Operations

Manned Hours

	April	May	June	Quarter
Computation Hours				
SLAC Facility Group	116	134	108	358
Users Groups	462	469	437	1,368
Total Computation Hours	578	603	545	1,726
Noncomputation Hours				
Scheduled Maintenance	87	83	100	270
Scheduled Modifications	--	24	--	24
Unscheduled Downtime and Reruns	20	15	27	62
Idle Time	6	1	12	19
Utility Failure	12	9	1	22
Total Noncomputation Hours	125	132	140	397
TOTAL MANNED HOURS	703	735	685	2,123

H. Special Operating Features

1. Beam Knockout

The beam knockout was used for 66 hours with experimental runs and for 27 hours of checkout during a machine physics run. It was run at 10 and 40 MHz.

2. Power Supplies

The 3.4 MW power supply was run for a total of 567 hours with the 82" bubble chamber and for 10 hours of magnet measurement.

The 5.0 MW power supply was run for a total of 743 hours with the 54" spark chamber and for 11 hours of magnet testing.

The 5.8 MW power supply was run for a total of 69 hours of magnet testing.

The motor generator facility was run for a total of 55 hours of magnet testing.

3. General

The accelerator was not scheduled for operation during the month of April.

II. EXPERIMENTAL ACTIVITY

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

The prime users of the accelerator during the period were:

E-40	Rho Production, Spokesman: J. Tenenbaum
CE-42	Proton-Proton Scattering at Forward Angles, Spokesman: A. Boyarski
E-43	Velocity of Light Experiment, Spokesman: G. Masek
E-45	Measurement of π^+ Photoproduction with Polarized Photons, Spokesman: L. Osborne
CE-48	Measurement of the ξ Parameter in the Decay $K_L^o \to \pi\mu\nu$, Spokesman: M. Sakitt
CE-69	Measurement of the Form Factors for K_L^o Decay, Spokesman: R. Zdanis
BC-11	Polarized Photoproduction, Spokesman: G. Wolf
BC-19	γ-d Experiment with an Annihilation Beam of 7.5 GeV, Spokesman: A. Levy
D-16	Detector Development, Spokesman: B. Hughes
ND-14	Charpak Chamber Tests, Spokesman: E. Bloom
S-4	Muon Production and Shielding Measurements at Electron Energies of 18 and 14 GeV, Spokesman: W. R. Nelson .

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* E-Approved counter experiments

CE-Checkout of equipment associated with counter experiments

BC-Approved bubble chamber experiments

P-Accelerator physics

R-Research area runs

N-Parasite runs

T-General research equipment tests

D-Special short particle physics runs

Y-Beam switchyard tests

S-Survey (usually Health Physics) runs

A. Status of Running Experiments

E-40 — High Statistics Study of the Production of Charged $\rho^{\pm}$ Mesons, Neutral ρ^{o} Mesons, f^{o} Mesons and Nucleon Isobars by Pions - J. Tenenbaum (SLAC)

During the first half of the May cycle, checkout of the spark chambers, fast electronics, and pion beam was completed. During the second half of the cycle, data were obtained with an incident pion momentum of 15 GeV/c. Approximately 53 rolls of film were taken which is slightly under 25% of the data. This data consists of 4.2×10^7 π^+ and 2.1×10^7 π^- passing through the target. The limiting factor on the experiment appears to be picture backgrounds caused by charged pions interacting in the solid plate sections of the spark chambers.

During the June cycle, final data taking was completed. The spark chambers, camera, fast electronics, and target all performed satisfactorily throughout the cycle. The second half of the 15 GeV/c data and all of the 8 GeV/c data were taken. These data may be summarized as follows:

Momentum of π's	Detected Particle	Number of π's incident on 50 cm H_2 target
8 GeV/c	ρ^+	3×10^7
	ρ^-	3×10^7
	ρ^o	1×10^7
15 GeV/c	ρ^+	10×10^7
	ρ^-	10×10^7
	ρ^o	25×10^7

Analysis programs are in the final stages of debugging and preliminary film scanning by physicists is under way. (T. Zipf)

CE-42 — Photon-Proton Scattering at Forward Angles - A. Boyarski (SLAC)

Seven shifts were used during May in studying backgrounds in the pair spectrometer for the $\gamma p \rightarrow \gamma p$ scattering experiment. Twenty-five feet of iron shielding reduced the counting rates to a level which would allow the experiment to operate at a beam intensity close to the design value. All the hodoscope counters were also checked out during this run.

Two days of running time were used in June for the final checkout of the equipment for the forward angle γp scattering run scheduled for July 1970. The checkout objectives were met, and some data were recorded at various angles. (A. Boyarski)

E-43 — Velocity of Light Experiment - G. Masek (UC, San Diego)

E-43 had a successful run in June and obtained a considerable amount of preliminary data.

New electronics were tried and found to be very successful.

The data obtained allowed us to see difficulties that were previously masked by other effects.

Further data taking is planned. (B. Brown)

E-45 — Measurement of π^+ Photoproduction with Polarized Photons - L. Osborne (MIT)

This experiment uses polarized photons produced by coherent bremsstrahlung from a diamond crystal in a measurement of π^+ photoproduction. The initial part of the May cycle was spent in setting up the electronics and measuring the behavior of the diamond under electron bombardment. Some problems were encountered with the diamond mounting (the diamond changed in orientation as more beam passed through it). This problem was finally minimized. Runs were taken to measure the π^+ photomeson yield with the polarization of the coherent photons perpendicular and parallel to the π^+ production plane. Enough data was acquired to make provisional asymmetry measurements and estimated running times for the next period.

The measurements continued in June. Because of the damage done to a collimator (C12) approximately three days of data taking were lost. However, due to an increased pulse rate during the remainder of the cycle, it was possible to complete measurements on photoproduction. At the end of the cycle, two shifts were used in an attempt to put the 1.6 GeV spectrometer in coincidence with the 20 GeV spectrometer so that the asymmetry for π^- photoproduction from deuterium could be measured. This attempt was unsuccessful and the remainder of the cycle was taken up making provisional asymmetry measurements on the photoproduction of the $\Delta(1236)$ nucleon resonance and a single pi-meson from hydrogen and deuterium. These final measurements will be useful for estimating running times for any future experiment using the coherent bremsstrahlung beam to produce Δ's .

During the course of the June cycle, evidence was found indicating rather severe radiation damage to the diamond radiator. The second diamond mounted in the goniometer was used for the remainder of the cycle and virtually no beam time was lost changing over from the damaged radiator. This diamond will be removed and studied to determine the cause and nature of the radiation damage. (L. S. Osborne and R. Schwitters)

CE-48 — Proposal to Measure the ξ Parameter in the Decay $K_L^o \to \pi\mu\nu$ - R. Mozley (SLAC)

The June run was used to test the rebuilt streamer chamber and new beam line. Collimator C2 in the beam line had been moved down beam in order to help in location of a new experiment. In addition collimator C3 and its sweeping magnet were moved down beam to help in sweeping more decay particles from the beam line.

Beam line checks were started on June 15. The beam line is normally blocked by a 6" Pb filter to remove γ rays. For a beam alignment check, the filter was moved to a position which allowed γ rays to pass through a 1/8" hole and collimator locations were checked using X-ray film. Analysis of the film indicates the possibility of some interference in the beam line. No clear check could be made since the target region is not accessible during operation.

The chamber was installed by June 18 and work started on plateauing and timing the internal counters. On the 19th pulsing of the new chamber started. The streamer quality was the best yet obtained. After about 100 pictures, arcing started in the center of the chamber. This was due to an Allen-head wrench which had fallen onto the upper surface of the chamber. A repair was made in about twelve hours.

Difficulties were experienced with power supply regulation. On June 22 the power supply current became unstable, ran up rapidly, and then shut off. The resulting stress caused audible effects on the magnet coils and distorted the chamber, breaking eight tie rods. These were repaired and after about five hours operation was restarted, using the power supply at half current where the danger of a crash-off was less.

Beam studies were made through the 23rd. The ratio of background to events was poorer than in the January run, so the "improvements" were unsuccessful. The collimator C3 and its sweeping magnet must be moved back to the previous location. The new chamber appears to perform adequately, but modifications must be made to the power supply to allow safe operation. New understanding of background problems was obtained. (R. Mozley)

CE-69 — Measurement of the Form Factors for K_L^o Decay - R. Zdanis (Johns-Hopkins)

CE-69 was designed to continue the study of K_L^o decays begun by this group on E-44. The events obtained from $K_L^o \to \pi\mu\nu$, $\pi e\nu$, $\pi^+\pi^-\pi^o$ of E-44 exceeded the previous world sample by a factor of 10. However, the experimental arrangement was not specifically designed for these reactions and the statistical sample was not large enough to allow the systematic problems to be studied in detail.

During the June cycle, the apparatus was constructed. Wire spark chambers, scintillation counters and electronic logic have been completed, installed and checked for performance. A Hewlett-Packard 2116B computer has been interfaced, programmed and brought into on-line operation. Trigger rates were measured and the spark chambers fired on events. Some preliminary data have been logged on tape. A mixture of free-flight decays, regeneration from copper and "straight thru's" were collected. These data are useful for finding spark chamber alignment constants, checking chamber performance and testing the computer interfacing and software. Some final checkout work remains to be done during the first week of the July cycle; the experiment will be completed during the July and August cycles. (E. Dally)

BC-6 — Study of One Pion Exchange Contribution to γ-Nucleon Scattering (University of Tennessee-Oak Ridge National Laboratory)

An exposure of 216,333 pictures of 3.2 GeV γ-d was obtained using the 82" bubble chamber filled with liquid deuterium. The total exposure was scheduled to be 250,000 but was terminated early due to a bubble chamber leak. The ruby laser system was operated without difficulty. (R. Gearhart)

BC-11 — Bubble Chamber Experiment with the Polarized Laser Induced Photon Beam - G. Wolf

An exposure of 409,055 pictures was taken of 9.47 GeV γ-p. The 82" liquid hydrogen bubble chamber with the single strip 46 mm film format was used. This was the first production run using the second harmonic generated by the ruby laser system.

The second harmonic generation efficiency, using two deuterated potassium dihydrogen phosphate (KDP) crystals of total length 7.5 cm, was of the order of 15%. To obtain reasonable photon flux in the bubble chamber, it was necessary to operate the laser at high power densities. The energy output of the laser was typically 2.5 joules with resultant average power density within the 50 nanosec pulse length of approximately 150 megawatts/cm^2 and with peak power density of 200-300 megawatts/cm^2. At these power levels, we have experienced failures of the ruby laser rods and damage to the KDP crystals.

It should be noted that the accelerator was run with rather stringent requirements for the experiment. The energy was 19 GeV with 40-42 mA peak current delivered to the interaction area. At the entrance to the beam switchyard, the peak currents were ~ 55 mA. At times, the machine was being run with all available stations on line. (R. Gearhart)

BC-19 — γ-d Experiment with an Annihilation Beam of 7.5 GeV in the SLAC 40" Bubble Chamber - A. Levy (Tel-Aviv University)

This experiment was originally planned and partly run with 40" hydrogen bubble chamber using the annihilation beam; however, by mutual agreement between the experimenter and SLAC the exposure is being completed using the 82" chamber and the polarized laser induced photon beam. At the conclusion of BC-11 run in May, the 82" chamber was converted over to liquid deuterium and the three-strip 35 mm cameras for this experiment. When the bubble chamber was again ready, the remaining scheduled time was less than 20 hours. However, the experimenters did obtain 28,145 pictures of 7.7 GeV γ-d out of their approved 200,000. (R. Gearhart)

S-4 — Muon Production and Shielding Measurements at Electron Energies of 18 and 14 GeV - W. R. Nelson (SLAC)

Reasonably large muon flux densities can be obtained from high energy electron beams, even when large shields (> 14 feet of Fe) are present. A recent study (Nucl. Instr. and Methods 66, 293 (1968)) shows a discrepancy between calculation (including multiple scattering) and measurement, and subsequent verification of the theory has indicated a need for more experimentation.

In May, this experiment attempted to measure the muon flux density as well as the energy deposition as a function of lateral position from beam centerline and for several shield thicknesses. The energy deposition was measured using LiF (thermoluminescent dosimeter) detectors, whereas the flux density was determined using nuclear track emulsions and plastic scintillators. Several counters and preliminary emulsion data indicate that for an 18 GeV electron beam and for a shield thickness of 16-18 feet of iron

$$\phi/Q = 2 \times 10^{10} \ \mu/\text{cm}^2\text{-Coul} \qquad \text{at } \theta = 0 \text{ mradians}$$

$$\phi/Q = 1 \times 10^{6} \ \mu/\text{cm}^2\text{-Coul} \qquad \text{at } \theta = 150 \text{ mradians}$$

The emulsion will be scanned and the data analyzed during the next few months. The results will be applied to the SLAC superconducting accelerator shielding design as well as to check the multiple scattering formulation used in the NAL muon backstop.

An additional measurement was made by inserting one radiation length of Be immediately upstream of the target-dump in order to observe the possible enhancement of wide-angle muon production via pion decay.

D-13 — A short test to measure muon yields from a 30 r.l., tungsten target was completed. (R. Gearhart)

D-16 — Detector Development - B. Hughes (Stanford)

In the June cycle several direct comparisons were made between the properties of hadronic cascade in matter initiated by high energy pions and protons. These tests included, (1) comparisons of the energy leakage from large absorbers of various dimensions, and (2) a comparison of the energy deposition probabilities in a large NaI (Tl) absorber 24 inches long and 16 inches in diameter. The most obvious results were: (1) that on average, at 9 GeV/c, pions deposited a larger fraction of their energy in the NaI (Tl) absorber than did protons, and (2) that whereas pions frequently deposited very large fractions (75 - 100%), this was most unlikely for protons. An immediate application of the latter result which is of interest to us is to the problem in distinguishing between positrons and protons in the primary cosmic radiation where a proton rejection factor of 1 part in 10^4 is required. (B. Hughes)

ND-14 — Charpak Chamber Tests - E. Bloom (SLAC)

This experiment ran about a week of 10-hour days in the June cycle. The 2 mm wire chambers were working well by the end of the run. 99.5% efficiency into a 30 nsec gate, and 98.5% efficiency into a 25 nsec gate were achieved. An offline program to analyze tapes generated online is now available. This has proved useful in timing the wires (individual TAC spectra are obtained for each wire offline).

Next cycle the 1 mm chambers and fast buffer storage units being built will be tested. Preliminary indications in lab tests indicate approximately a factor of 2 better time jitter for 1 mm vs 2 mm, i.e., 99.5% efficiency into a 15 nsec gate. (E. Bloom)

B. New Experiments

During the May 22-23, 1970 meeting of the SLAC Program Advisory Committee, experiments E-55, E-68, and E-69 were approved.

The next scheduled meeting of the SLAC Program Advisory Committee will be held on August 14, and 15, 1970.

Summaries of Newly Approved Experiments

E-55 — Study of Dalitz Plot for the Decay $K_L^o \rightarrow \pi^+\pi^-\pi^o$ - D. Dorfan (UC, Santa Cruz)

The aim of this experiment is to study the Dalitz plot distribution of the decay products of the reaction $K_L^o \rightarrow \pi^+\pi^-\pi^o$ and to compare its Dalitz distribution to that of the decay $K^+ \rightarrow \pi^+\pi^+\pi^-$ in order to search for the presence of I=2 final states in the latter reaction. There is strong evidence for a $\Delta I \neq 1/2$ amplitudes in the K decays, from the relative decay rates for the various modes. In the first reaction, however, the I=2 final state is forbidden, or strongly suppressed by CP "conservation," and consequently it acts as a "monitor" for the latter reaction.

The aim is to get $\sim 10^6$ events which is comparable to the number which will be obtained for the K^+ decay in an experiment currently being run at the AGS. The spectrometer system presently being built by Group G for use in the neutral K-beam will be used with a bank of lead glass Cerenkov counters to detect the γ rays from the π^o.

E-68 — Inclusive Pion-Proton Scattering - J. E. Rothberg (U. Washington)

This is an experiment to study the reactions $\pi + p \rightarrow \pi + \ldots$ and $\pi + p \rightarrow p + \ldots$ for a range of incoming pion momenta from 8 to 16 GeV/c. The production angle and laboratory momentum of the outgoing particle will be measured with sufficient precision to provide determinations of the longitudinal and transverse momenta (or the Feynman variables X and Q) to within 10% at the worst. For several fixed values of transverse momentum, data will be taken over a wide range of X.

The distributions in longitudinal momentum at several values of center-of-mass energy ($\sqrt{S}$) will be studied to see whether, aside from kinematical factors, they approach a limiting form. The detailed form of the functional dependence on X and Q will be determined. By looking at the various change states of the pions it will be seen whether the secondary pions can be categorized as pionization, leading particle, etc. A comparison of the pion yields and distributions with those obtained in γp and pp experiments should be instructive.

The experiment will be carried out with a spectrometer consisting of a large bending magnet, wire spark chamber planes, and Cerenkov counters. The acceptance of the system is large enough to provide statistical errors of about 2% for each setting of S and Q.

E-69 — A Proposed Improvement of the Statistical Accuracy of the Measurement of the Form Factors for K_L^o Decay - R. Zdanis (Johns-Hopkins)

The goal of this experiment is to acquire 10^6 K_L^o decays. After all appropriate cuts, this data sample will yield approximately 6×10^5 K_L^o decays which can be separated with less than 2% contamination into the μ_3, e_3 and 3π modes. This data will improve this group's previous measurement of the form factors for the three K_L^o decay modes by a factor of 7. The combined data from this experiment and the previous one (E-44) will be 60 times larger than any presently published K_L^o experiment and will allow measurement of tensor contributions to the μ_3 decays and a quantitative test of $\Delta I=1/2$ and C violation in the 3π mode. This experiment will yield the most accurate determination of the form factors for the three modes.

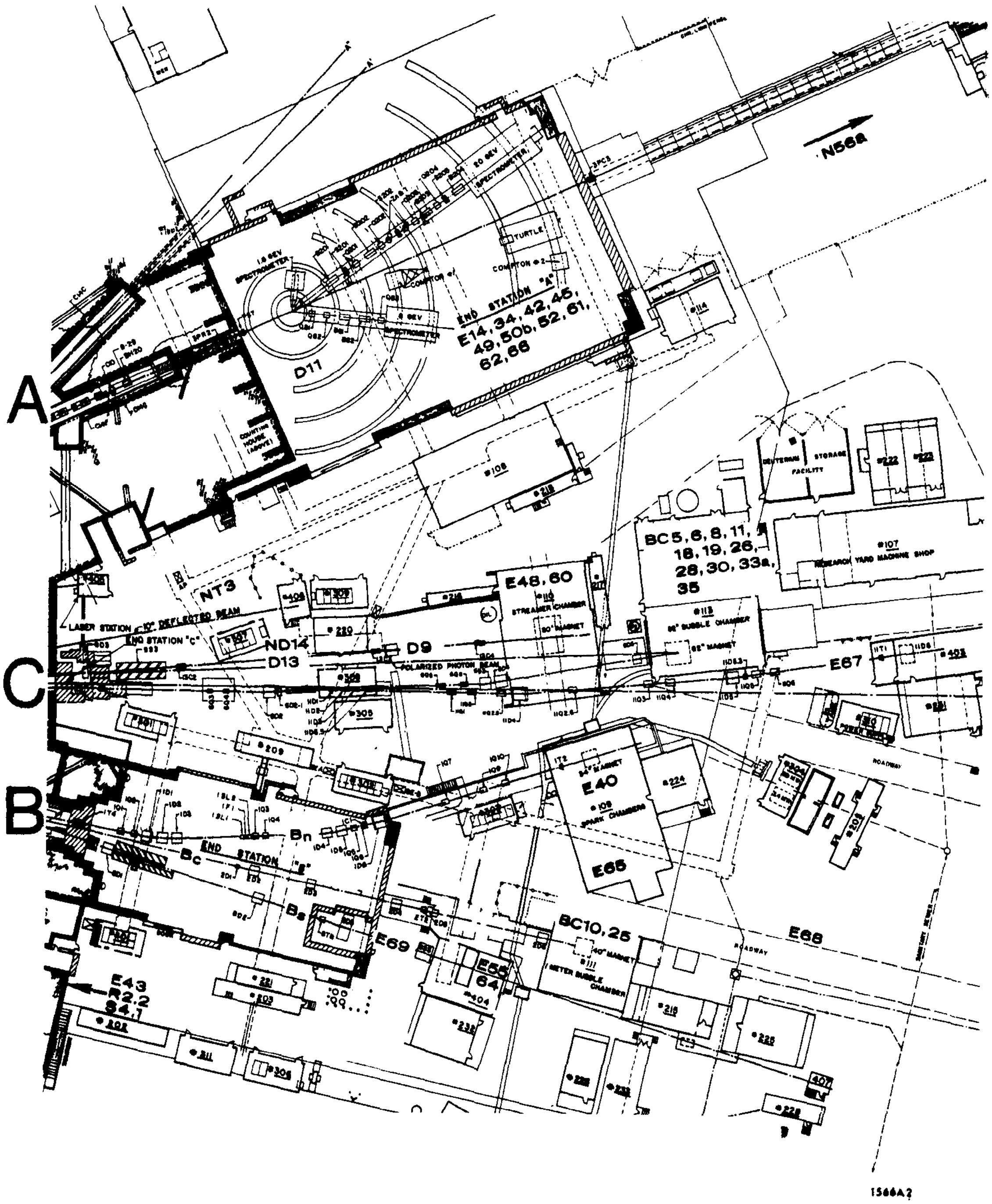

FIG. 1--Experiment locations.

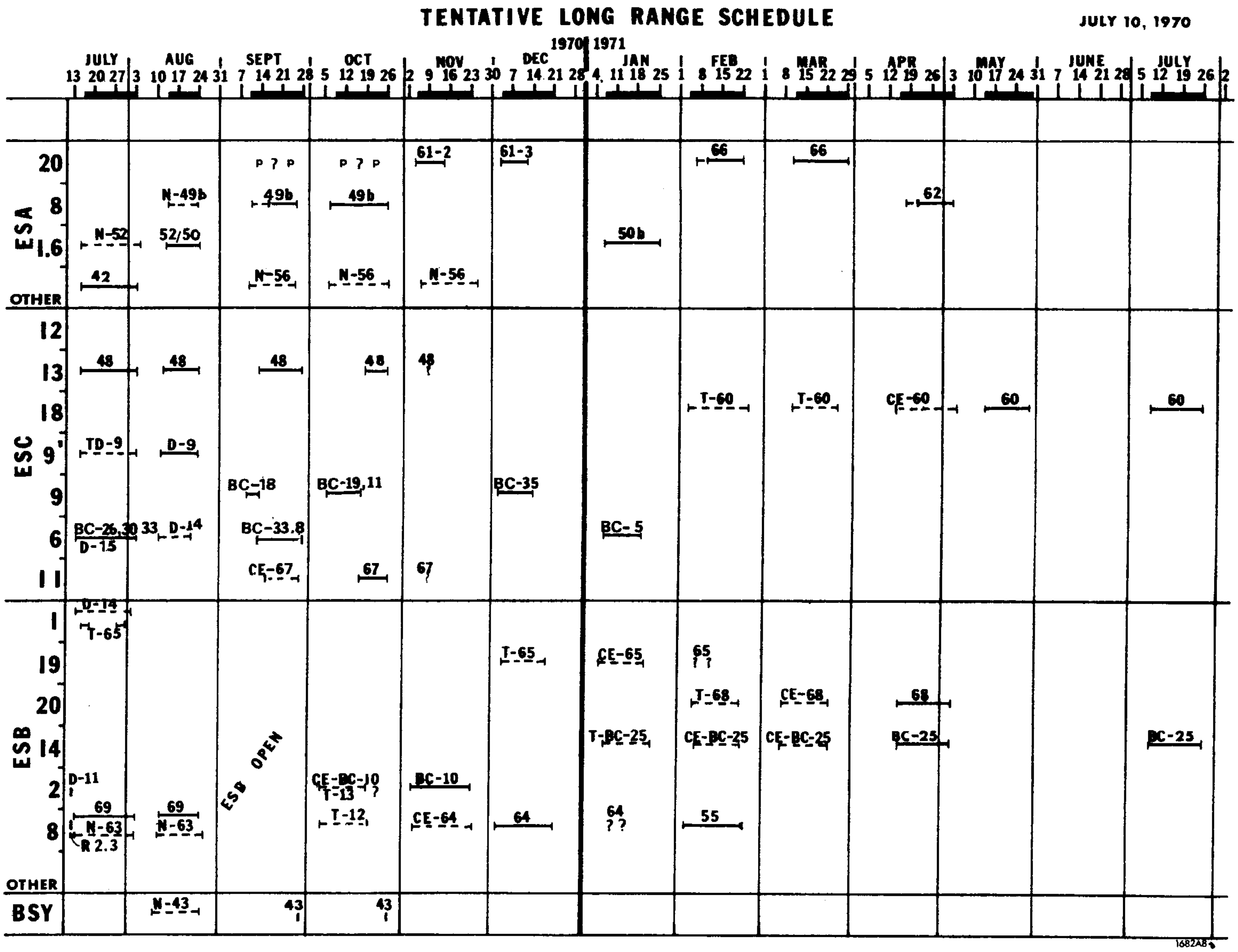

FIG. 2--Tentative long-range schedule.

TABLE I

TABLE OF PROGRAMMED EXPERIMENTS

Number	Title	Authors	Date Approved	Status
E-14	Proposal for Testing of Quantum Electrodynamics by Photoproduction of Asymmetric Muon Pairs	STANFORD (Group A) W. Panofsky, D.H. Coward, H. DeStaebler, J. Litt, A. Minten, L.W. Mo, R.E. Taylor MIT J.I. Friedman, H.W. Kendall, L. VanSpeybroeck	11/18/66	Inactive
E-34	Electron-Deuteron Quasi-Elastic Scattering	STANFORD E. Bloom, D. Coward, H. DeStaebler, J. Drees, J. Litt, R.E. Taylor MIT J. Friedman, G.C. Hartmann, H.W. Kendall CAL TECH B.C. Barish	7/2/68	Inactive
E-40	High Statistics Study of the Production of Charged $\rho^{\pm}$ Mesons, Neutral ρ^{0} Mesons, f^{0} Mesons and Nucleon Isobars by Pions	SLAC J. Cox, B. Dieterle, W. Kaune, M. Perl, J. Pratt J. Tenenbaum, W. Toner, T. Zipf	8/5/68	Running/ Complete
E-42	Photon-Proton Scattering at Forward Angles	SLAC A. Boyarski, F. Bulos, W. Busza, R. Diebold, S. Ecklund, G. Fischer, H. Lynch, B. Richter	3/22/69	Special Test
E-43	Velocity of Light Experiment	UCSD G. Masek	12/14/68	Running
E-45	Proposal for the Measurement of π^{+} Photoproduction with Polarized Photons at SLAC	MIT D. Luckey, L.S. Osborne, R. Schwitters SLAC A. Boyarski, R. Diebold, S. Ecklund, B. Richter	12/14/68	Running/ Complete

Table of Programmed Experiments (cont'd) - 2

Number	Title	Authors	Date Approved	Status
E-48	Proposal to Measure the ξ Parameter in the Decay $K_L^o \rightarrow \pi\mu\nu$	BNL D. Hill, R. Palmer, M. Sakitt, N. Samios SLAC D. Fries, F. Liu, R. Mozley, A. Odian, J. Park, W. Swanson, F. Villa	2/8/69	Checkout
E-49b	Inelastic Scattering From D_2 and Other Nuclei: Large Angles	SLAC D. Coward MIT J. Elias, J. I. Friedman, H. W. Kendall, M. Sogard, K. Tsipis, M. Breidenbach, R. Verdier	8/6/69	Inactive
E-50a	Comptom Scattering at High Energies From Hydrogen	SLAC R. Anderson, D. Gustavson, J. Johnson, I. Overman, D. Ritson, B. Wiik HARVARD UNIV. J. Walker NORTHEASTERN UNIV. R. Weinstein	3/22/69	Inactive
E-50b	Asymmetry in the Photoproduction of π^o Mesons by Polarized Photons	SLAC R. Anderson, D. Gustavson, J. Johnson, I. Overman, D. Ritson, B. Wiik HARVARD UNIV. J. Walker NORTHEASTERN UNIV. R. Weinstein	3/21/70	Inactive
E-52	Determination of γ_ρ^2 and the Total ρN Cross Section From Coherent ρ-Photo-productions on Deuterium	SLAC R. Anderson, D. Gustavson, J. Johnson, I. Overman, B. H. Wiik NORTHEASTERN UNIV. R. Weinstein	8/6/69	Parasiting
E-55	Study of Dalitz Plot for the Decay $K_L^o \rightarrow \pi^+\pi^-\pi^o$	SLAC H. Saal U.C. SANTA CRUZ D. Dorfan UNIV. COLORADO U. Nauenberg	5/23/70	In Setup
E-56a	A Search for Short-Lived Sources of Neutrino-Like Particles	SLAC D. Fryberger, A. Rothenberg, M. Schwartz, T. Zipf UNIV. OF PENNSYLVANIA E. Beier, A. Mann, E. Rybaczewski U.C. SANTA CRUZ D. Dorfan	3/21/70†	Setup

Table of Programmed Experiments (cont'd) - 3

Number	Title	Authors	Date Approved	Status
E-60	Hyperon Production in K^-p Interactions	SLAC K. Bunnell, R. Mozley, A. Odian, J. Park, B. Swanson, F. Villa, L. Wang U.C. RIVERSIDE S. Fung, A. Kernan, R. Poe, T. Schalk, B. Shen LRL BERKELEY M. Alston-Garnjost, R. Bangerter, A. Barbaro-Galtieri, F. Lynch, F. Solmitz	12/12/69	Inactive
E-61	Forward Electron Scattering	SLAC E. Bloom, R. Cottrell, H. DeStaebler, C. Jordan, M. Mestayer, H. Piel, R. E. Taylor	2/21/70	Inactive
E-62	Particle Spectra at High Energies	CAL TECH B. C. Barish, A. Dzierba, W. Ford, R. Gomez, Y. Nagashima, P. Oddone, C. Peck, J. Pine, F. Sciulli, A. V. Tollestrup	3/21/70	Inactive
E-63	Measurement of K_L^o and Neutron Total Cross Sections on Nuclear Targets	STANFORD UNIV. J. Crawford, R. Ford, E. B. Hughes, L. Middleman, L. H. O'Neill, J. Otis	3/21/70*	In Setup
E-64	Study of the Decay $K_L^o \longrightarrow \pi^{\pm}\mu^{\mp}\nu$	SLAC D. Fryberger, D. Hitlin J. Liu, M. Schwartz, S. Wojcicki U.C. SANTA CRUZ D. Dorfan	3/21/70	Setup
E-65	Proposal for an Experiment to Study Electroproduced Hadrons	SLAC B. Dieterle, W. Lakin F. Martin, E. Petraske, M. Perl, J. Tenenbaum, W. Toner	3/21/70	Inactive
E-66	Inelastic Photoproduction of Charged Pi and K Mesons in the Forward Direction	SLAC A. Boyarski, S. Ecklund, B. Richter, R. Siemann	3/21/70	Inactive
E-67	Study of $\pi N \longrightarrow N\bar{N}N$ at 15 GeV/c	SLAC F. Bulos, R. Carnegie, E. Kluge, D. W. G. S. Leith, H. Lynch, B. Ratcliff, S. Williams, H. Williams	3/21/70	Inactive

Table of Programmed Experiments (cont'd) - 4

Number	Title	Authors	Date Approved	Status
E-68	Inclusive Pion-Proton Scattering	UNIV. OF WASHINGTON J.E. Rothberg, R.W. Williams K.K. Young, A. Schenck, L. Sompayrac, M. Delay	5/23/70	Inactive
E-69	Proposed Improvement of the Statistical Accuracy of the Measurement of the Form Factors for K_L^o Decay	JOHNS-HOPKINS UNIV. B. Cox, C. Chien, L. Ettlinger, L. Madansky, A. Pevsner, L. Resvanis, V. Shreedhar, R. Zdanis SLAC E. Dally, E. Seppi UCLA C. Buchanan, D. Drickey, F. Rudnick, P. Shepard, D. Stork, H. Ticho	5/23/70	Setup/ Checkout
BC-5	A Proposal to Study Many Particle Final States Produced by 12 GeV/c π^- Mesons at SLAC	UNIV. OF HAWAII A. Kohya, M. W. Peters, V. Peterson, V. Stenger, A. Johnson, N. Rogers, P. Wohlmut	12/16/67	Inactive
BC-6	Proposal to SLAC for Study of the One Pion Exchange Contribution to γ-Nucleon Scattering (in 82 Inch Deuterium Bubble Chamber)	OAK RIDGE H. O. Chon, R. D. McCulloch UNIV. OF TENNESSEE G. T. Condo, W. M. Bugg	9/28/68	Running
BC-8	Exposure of the 82 Inch Hydrogen Chamber to a Beam of π^+ Mesons at 7.0, 11.0 and 14.0 GeV/c	PURDUE D. D. Carmony	Ext. 3/21/70	Setup
BC-10	A Proposal to Investigate $K_2^o p$ Interactions with the 40-Inch HBC	STANFORD B. C. Shen, D. W. G. S. Leith, A. D. Brody, W. B. Johnson, R. R. Larsen, G. A. Loew, R. Miller, W. M. Smart	5/11/68	Setup

Table of Programmed Experiments (cont'd) - 5

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

Table of Programmed Experiments (cont'd) - 6

Number	Title	Authors	Date Approved	Status
BC-33a	300,000 Pictures, 4.5 GeV/c π^- in H_2 82-Inch Bubble Chamber	UNIV. OF PENNSYLVANIA S. Barish, J. Bensinger, E. Bogart, P. Jacques, W. Selove	3/21/70	Setup
BC-35	γ-d Interactions at 3.5 and 5.5 GeV with Polarized Photon Beam	U.C. RIVERSIDE S. Fung, A. Kernan, R. Poe, T. Schalk, B. Shen U.C. BERKELEY R. Birge, R. Ely, G. Gidal, D. Grether, G. Kalmus, W. Michael	3/21/70	Inactive
D-9	Magnetic Bremsstrahlung	ILLINOIS INST. OF TECH T. Erber, F. Herlach, H.G. Latel	2/8/69	Setup
D-11	Shielding Test	SLAC T. Jenkins, J. Harris		Inactive
D-13	Low Mass Particle Search	SLAC J.J. Murray	3/21/70	Special Test
D-16	Detector Development	STANFORD E.B. Hughes	6/16/70	Running/ Complete
ND-14	Charpak Chamber Tests	SLAC E. Bloom		Parasiting
NT-3	Fast Cycling Bubble Chamber Development	SLAC H. Barney, R. Blumberg, A. Rogers, S. St. Lorant	12/15/68	Inactive
R2.2	Position Monitor Test	SLAC J. Faust		Complete
S4.1	μ Scattering Distribution	SLAC W.R. Nelson		Complete

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

*Approved for checkout only.

†Approved for parasite time only.

III. RESEARCH DIVISION DEVELOPMENT

A. Physical Electronics

1. Glass Semiconductors

Devices fabricated during the early stages of the project were remeasured for aging effects and showed no deterioration from storage in room atmosphere. Although they switched satisfactorily with electrical impulses, they could not be made to switch with electron beam excitation.

2. Gallium-Arsenide Statistics Tube

A differential ionization pump has been installed to increase noble gas pumping speed. A pinch-off failed after bakeout; the system had to be repumped and rebaked, and it is presently approaching pressures satisfactory for GaAs surface studies.

3. Secondary Emission Detector

A successful experiment has been performed to determine the excitonic states of CsI scintillator material. A paper describing the results is being written for publication in one of the letters journals. In essence, a source of constant UV flux is scanned over the range of excitonic absorption in CsI. A peak in modulated photocurrent is produced by chopped laser light when the UV light creates excitons.

An attachment for the monochromator was constructed which permits constant monitoring of light flux. With this attachment (sodium salyciltate-light pipe - red blind photodiode), constant flux scans are possible.

B. Magnet Research

1. Magnetic Field Screening with Superconducting Shields

Field-screening tests with spirally-wound Nb_xTi sheet to form a tube were started. The magnetic field is perpendicular to the axis of the tube. The field is shielded from the bore in a layer up to 0.2 T. Although theory indicates that field piercing through the superconductor may be encountered, the measured value of 0.2 T for a 0.5 mm sheet seems too small. Further work is being performed.

2. Magnetization and Susceptibility of Pure Niobium

A preliminary report of the first stage of this work was presented at the Applied Superconductivity Conference, June 15-17, 1970, at Boulder. The tests have been performed from 1.5° to 9° K. Some results obtained disagree with published information, and it is believed that the samples are not as pure as the manufacturer has guaranteed. Chemical analysis of the pieces, 0.2" dia, 2.5" long, is being performed. Further work is continuing.

A low-field superconductive coil, 5" dia × 17" long (coil no. 42), with a bore of 4", was built and installed. The form is made from linen-base phenolic. This test facility enables us to measure thermal conductivity, susceptibility, and magnetization properties of niobium in the field range up to 10 kG, in the temperature range of 1-20^{o} K, with a field uniformity of 10^{-4}.

C. SPEAR

SPEAR (Stanford Positron-Electron Asymmetric Ring) is a storage ring system to be installed in the North Research Yard at SLAC to carry out colliding-beam physics experiments. SPEAR uses electrons and positrons from the SLAC linac stored in counter-rotating beams in the storage ring. The principal systems of the Storage Ring are the main magnet system, the vacuum system, the radiofrequency system, the instrumentation and control system, the injection system, and the beam transport system. Work on SPEAR during this quarter consisted of research and development in preparation for later fabrication of the device.

1. Magnet System

Of the 85 magnets in the main magnet system, all but 8 are either standard bending magnets (10D90) or standard quadrupole magnets (6Q20). Much of the development effort in this quarter has been concentrated on these magnets. A prototype two-part bending magnet has been fabricated and is now ready for magnetic measurements. The remaining 8 magnets in the main magnet system are called special quadrupoles. The core for one of these (6Q40) is 90 percent complete, and the first coil for it is being wound.

SPEAR is to be constructed of modules consisting of eight magnets mounted on a concrete girder complete with vacuum chamber, cabling, water distribution, etc. A mockup module assembly is nearly complete.

Development work on sextupole correcting magnets utilizing case steel yokes and poles has been successful. Examples of these sextupoles have been magnetically measured and appear to be satisfactory. The casting technique represents a major cost saving in core costs.

Survey monument coordinates have been determined for all monuments, and test monuments have been poured. Extensive stability tests will be conducted on these monuments to determine whether they are of adequate depth and cross section to achieve the long-term stability necessary for control of the ring alignment.

2. Vacuum System

Vacuum chambers for SPEAR will be fabricated from aluminum extrusions. A prototype extrusion from each potential vendor was thermally cycled to 200°C twenty times after having been bent to fit the module. There was no indication of leaks at room temperature or at elevated temperatures. Base desorption rates of approximately 4.5×10^{-6} molecule/electron were obtained on a prototype extrusion without a bakeout. Bakeout tests have started.

Machining, chemical cleaning, welding, and finish machining operations were done on the prototype vacuum chamber. The weld joints are leak-tight and they look acceptable. The heating tapes, insulation, spacers, and thermocouples for temperature monitoring were installed on the prototype chamber. The chamber was placed on the girder in the magnets and appears to be dimensionally acceptable.

Flange testing continued with in-house fabricated flanges. Two flange pairs have currently received twenty 200°C bakeouts, each with no detectable leaks. One aluminum-aluminum diaphragm survived 50 cycles of 1-1/8" excursions at room temperature, 10 cycles at 160°C, and 20 cycles at 180°C.

A 10-foot desorption chamber was assembled and pumped down, and desorption measurements were started. The desorption rates appear to be compatible with current data. Tests will continue. Tests also continued on the distributed ion pump with the low-purity titanium electrodes replaced by high-purity titanium (99.8%). Speeds of 500 liters/second were measured with the ground and sputtering shield in place. It appears that the high purity titanium is necessary to insure this speed.

3. Radiofrequency System

Work is continuing on combining the transmitters into a single power source. A "branch-line" coupler has been ordered and will be evaluated as a component in the power-combining networks. If it proves suitable, its use will reduce the cost, size, and weight of the combining network.

Initial fabrication and assembly of the prototype radiofrequency cavity have been completed, and preliminary measurements of radiofrequency properties are being made.

4. Instrumentation and Control System

Technical specifications for the computer system for SPEAR were completed, and proposals were invited; they have now been received and are being evaluated.

Design of the prototype for the low-resolution version of the digital-to-analog converter was completed and tests are in progress. Tests of the improved voltage-to-frequency converter showed a basic problem with the commercial amplifier used. A call to the manufacturer provided the solution, which involves a special internal change in the amplifier. Two more isolation elements, an ac relay and a zero-offset dc relay, have been designed and are undergoing tests.

A preliminary design of the position monitor has been completed and a prototype is being built. A trial circuit for computer display has been designed and built, and a controller is in fabrication. A preliminary design for a magnet controller for magnetic measurements has been made, and it will be built next quarter.

5. Injection System

During the last quarter work continued on the prototype kicker power supply. A hydrogen thyratron was tested in place of the solid-state switch used earlier. The tests proved the thyratron to be satisfactory. The model septum power supply was energized for the first time. Assembly of the prototype kicker magnet is proceeding, and the septum magnet is nearly completed.

6. Beam Transport System

Planning drawings for all the magnets in the transport system are complete. The 3-1/4-inch quadrupole-prototype core is complete, and the first prototype coil is being wound. Preliminary design of the beam transport vacuum pumping system shows that pumping through existing beam switchyard pump stations and through three additional external diffusion pump stations will meet criteria.

Initial design review of the requirements for computer involvement in beam controls is complete. Block diagram design and cost review are in progress.

It is proposed to modify a bending magnet supply on hand (ANL surplus) by adding a transistor bank and a filter and to power all beam transport dipoles in series with this one supply. Tests have shown that stock power supply is suitable for use with the quadrupole magnets.

A new design combines the slit and spectrum analyzer into one housing. The result is a significant dollar saving since the spectrum analyzer can now be positioned using the slit actuator. In a meeting held April 30 it was decided to investigate the feasibility of using tape-wound cores rather than ferrite cores. The turns ratio will be 1 to 1.

An analysis has been made of dc power cabling requirements in order to determine the optimum location of the beam transport power supplies based on cable length and power availability. A tentative layout of equipment in Building 101 has been made. An analysis is being made of all instrumentation and control cable requirements based on similar equipment now in the beam switchyard. It has been determined that there is ample space in the existing cable trays and terminal cabinets in the beam switchyard except in the A area. The beam path alongside SL-10 has been examined by the alignment team. The results indicated that there are more problems than expected in installing a drift tube with minimum disturbance to the existing installation.

D. Conventional Data Analysis

1. Hardware

The second NRI machine, M3, was upgraded and reinstalled on-line at the end of June. As soon as any remaining bugs are corrected, the third machine (M2) will be removed, probably early in July.

A new calibration pattern, measured to an accuracy of about 1 micron, was made for Hummingbird 2. A new platen and condenser lens system, including a better calibration pattern mount, has also been proposed.

2. Programming

A 360/91 program to assemble programs written in 6020 ASIST assembler language has been written and is undergoing checkout. It is part of a larger software package whose purpose is to allow most 6020 programming improvements to be assembled and link-edited on the 91, thereby decreasing the amount of 6020 production time preempted for this purpose.

Late-stage debugging of the Hummingbird program for the cosmic-ray experiment is continuing. Overall program efficiency, i.e., reaching the correct decision as to event identification, is at the 96% level, which is nearly sufficient to warrant full-scale production.

Further work has taken place on the NRI data sorting and reformatting programs (MERDER, STOPGAP) to improve the efficiency of their running on the 360/91. Computer costs have been reduced about 25% so far.

3. Scanning Operations

In April 300,000 frames were scanned in 1400 man-hours. The overall scanning load was low as several experiments were nearing completion. About 45,000 events were measured in 3300 man-hours. Of this total, 20,000 events were measured on six NRI machines, 13,600 were measured on the Spiral Reader, and the remainder was done on other machines. The Hummingbird was not in production in April. Spiral Reader production time increased from 220 hours in February, to 335 hours in March, to 400 hours in April (which is about the maximum attainable).

In May, 215,000 frames were scanned in 1200 hours. Over 40,000 events were measured in 2500 hours. Of these events, 13,800 were measured on five NRI tables; there were considerable difficulties with the NRI computer during the month and it was down 38.5 percent of the available hours. The Spiral reader produced about 12,000 events in 300 hours; the decrease in production on this machine was due to an increase in the number of maintenance hours during the month and it was down 38.5 percent of the available hours. The Spiral Reader produced about 12,000 events in 300 hours; the decrease in production on this machine was due to an increase in the number of maintenance hours during May.

In June, 270,000 frames were scanned in 1700 hours, and 46,000 events were measured in 2700 hours, with the breakdown by system as follows:

17,000 on the NRI system
20,000 on the Spiral Reader
9,000 on the conventional machines

NRI system downtime was 26%; Spiral Reader downtime was about 22%. In order to meet peak measuring demands, three of the weeks in June were extended to six days (by paying overtime). This practice will probably be continued in July.

There were 45 scanners on board, on the average, during the quarter.

E. Computation Group

Microprogramming and Machine Architecture

The OCTAVIA MLP-900 assembler is now over half complete. Many sections of code have been checked out, although not placed in the assembler itself. The next area to be completed is the address "fix-ups" required after the pass over the program. A new version of the OCTAVIA manual will be available shortly. It will reflect changes in the MLP-900 instructions, a few small modifications to microprogram notation, and new SHIN opcodes. Our understanding of the subtleties of the machine seems sufficient to proceed directly to the simulator writing. The simulator has been completely designed and implementation recently begun. Several months will see its completion.

The SLAC System Programming Language definition stage has been dormant. At this time a paper is being prepared for publication. It will describe the concepts and applications of "extended semaphore" variables. Once it is complete, we will refine SSPL and attempt to use it for text editor construction.

The STAGE2 Macro Processor at last works on the 360/91. We are defining a pseudo-FLUB machine for the MLP-900 and will produce a running macroprocessor in that manner.

The nature of a SNOBOL 4 machine is under study. Work on the macro-implementation has halted. We are studying the problems of implementing the interpreter and/or pattern scanner in microcode and should have a design finished this summer.

Planning for the installation of the Standard machine, contract details, etc., continues.

IV. RESEARCH AREA OPERATIONS AND DEVELOPMENT

A. General Research Area Development

There was no accelerator operation during the month of April. During this long shutdown, a goniometer was installed in the A-line in the beam switchyard. This device, designed and built at MIT, is now a permanent facility at SLAC. It precisely positions a thin diamond in the primary electron beam to produce a polarized photon beam. This beam was successfully used in Experiment E-45 in May and June.

During this quarter it was decided that SLAC would build another large experimental magnet and another rf separated π-K beam. A study of detailed parameters for the large magnet and preliminary design of the new beam is under way. This information was presented and discussed at the Users Meeting in June.

A comparison of the new 70D43 magnet with the existing SLAC large transport magnets is given in the table below.

Magnet	Gap Width Inches	Gap Height Inches	Effective Length Meters	BdL Kilogauss-Meters	O.A. Length Mirror to Mirror Inches
40D48	40	24	1.6	25.7	84
72D36	72	24	1.15	18.3	72
100D40	100	40	1.566	10.7	94
70D43*	70	23½	1.6	27	79

*In construction.

The new rf separated beam may have two separators while the present beam has one. The new beam would have a wider distribution of pass bands.

B. Hydrogen Bubble Chamber Operation

The 82" hydrogen bubble chamber operated on both liquid hydrogen and deuterium in May. The major part of the cycle was spent on BC-11. In May the chamber was expanded 1,093,668 times. BC-11 got 409,055 pictures. BC-19 got 28,145 pictures. The chamber operated well on both hydrogen and deuterium; only minor breakdowns occurred.

The 82" HBC operated on deuterium for BC-6 in June. A crack developed in the refrigeration system, causing a hydrogen leak to the main insulating vacuum. It was decided to continue operating until the leak progressed to the point at which further running was impractical. This point was reached on June 12, and BC-6 was terminated.

In June the chamber was expanded 485,503 times for BC-6 and 216,333 pictures were taken.

After warm-up, the platinum target for BC-30 was installed and at the end of June, all repairs to and clean-up of the chamber were completed and reassembly for July operations had started.

Tests were made in May on the 40" hydrogen bubble chamber to determine the feasibility of operating it at 20 pps. To minimize the sources of spurious bubbling inside the chamber, unshrouded heat exchangers were fabricated and installed. The Scotchlite was attached directly to the stainless steel piston, eliminating the fiberglass liners that had been a source of bubbling in the past. A new hydraulic expansion system was constructed and installed. This system is more efficient than the previous one, in that 80 percent of the stroke is recovered during a pulse, allowing for faster pulse rates without unreasonably large hydraulic systems. The results obtained during testing looked somewhat promising for faster chamber operation. The chamber was pulsed 180,000 times at rates of 3 and 4 pps, and for short bursts of 12 pps and was sensitive during this pulsing.

The chamber bellows developed a bellows leak on the last day of testing in June. The leak was found to be a crack across a weld joint and it has been successfully patched. However, to reduce the high bellows stresses involved in deuterium, neon, and rapid cycle operations, this present bellows system will be discarded. A new system is being designed and materials for it have been ordered. The enlargement of the holes in the magnet iron for BC-10's counter system has been completed.

The refrigerator that will replace the liquid hydrogen trailers on the 40" chamber is 90 percent complete and work has started on the instrumentation systems.

V. RESEARCH AREA ELECTRONICS INSTRUMENTATION
(July 1969 - June 1970)

A. Circuit Design Group

1. Group G FET Chamber Electronics

This project consisted of the design and construction of a 64-wire readout with visual display, to demonstrate the feasibility of FET-capacitor memories. After successful testing of a prototype, a PC board was built with 64 such memories and address circuitry. It was then decided to equip a chamber with 18 of these boards. At the same time a scanner was developed in order to display the contents of the FET-capacitor memories and analyze the behavior of the chamber; a register of 32 lamps indicates the content of the first significant word, whereas a similar register displays the contents of all remaining words. The scanner can also be used to test individual boards after fabrication. A parallel effort was made to develop a diode-capacitor memory. This circuit was found to be more reliable and easier to package, and the design is likely to be adopted in future.

Support was also given by modifying 13 thyratron pulsers; all units were equipped with avalanche transistor front ends which can be triggered by NIM pulses. Furthermore a floating output was provided in order to accommodate the chamber clearing field.

2. Proportional Wire Chamber (PWC) Electronics

Two systems have been designed.

2.1 The first approach consists in using amplifiers (Motorola MC1035) and cable drivers at the chamber itself, with the fast coincidence circuits and buffers in a remote location. This system (requested by Group A) involves an initial order of 40 8-channel amplifier boards and 40 8-channel coincidence-buffers. The coincidence-buffers are quadruple; that is, 4 events/wire/beam pulse can be detected. The format for this part of the electronics is CAMAC. Each crate will include 10 8-channel modules, 4 fast gate fan-out modules, and a crate controller. This work is scheduled for completion by August 31, 1970. Design and fabrication are proceeding on schedule.

2.2 The second approach consists in having all the electronics at the chamber. In this case the event pulse must be delayed.

A 4-channel board (this circuit has been named "Teddy") was developed, each channel consisting of the following:

a. an amplifier-discriminator with a sensitivity of 0.5 mV

b. an active delay of 200 nsec (using Motorola MC1020) which is voltage controllable and has a temperature coefficient of $0.15\%/^{o}C$

c. a 1-event/wire coincidence-buffer.

This circuit is insensitive to wide input pulses, and the delayed pulse of all channels can be easily matched within ± 3 nsec. The crosstalk level between adjacent channels is at least 40 dB above threshold.

2.3 A chamber mother-board for a 96-wire chamber has also been fabricated with a 20 × 20 cm aperture. The board supports 24 connectors in order to accommodate the electronics described under (2.2), as well as a fan-out circuit for the fast gates and the interface line drivers and receivers for the 12-bit data bus and the 8 read lines.

2.4 A complete chamber will be built around the above equipment and different fabrication techniques are being studied for this purpose.

2.5 In order to supply and monitor the chamber gas pressure a control system with the following characteristics was developed:

a. regulation of chamber pressure between 1 and 2 atmospheres

b. interlocks turning off the chamber high voltage in case of high or low pressure

c. automatic switching into system of up to 3 gas cylinders as needed.

2.6 The circuit and layout of the amplifiers described under (2.1) are being used also by Group E in its study of proportional wire chambers. In addition a group at the University of Washington was provided with a sample of this circuit. A group from MIT, and the Physics Department of the University of Maryland, College Park, Maryland, have requested copies of all printed circuit layouts.

3. Video Intensity and Position Monitors

At the request of the Spectrometer Facilities Group, an intensity monitor system was designed which permits monitoring of up to four toroids from three control stations. The system is now operational.

A triple position monitor was instrumented for beam line B. Installation and tests of the electronics have been completed.

Besides the construction of the above systems, the response of position and intensity monitors to chopped beams was studied and led to some modifications in the circuitry. In particular, the monitor sensitivity was found to be very much improved when using a signal averaging instrument which detects position signals corresponding to small beam displacements. A factor of 10 increase in sensitivity was attained. The design for such a signal averaging circuit was started. Chopped beam performance appeared improved when the integrator was bypassed. This investigation is continuing.

4. Integrated Circuit Discriminator

This design was aimed at developing a 100 MHz discriminator using MECL II logic. Development of a prototype has continued at a very low priority. A final printed circuit layout for this circuit has been completed. Some difficulties were encountered in the front end and required a design review. A report on the performance of this type of discriminator is in preparation.

5. Switched Laser Thyratron Pulser

A thyratron pulser is being built at the request of the Spectrometer Facilities Group. The circuit will replace the present pulser which has a relatively short life.

6. Maintenance Effort

In addition to the development work described above, followup and maintenance have been provided in certain areas.

6.1 ESB charge monitors. Two toroids (μ beam and K^0 beam) exhibited lower resonant frequencies due to cracked ferrite cores. Periodic readjustments of timing were required until the toroids could be replaced. Some radiation effects were observed on transistors and necessitated their replacement after 9 months of operation.

6.2 ESA charge monitors.

6.3 Evaluation tests on LRS 321B discriminators.

6.4 Spark gap trigger amplifiers. After 9 months of successful field operation, four units out of five exhibited a change in trigger electrode threshold (from 5 kV to 8 kV in air), causing unreliable firing. No apparent wear of the trigger electrode could be observed and it is not clear whether the gas supply was to be blamed or the gap itself. The Group E run (μ-p experiment) could, however, be completed without any significant downtime but with considerable support. At the present time all five units have been restored to proper operation by modifying the geometry of the trigger electrode and introducing a ceramic sleeve to create a higher electric field gradient.

B. Digital Design Group

1. Group D Support

The electronics for the K^0 decay experiment (E-48) was completed and successfully used during the period October 1969-January 1970. This includes interfacing of A/D converters, fixed data thumbwheels, multiplexers, and strobe generators into the PDP-9; and construction of a sequence timing generator "Guiseppe". In addition, interface electronics for TSI scalers, LeCroy scalers, and the phototube high voltage scanning system were constructed and implemented.

Trigger electronics for the E-60 experiment with the streamer chamber is under development. The majority logic consists of 64 channels of discriminator-gated latch to input data to the PDP-9, a logical threshold analyzer, and a trigger logic analyzer. An inexpensive discriminator was built with MECL II integrated circuits with a threshold of 100 mV for 5 nsec input, and a slewing of 2 nsec. The LeCroy Omnilogic system is being evaluated as a possible alternative.

2. Group E Support

Additional work has been carried out to increase the maximum speed of the camera advance system to 10 frames/sec.

Some recent tests were conducted to evaluate the timing resolution capability of an EG&G TD101 discriminator driving a C104 coincidence. In order to obtain coincidence widths below 12 nsec, it was found that the TD101 outputs could be clipped with a 1 nsec clipping line. This gives full width outputs of 5-6 nsec.

A photographic data box and control electronics have been constructed for the E-40 experiment. The data box displays both horizontal and vertical parity bits. In addition, 16 EG&G C142's were interfaced to the PDP-8 to read in event tagging information.

3. Group G Support

A digital interface between the wire chamber electronics and computer electronics in the Counting Room has been designed and constructed. The interface handles 4 chambers, and is mounted on the chamber assembly. The first unit is presently being tested and delivery is scheduled for July 1970. After final testing and approval it is planned to construct 6 more units.

4. Spectrometer Facilities Group Support

A new remote toroid accumulator is being designed for end station A using integrated circuits. The unit will have outputs compatible with the ESA computer and will include a preset counter to allow termination of a run when a predetermined charge has been reached.

5. Proportional Wire Chamber Data Handling

Many alternatives to the problem of single and multiple event per wire event storage were studied during this period in collaboration with the Circuit Design Group (see Section A.2). Conventional cross coupled MECL gates (Set-Reset Flip-Flop) were found to give the most satisfactory solution. Packaging of buffer latch units in CAMAC was suggested, and simplified addressing schemes were developed.

A simplified CAMAC crate controller has been designed in block diagram form. This controller selects the desired module, the desired event, and places the data on a data bus (branch highway) which interconnects several CAMAC crates. The controller will be used in Group A C-beam tests later this summer in conjunction with a PDP-8/L.

The general data handling problem for proportional chambers has been studied and alternatives proposed. A data pre-processor is under design for a Group A experiment later this year which scans the wire chamber data and generates wire addresses. Such a scheme significantly reduces input data flow and data processing in the SDS 9300.

6. Magnetic Measurements Support

Considerable work was done during this period on a rotating coil magnet harmonic analysis system to be used to measure the storage ring magnets. The system was based upon the use of Fourier analysis of data from a precision A to D converter using a small digital computer. However, budgetary considerations prevented the construction of the system. A paper (SLAC-PUB-750) on the technique was presented at the 3rd International Conference in Magnet Technology. Some improvements in the use of the present wave analyzer have been implemented for harmonic analysis.

7. NMR System

An NMR magnetic field measurement system based upon a design from the Stanford High Energy Physics Laboratory is being re-packaged for operational use in the beam switchyard. All of the printed circuit cards have been completed and tested. Integration and system tests of the first unit are now under way.

8. Laser Protection Logic

The Q-switched ruby laser system has a quirk of emitting a large pulse immediately following a missed pulse. These large pulses can be dangerous if the laser is operating at a high level just below a destructive level. A protective device was designed and built which, after two missed pulses, changes the mode of the laser from Q-switched to normal for some preset number of pulses (N = 1 to 15) before again permitting Q-switching. The device was built with integrated circuits and successfully tested.

9. CAMAC Activities

A captive extraction screw for the CAMAC modules was proposed to ease extraction of modules. This method was implemented, and is now in use at SLAC and LRL-Berkeley.

Plans are under way to improve the standard CAMAC modules by (1) addition of extraction screw (2) addition of protective shields (3) standard blank board negative with CAMAC rear connector. These improvements will be made available to all users through SLAC Electronics Stores.

A collaboration with LRL-Berkeley resulted in a "standard" specification for a 100 MHz CAMAC scaler. Two orders based upon this specification were placed, and the units were received. They are now undergoing evaluation and acceptance tests.

C. <u>High Energy Electronics Pool (HEEP)</u>

1. General Activities

A number of rather heavy modular equipment procurements were made in May and June. These included 60 channels of dual 150 MHz discriminators, 80 channels of quad 100 MHz discriminators, 40 channels of CAMAC 100 MHz scaler, approximately 30 NIM bins and power supplies, 6 CAMAC bins, CAMAC power supplies, and miscellaneous additional modules. All procurements listed are scheduled for installation in scheduled experiments starting late August. Equipment utilization continues to be extremely heavy, and is essentially 100% on discriminators, scalers, and powered bins. Maintenance and scheduling activities have steadily increased over the past year.

2. Inventory Program

A subroutine has been recently completed which allows listing of on-line equipment by experiment number. Other general improvements have also been made to simplify use of the program.

3. SHV Connector Retro-Fit

All old style 5 kV connectors on the project are slowly being changed over to the NIM standard SHV series. The work is being performed by Electrical Installation Group of the Experimental Facilities Department (EFD), coordinated by HEEP. To date, Group G changeover is 98% complete, while Group D and the laser beam hut changeovers are in the planning stages. Difficulties in obtaining sufficient supplies of connectors and coax have been experienced.

4. E-69 (UCLA) Support

The Science Accessories (SAC) wire chamber electronics controller and IBM 1800 interface were modified for the UCLA HP 2116B computer. The system is now operational.

D. SPEAR Instrumentation and Control

1. General Activities

The SPEAR I&C design effort began in November, 1969 with general system studies, which continued throughout the rest of the fiscal year. Preliminary designs of beam position and intensity monitors were completed and prototypes built. These were undergoing tests at year's end. Circuit design efforts centered on certain small but key system elements which affect basic system design. These include

a. digital-to-analog converters

b. current-to-frequency converters for ion pump readout

c. voltage-to-frequency converters for magnetic measurements

d. electronic relays for analog switching

e. digital circuits for magnet control

f. a high output distributed amplifier for beam feedback control.

The computer procurement cycle was begun with the writing of specifications for a complete computer system, and a request for proposals was sent out to vendors. The proposals were received in June and evaluation was in progress at year's end. Preliminary investigation of computer display units presently available indicated that a SLAC-designed unit might be the best choice and a preliminary design was completed and production of a prototype begun. This unit was not quite finished by the end of June.

E. Group B Support

1. E-41 Support

The equipment for E-41 was successfully maintained and operated during the December and January cycle.

The following is a summary of developments on wire chamber electronics:

1.1 Debugging and maintenance of SAC system cards:

a. use of the controller register and internal scan mode addressing instead of a computer readout

b. development of an independent test box for SAC 1124 system cards

c. completion of a stand-alone test program for the IBM 1800 computer for system checkout of the SAC 1124 scalers.

1.2 Construction of a veto generator to establish a busy signal for computer readout programming.

1.3 Installation of a transfer gate logic to prevent event overflows. The number of desired events can be selected.

1.4 Checkout and installation of the final design of the SLAC scanner; subsequent interface with a third SAC system bin.

1.5 Work on a new magnetostrictive wire chamber preamp with dynamic exponential discrimination level.

2. Vector Generator

A new graphic scope controller utilizing large scale MOSFET integrated circuits has been designed, built and tested with the PDP-9 and IBM 1800. The device will draw 10-bit vectors in any direction and ASCII characters in seven sizes. It utilizes two 20-bit accumulators to draw vectors and a 2240-bit read only memory to draw characters. The display uses a Tektronix memo-scope.

3. IBM 1800 Additions

A new 8-word digital input for the IBM 1800 has been designed and built. It is a direct replacement for an IBM digital input consisting of a group adapter and 8 digital inputs. The new device is improved in that the computer READY line is automatically selected in conjunction with the particular digital input initialized by the program.

4. BC-10 Support

The final improvements of the peak hold and scanning system and debugging for the initial test run have been completed. Work was accomplished on the peak hold and linear gate circuits to improve the resolution to 1/4%. With an additional improvement in the time mode, resolution is less than 100 picoseconds or 0.1% full-scale.

5. Vidicon Scanner[1]

A prototype vidicon scanning system was built to determine the feasibility of using the latest integrated circuits in conjunction with video and computer equipment to scan and digitize bubble chamber events in real time. The system digitized the picture into a 400 × 437 XY grid and detected an 18 micron wire in a 15" background. In addition, an RCA solid state vidicon Model C23136A developmental type having a target array of 750,000 photoconductive diodes was tested and found to have higher sensitivity and reduced blooming.

6. Science Accessories (SAC) Scaler Display

The scaler display system reported previously has been summarized in the Technical Note SLAC-TN-70-18.[2]

F. Group G Support

1. Data Acquisition Facility

Three subsystems were developed to provide a complete data acquisition facility for experimental Group G. The new experimental building (Bldg. 232) contains 20 racks of electronic equipment and a PDP-9 computer with its auxiliary equipment. Of the 20 racks of modular instruments, 5 are occupied by standard commercial fast logic, 2 are designated for Data Assembly Building (DAB) equipment and the remainder consists of instruments primarily designed by Group G.

Three subsystems comprise the data acquisition facility: (a) a 256 channel time-multiplexer operating under PDP-9 program control; (b) a spark chamber system consisting of 20 planes with a total of 31,000 wires; (c) counter data acquisition having a system capacity of 512 modules.

2. 256 Channel Time-Multiplexer (Device 37_8)

This device operates under program control of the PDP-9. One hundred forty-four channels are utilized for remote control setting of photomultiplier

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1. R. G. Friday, D. W. G. S. Leith, D. G. McShurley, "An on-line vidicon scanning system for rapid cycle bubble chambers," Report No. SLAC-PUB-792 (in publication).

2. R. G. Friday, K. D. Mauro, "A numeric display and computer controller for Science Accessories Blind Scaler 1148AS," Report No. SLAC-TN-70-18 (in publication).

voltages. The variable part of each voltage has a resolution of six binary bits. The subsystem can be extended to serve 168 photomultipliers, and with some minor additions up to 192 photomultipliers. The remaining address locations are utilized for computer control of PM testing with the aid of nanosecond light sources, for control of the spark chamber logic and for a variety of monitoring functions, including two oscilloscope displays. The full capacity of this subsystem has not yet been realized and requests for new uses come from the experimenters at frequent intervals.

3. Wire Spark Chamber System

This spark chamber spectrometer consisting of 20 planes is of a novel type utilizing capacitors as memory elements. The advantages of the system are: (a) it can operate in large magnetic fields, (b) it has good multitrack efficiency. The size of the planes ranges from 4' × 4' to 8' × 6'8". With a separation of 1 mm between wires the total number of detection circuits required is 31,000.

Starting in August of 1969, proposals were issued to members of Group G describing the complete data acquisition system and computer interface. The proposals included (a) two alternative methods of signal detection utilizing either FET's or diodes for isolation of the capacitor memory, and serving also as strobed readout elements; (b) two alternative methods of addressing the readout elements; (c) extensive logic circuitry for pre-processing of data and reformatting in hardware. This was especially required to minimize on-line computer time which is the limiting factor in event acquisition rate; (d) computer-aided tests for proper operation at the system, subsystem and components level.

Detailed design of the detection and data acquisition system followed. The FET circuits were tested extensively and showed high failure rates. Capacitor-diode elements were produced for SLAC by CENTRALAB and our tests with one board (64 channels) showed no failures thus far. The positive test results warranted the ordering of components for the complete system (16,000 dual circuits) with latest delivery of components expected 9-3-70. In the meantime PC boards were developed and tested showing very good results together with ease of fabrication. Test circuits were developed to test the capacitor-diode memories (15 sec/both channels in package) and to test a complete PC board including dynamic test of address, tests for clear and for both strobes as well as functional testing of all capacitor-diode (C-D) memory elements on the PC board. A copy of the C-D test box was sent to the manufacturer to ensure equivalent conditions of acceptance testing.

The direct memory access (DMA) interface has been completed and tested. The total logic, complete with the pre-processing and reformatting circuits, has been constructed. It includes additional test modules to aid in isolating faults in crucial or complex parts of the system. Debugging of circuits started in June. The greatest unknown is the behavior of the logic circuitry in presence of pulsing of 20 wire chambers (7 kV, several thousand amperes, 100 nsec).

The operation of the spark chamber system is initiated under computer program control utilizing device 37_8 (see paragraph 2) for initiation, simulation, enabling and disabling of logic, selection of individual wire chamber planes for test, etc. Data are fed into the PDP-9 via DMA channel 0.

4. Counter Data Acquisition System

This subsystem has a capacity of 512 addresses and brings onto common bus lines data from scalers, nanosecond ADC's for pulse-height and pulse duration, coincidence latches, thumbwheel indicators for experiment identification, etc. A 9-bit address code is distributed throughout the total system. Each chassis is selected via 5 msb (bits) of the address code, while individual locations within the chassis are addressed through the 4 lsb (bits). The system utilizes NIM plug-in modules predominantly of Group G design that were available from previous experiments. New equipment such as coincidence latches, some ADC's buffers, decoders, fan-in of data and fan-out of address utilizes CAMAC hardware. As in paragraph 3, test facilities have been incorporated for off-line testing. Data are fed into the PDP-9 via DMA channel 1.

The subsystem has been designed, constructed and tested off-line.

The hardware logic discussed in paragraphs 3 and 4 is shown in Fig. 3.

5. Publications

1. R. Coombes, D. Dorfan, D. Fryberger, D. Porat and R. Piccioni, "A wire spark chamber spectrometer with a capacitor memory and FET readout," IEEE Trans. Vol. NS-17, 50-54 (1970) (presented at the 12th SSCS, Washington, D.C.).

2. R. Anderson and D. Porat, "Dual frequency BKO system for the 1.6 GeV spectrometer," Report No. SLAC-TN-69-17.

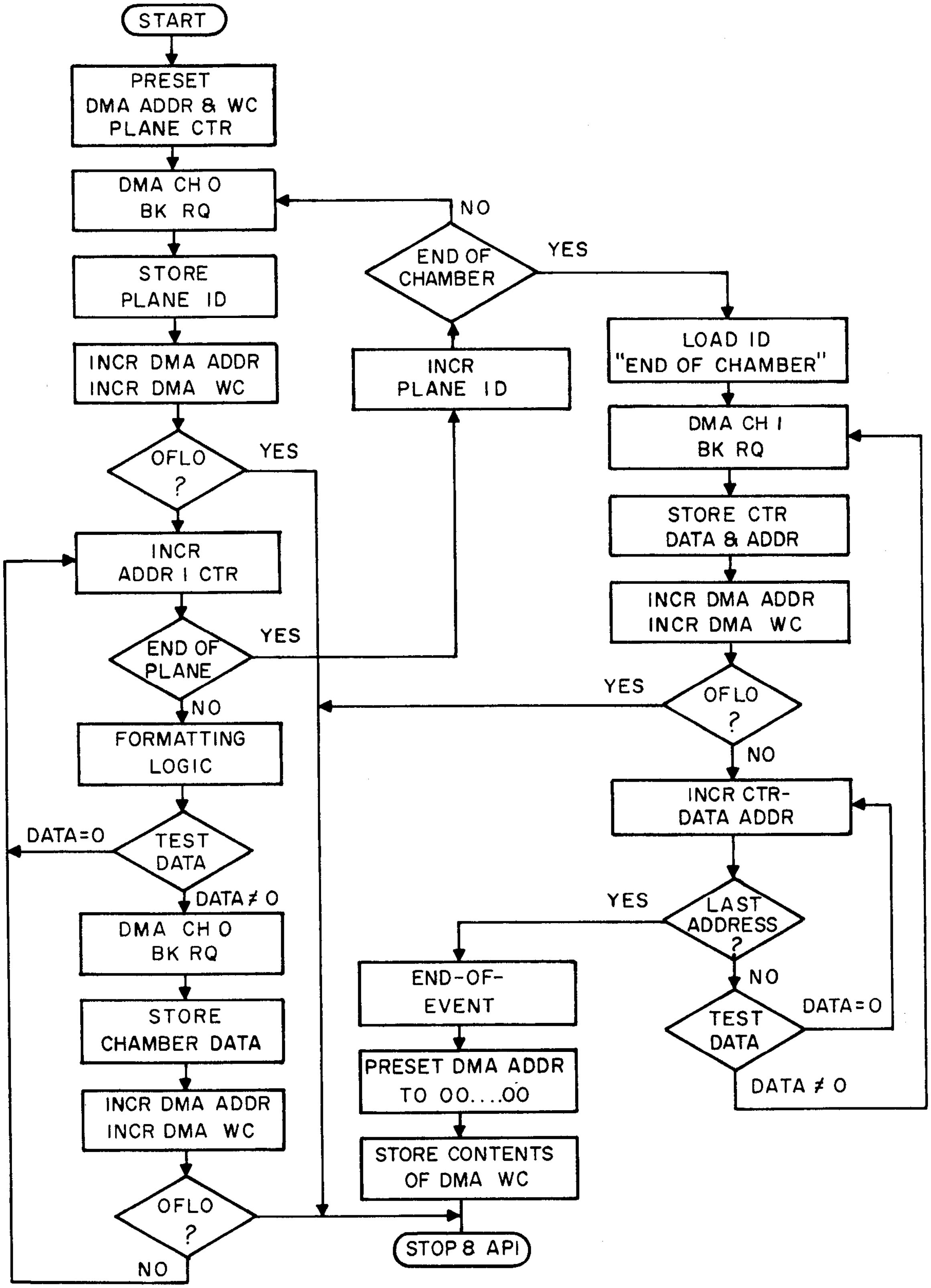

FIG. 3--Flow chart for the data-processing hardware.

G. Spectrometer Facilities Group (SFG) Support

1. General

The following items have been the result of a collaborative effort by SFG and Electronics engineering personnel. This subgroup within SFG has cognizance of the computers, data interfaces, and high speed electronics.

2. Computer Interface Project

2.1 Two external device controllers (EDC's) No. 1 and No. 2 have been built, tested, and are now on-line servicing the SDS 9300 and 930 computers respectively. EDC No. 3 is in construction at present.

2.2 The switcher for the EDC's has been built, tested, and is also on line.

2.3 The interrupt router has been constructed and will be installed for test prior to the end of the present shutdown (10 July).

2.4 Design has started on the modification of the data interface (primarily EDC No. 1) to accommodate the block transfer of data at the higher rates required by the operation of proportional wire chambers in November.

3. Multiplexers

3.1 A new scaler multiplexer was designed, constructed, and is in operation.

3.2 A new magnet power supply multiplexer is in design. It is to be located in the power supply house. The new unit will be tested in parallel and on-line with the present power supply multiplexer and will supplant the latter upon completion.

4. Blind Scaler Data Interface

A data interface for the recently purchased 40 channels of blind scalers is in design. It will be constructed on a dual-width CAMAC crate-controller module. The system is to be installed in September.

5. Redesign and expansion of the Experiment Beam Gate Rapid Kill and Event Interrupt Electronics is under way. Two units are to be constructed for use in November.

6. Occupation of New Half of Counting House

6.1 Several major items have been relocated in the new end of the Counting House, specifically, the 930 computer and its peripherals, and the 9300 CPU and tape units.

6.2 Detailed plans are being formulated for the transfer of equipment including the 20 GeV high speed electronics.

7. A new Experimenter's Control Panel was designed, built, and is now in service.

H. Data Assembly Building (DAB) Computer Support

The following jobs are in progress or were completed during this period for the SDS 925 computer.

1. A new flip-coil interface to provide field strength data from both A and B bends. The hardware is complete and checked out.

2. A contract-closure pulse generator produces standard interrupt signals from noisy contacts, e.g., push-buttons, relays, etc. The prototype has been in service 2 months. Further cards are in production.

3. A digital input interface to handle status and interlock signals (capacity $2^8 \times 24$ bits) is presently under construction.

4. Touch panel. This is a glass panel over the face of a computer-generated push-button display. A matrix of highly collimated sound waves is transmitted across the surface of the panel. Finger pressure on the glass absorbs the wave and the X-Y coordinates are fed to the computer. A prototype has been in operation 2 months. A production model is being designed with curved face-plate (to eliminate parallax) and simplified electronics.

I. Data Analysis Support

1. Hummingbird II System

The HBII flying spot measuring system was maintained in operation for production measurements and software development. Several small modifications of the electronic and mechanical hardware were carried out.

A new interface was designed and constructed to drive HBII with the special purpose electronics of the HBIII system. Testing of this system configuration will be completed in the near future.

2. Hummingbird III System

2.1 HBIII scanner. After completion of preliminary tests of the CRT system and the optical system, HBIII has been moved from the laboratory to its final location in the computer building. All hardware is installed and tested. First calibration tests showed an overall accuracy and short term repeatability of $\leq 2\ \mu m$.

Production measurements of streamer chamber film are scheduled to start beginning of August 1970. Development and design work has been started of CRT control electronics with a temperature coefficient of ≤ 10 ppm/^{o}C.

2.2 Film drive system. A drive system for 35 mm film has been designed, constructed and installed. Three strips of film can be moved independently. The particular frame to be measured or a calibration pattern is positioned in front of the optical platen by means of air-driven actuators. Digital control electronics interface the drive system to the HBIII logic. All hardware has been tested under computer program control.

2.3 Digital logic. After the initial design and construction had been completed, extensive simulation tests revealed noise and cross-talk problems. Several modifications have been made in order to eliminate these problems. Further work is scheduled for July and August 1970. Preliminary design work has started on a digital simulator system to allow off-line testing of the HB scanning systems.

3. TV-Disc Display System

3.1 4-2-1 system. The system has been used for software debugging and development during the last 6 months. A second TV monitor has been purchased and modified and is available as a backup unit. In conjunction with HBIII this display terminal will be used for streamer chamber film measurements. Design and construction work on an expanded version of this terminal will start in August.

3.2 Keyboard system. This special keyboard is part of the TV-Disc Display terminal to be used with the HBIII. Construction of hardware was completed during June 1970. Testing and debugging will be completed in August 1970.

4. HB Support Systems

4.1 Pressure and vacuum systems. After installation of the HBIII scanner an expansion of these systems became necessary.

A new vacuum pump has been installed and the pressure system has been enlarged to 4 each vane pumps. A backup system consisting of 2 vane pumps is available for the vacuum. Regular maintenance has been arranged for these pumps.

4.2 Utilities. A three-phase service of filtered and shielded ac-power has been installed for the HB scanning systems.

To reduce noise and to allow proper grounding of all digital and analog hardware a high quality flat ground bus has been installed.

5. Spiral Reader

The Spiral Reader has been operational since August 1969. Since that time production has risen from 2000 events/week to 5000 events/week. Besides normal maintenance, development work is continuing on the design of an effective bright-field AGC card, an autofiducial measuring system and a crutch-point measuring system.

6. NRI System

The NRI system is in the process of being revamped into an all IC machine. Although the system is basically the same, the machines have been redesigned to correct some of the previous problems. Two of the machines have been overhauled and the sub-chassis of the other four have been constructed. The project should be complete by October 1970.

A new MDS 6002 card reader has been interfaced into the EMR 6020 computer. An existing Burroughs card reader can be switched into the system as a backup unit.

An automatic ionization measurement device is being developed using the CRT scan of the TV camera.

7. Scanning Machines

The design of an SP-6 scanner is complete. This new scanner uses the principles of existing SP-6's but adds some features to increase the efficiency of the machines. The two existing SP-6's as well as four SP-5's will be converted.

J. <u>LH_2 Target Group Electronics</u>

1. E-41 Target

A new target control system for the E-41 target was designed, fabricated and installed during this period. This new control system for the refrigerated target implemented a new concept in that the front panels are a flow diagram schematic of the target system. Also, all individual chassis were integrated into two chassis, one controlling the target and one controlling the refrigerator. After some initial installation problems with cross-talk and faulty connectors the system functions satisfactorily.

2. E-49a Target

The control system of the LH_2 target for the E-49a experiment was instrumented to allow selection of any one of 12 possible targets. Encoders are utilized to read out both vertical and rotational target positions. SLAC-PUB-753 describes the target control system.

3. ESA System

The preparation for the move of the ESA controls and fill systems up to the Counting House was accomplished during this period.

VI. ACCELERATOR IMPROVEMENTS

Installation of pulsed steering and focusing equipment with six-level control was completed in Sectors 11, 25, 28 and 29 during April and work was started to provide the same capability in sixteen additional sectors over a two-year period. Because of restraints limiting quadrupole installation to one sector a month, the initial effort was expended in this area and coil winding was started in June. Procurement of laminations was initiated and bids are being solicited.

Work continued on pulsed beam loading compensation during the quarter. A pulsed system for six-channel operation was installed in one sector during April and successfully tested in May. Four additional units were fabricated in June and will be installed in August at which time the instrumentation will be ready. Installation of these four additional units will complete the project.

Conversion of the off-axis injector from dc to pulsed operation was started during the quarter. Mechanical design of the pulsed alpha magnet neared completion and fabrication was to be started in July. Preliminary design of the power supply was completed, but final design will be deferred until after completion of the alpha magnet. Fabrication of the pulsed gun modulator continued and neared completion. It is planned to complete the conversion from dc to pulsed operation by the end of calendar year 1970 at which time simultaneous use of the on-line and off-axis injectors on a pulse-to-pulse basis will be possible.

Engineering continued on modification of the pulsed phase closure system to provide four independent phase closure adjustments. The present system can handle only three beams and under certain operating conditions the units operating on separate beams interact adversely with each other.

Engineering was started on the short pulse generation system improvement. Better and more reliable oscilloscope triggering, installation of a transient energy analyzing system, and improvements to the EG&G fast pulser are some of the improvements to be made.

Work on the B-beam slit continued during the quarter. Fabrication of the slit modules, the precision shafting coder, the modular-supporting strongbacks, and the internal drive assemblies was completed during the quarter. The prefabricated vacuum tank assembly, bellows, and flanges were delivered and are in the shop for final fabrication. Final assembly is to be started in July. Over all, fabrication of the slit is about 83% complete.

Consolidation of the two control rooms was started during the quarter. A prototype touch panel was built and tested and an improved panel is being developed to eliminate the parallax problems inherent in the first model. Television monitors to be used with the display system are being evaluated. Bids for the display system are being evaluated. Design of the link hardware has been started. Extensive use of the two presently installed computers is planned and software development is proceeding in parallel to the hardware development.

Fabrication of an additional main frame in the data assembly building was started during the quarter and is nearing completion. Additional cables and coaxial terminations will be provided to handle the normal expansion of experimental requirements.

Work was started on improvements to the profile monitor system in the beam switchyard. A prototype relay box was built and installed in the beam switchyard for testing. Results were satisfactory and an order has been issued to the electronics shop to build 20 production units at the rate of one a week. Manpower limitations restrict fabrication at a faster pace. Cabling to connect the various relay boxes has been installed.

Design of a magnet warning system for the beam switchyard was completed and fabrication and installation of the system was begun. Installation will be completed during the next two or three down periods. The system will provide a flashing red light when magnet power is on and the switchyard is open.

Work started on improvements to the SDS 925 computer interface equipment in the Data Assembly Building. Fabrication of a digital input multiplexer was begun and link hardware to handle new power supply controls is being designed.

Design and fabrication of hardware to expand the data system was begun. Over a two-year period this system will be improved to speed up reporting to and from the Central Control Room and the computer of various signals along the machine.

VII. KLYSTRON STUDIES

A. Development

1. High Power Klystrons

Litton subcontract. Acceptability of Litton tubes during the quarter continued satisfactory. However, Litton experienced some difficulties with their window coating equipment which reduced the total number of deliveries because of high window temperature observed at Litton.

RCA subcontract. Tubes delivered during the previous quarter for 30 MW operations were successfully tested during this quarter. RCA appears to have achieved a substantial increase in operating efficiency although the maximum efficiency is not as high as that obtained with the SLAC design.

SLAC. The yield off bake was very low this quarter because of 4 consecutive leaks around a new rf input seal and 1 window leak. As a result a mechanical redesign of the input cavity was necessary, which slowed down the fabrication and further decreased the number of tubes available for tests. Additional modifications have also been designed into the output system to decrease the rf breakup observed on some tubes when the output exceeds 30 MW.

2. Klystrons for Superconducting Accelerator

The first tube built for this program has been reworked and retested during the quarter. Unfortunately the input seal leaked on bake and it is believed that the tube was slightly gassy during tests. Because of this gassiness we believe the test results are not valid. The second tube is being readied for assembly including changes to improve the cooling and coupling of the output cavity.

Cathode tests on both life test diodes are continuing without any evidence of decrease in emission for either the oxide cathode or the dispenser cathode. The diodes have accumulated well in excess of 4,000 high voltage hours each.

3. High Power Windows

Two SLAC windows failed in operation during the quarter from what appears to be excessive temperature. One window cracked after 2208 hours of operation at 265 kV, and total operating life of almost 7100 hours. The indicated window temperature rose by almost 50° shortly after the operating level of the tube was increased from 245 kV to 265 kV in January. The other cracked window was on a klystron which operated over 10,000 hours at 245 kV without any indication of window failure from either the tube operating behavior or the window temperature data for that station.

Another operating tube had a window failure which consisted of a minute leak through the ceramic. The tube failure was because of excessive arcing after 17,000 hours and probably not related to the window failure unless the sector had been let up to nitrogen. Leaks of this type have been observed in the past, specifically 2 during the previous quarter.

In addition a window seal failed during the vacuum bake. This particular window was one of the last of a batch of metalized ceramics purchased in 1966. No further trouble is expected from the present ceramics batches.

On the basis of present evidence it appears that water cooling of the waveguide adjacent to the window is desirable on tubes operating at high voltage with an output power in excess of 25 kW average. Some tests have been conducted in the resonant ring to verify the need for cooling. This additional cooling and a very careful control of the titanium coating thickness will presumably enable us to continue window operation within safe temperature limits in spite of the increase of power output.

4. Driver Amplifier Klystrons

Some problems have been experienced in mating tubes with the crucible magnets procured during the past year. It was determined that the axial magnetic field although within specifications was higher than desirable for optimum operation of the tube. By using a special pole piece arrangement during remagnetization the field has been reduced in a portion of the drift region. This appears to have solved the problems of interchangeability between tubes and magnets.

5. Special Problems

RF loads. Three rf loads of the new design have been completed and tested during the quarter. The results appear very satisfactory. No evidence of breakdown or of localized heating has been found even at peak power approaching 50 MW. In addition the loads are physically smaller and easier to handle than those previously in use. Additional loads of the same design are in the process of being built.

Computer programs. The remaining theoretical work of Wessel-Berg on the large signal analysis has been received during the quarter and is being adapted for computer programming. To date the small signal program is completed and a large signal program for the drift space has been tested and appears to be working satisfactorily. The remaining work will include large signal gap calculations and the output format to help us establish both the correctness and theory.

To date the small signal program applied to the high power SLAC tubes indicates a computed small signal gain of slightly higher than 60 db. The measured small signal gain is slightly less than 60 db if the tube is focused for large signal operation.

B. Operation and Maintenance

The number of operating hours for the quarter was substantially decreased because of budget limitations. As a result we experienced only 18 high power klystron failures and 1 driver amplifier klystron failure.

1. High Power Klystron Operation

Table II gives the summary of usage and failures for all klystron vendors since the beginning of operation.

The data is also plotted in Fig. 4 in which we have added the mean age of operating tubes and the cumulative hours average per socket since the beginning of operation.

The tube age distribution of both living and failed tubes for all vendors is shown in Fig. 5. For tubes now living the mean age is 11,200 hours and the median age is 11,300 hours. Forty-two percent of the tubes have operated in excess of 15,000 hours and five percent in excess of 20,000 hours.

The data presented in Fig. 5 has been analyzed to determine the failure and survival probability. The results are shown in Fig. 6.

The effect of operating level on operating failures continues to be carefully reviewed. On the basis of the failures experienced this quarter it appears that the mean time between failures (MTBF) at high voltage (265 kV) stations is approximately 80% of the average MTBF. Three (16.5%) out of 18 failures occurred at high operating level stations, which comprise 13% of the whole machine.

2. High Power Klystron Maintenance

In spite of the continuing increased performance demand in so far as accelerator beam is concerned, the trouble reports and general difficulties with high power klystrons were less than last quarter although still somewhat higher than the average for 1969.

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	16	7,280	19,700	3,425,000	221	4,190	15,400
To 9/30/69	179,800	8	11,670	22,500	3,608,100	229	4,450	15,750
To 12/31/69	303,600	10	10,230	30,400	3,911,700	239	4,690	16,300
To 3/31/70	358,700	32	9,950	11,200	4,270,400	271	5,270	15,800
To 6/30/70	257,200	18	11,350	14,300	4,527,600	289	5,650	15,700

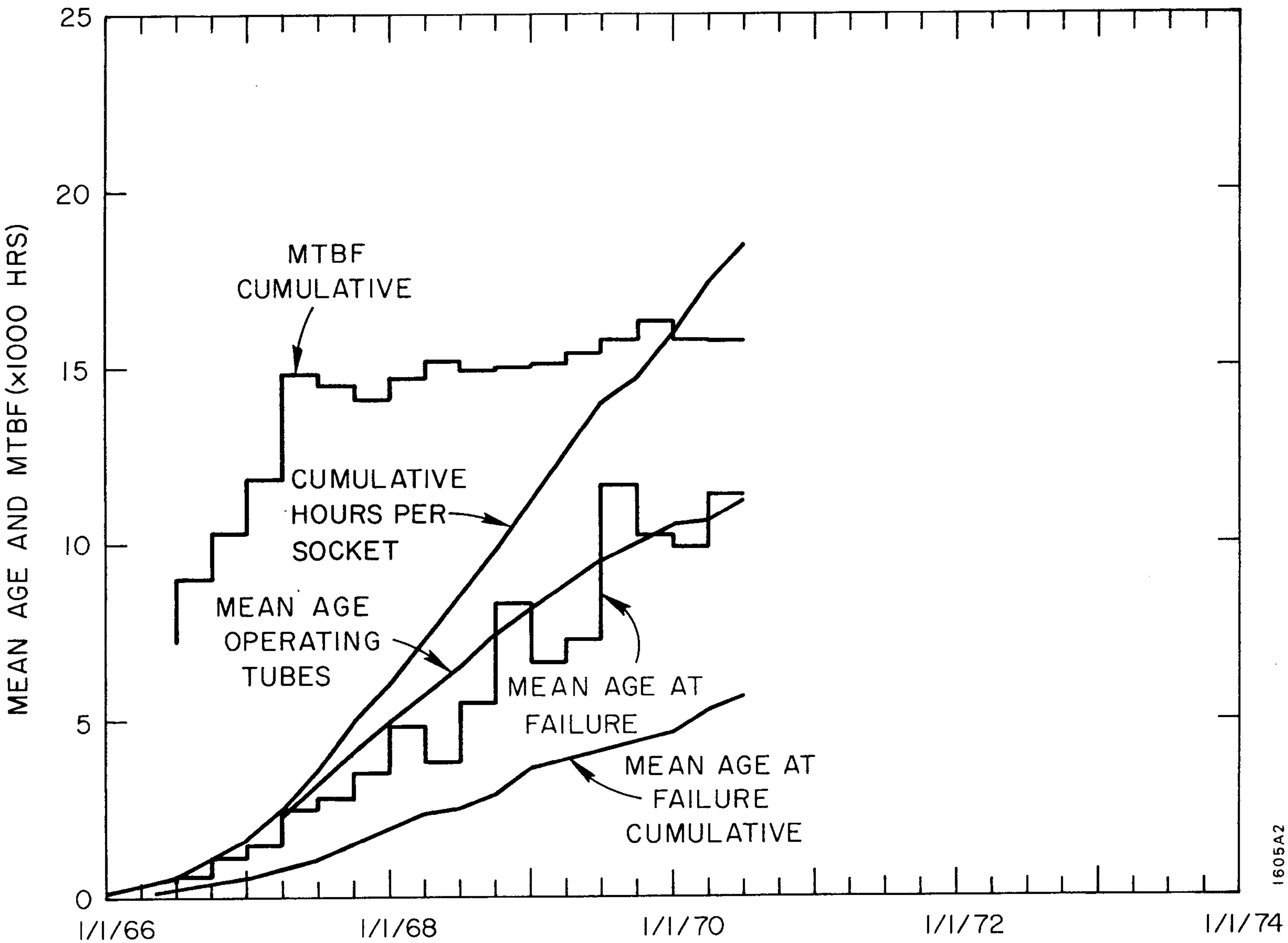

FIG. 4--High-power tubes: cumulative MTBF, mean age, mean age at failure, cumulative age at failure, and cumulative hours per socket, June 30, 1970.

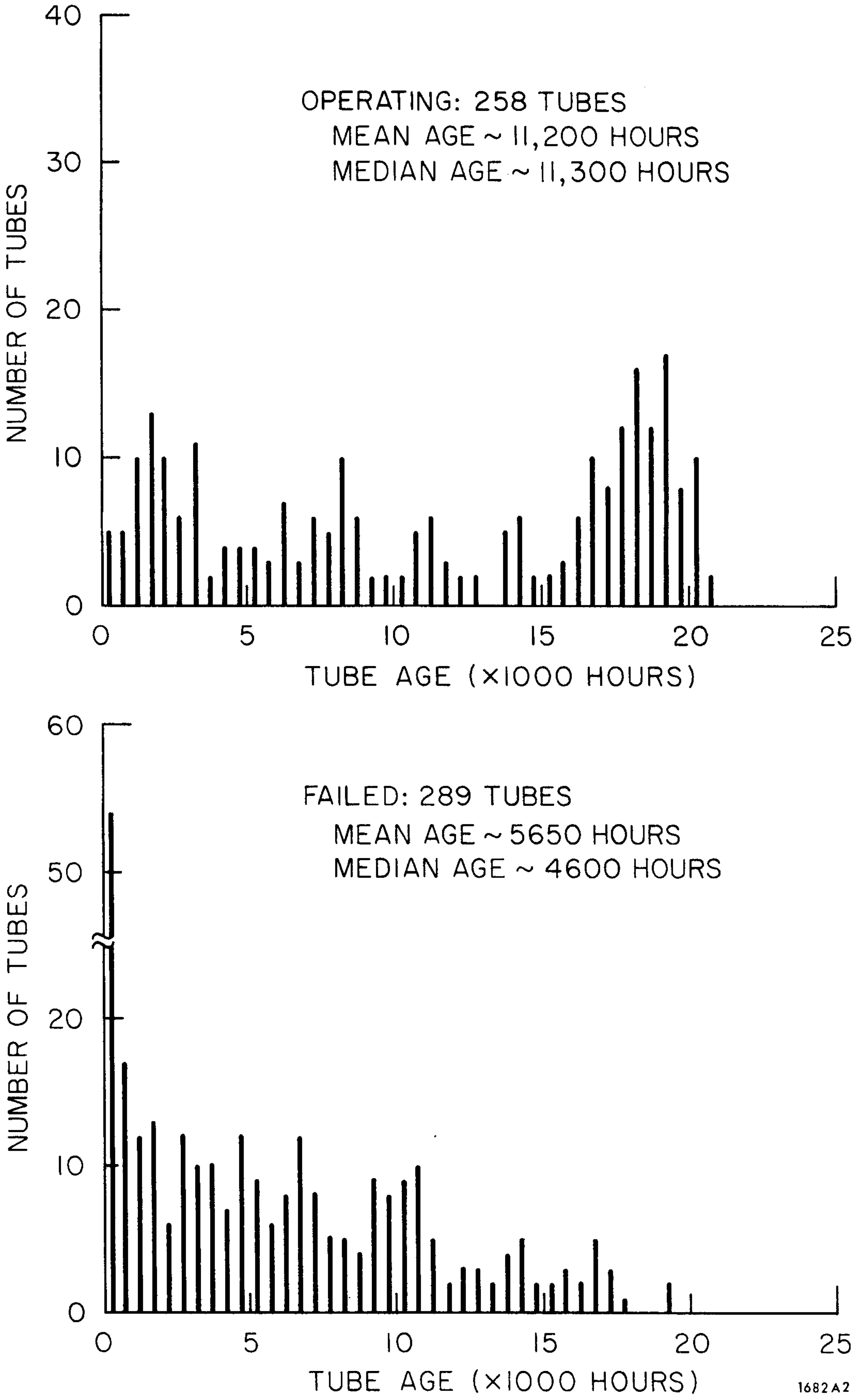

FIG. 5--High-power tubes: tube age distribution of both operating and failed tubes, June 30, 1970.

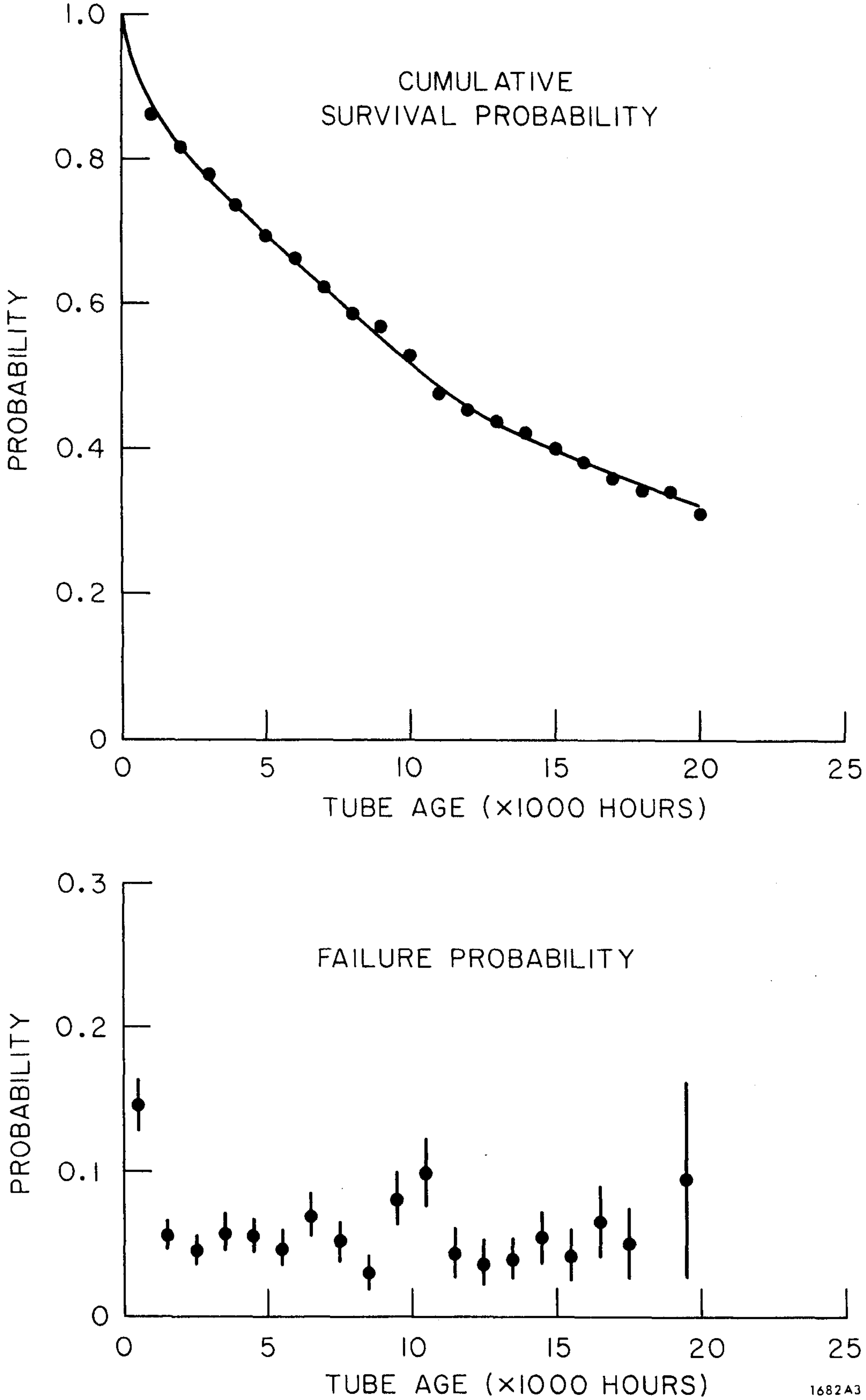

FIG. 6--High-power tubes: survival and failure probability, June 30, 1970.

The replacement rate was approximately 1-1/3 per 10,000 hours of klystron operation for all stations.

The main difference during the quarter is the much higher rate of filament circuit shorts causing replacements. These short circuits were caused by capacitor failures. The capacitors were installed at various times from January 1968 to January 1970. The accelerator electronics group is now installing higher working voltage capacitors in the pulse transformer tanks.

There were no substantial changes in the relative frequency of causes of klystron failures; no wear out mechanism which would be evidenced by a large number of temperature limited cathodes has been detected yet.

The operating experience for all klystrons since the beginning of operation is shown is shown in Fig. 7.

3. Driver Amplifier Klystrons

Only one driver amplifier klystron failed during the quarter; a SLAC with an age at failure of 1900 hours. There are still 6 Eimac tubes in the gallery and 3 in the test laboratory. All remaining Eimac tubes have a mean age of almost 25,000 hours with a median age greater than 26,000.

The SLAC tubes have now accumulated sufficient operation to give us some meaningful analysis on the failure rates. The results are given in Fig. 8 which shows the age distribution of operating and failed SLAC driver amplifiers in 500 hour increments; the results of the failure analysis performed from that information is also given. It can be seen that to date the failures appear to be random with approximately 20% loss in the first 1,000 hours of operation and 6% per thousand hours thereafter. This is very similar to results obtained for the high power klystrons. However, since no failures have been observed on tubes with more than 5,000 hours of operation we may have outgrown the infantile mortality rate for these tubes.

4. Main Booster Klystrons

No replacements or failures of main booster klystrons occurred during the quarter. Operation of station no. 2 has continued with the klystron operating at a perveance of $.55 \times 10^{-6}$. The improvement in performance with more stable output, reduced body current, and less critical adjustment of focus current and drive power has remained.

During the quarter approximately 24 hours of accelerator beam time was made available for investigation of the relationships between beam instabilities and main booster performance.

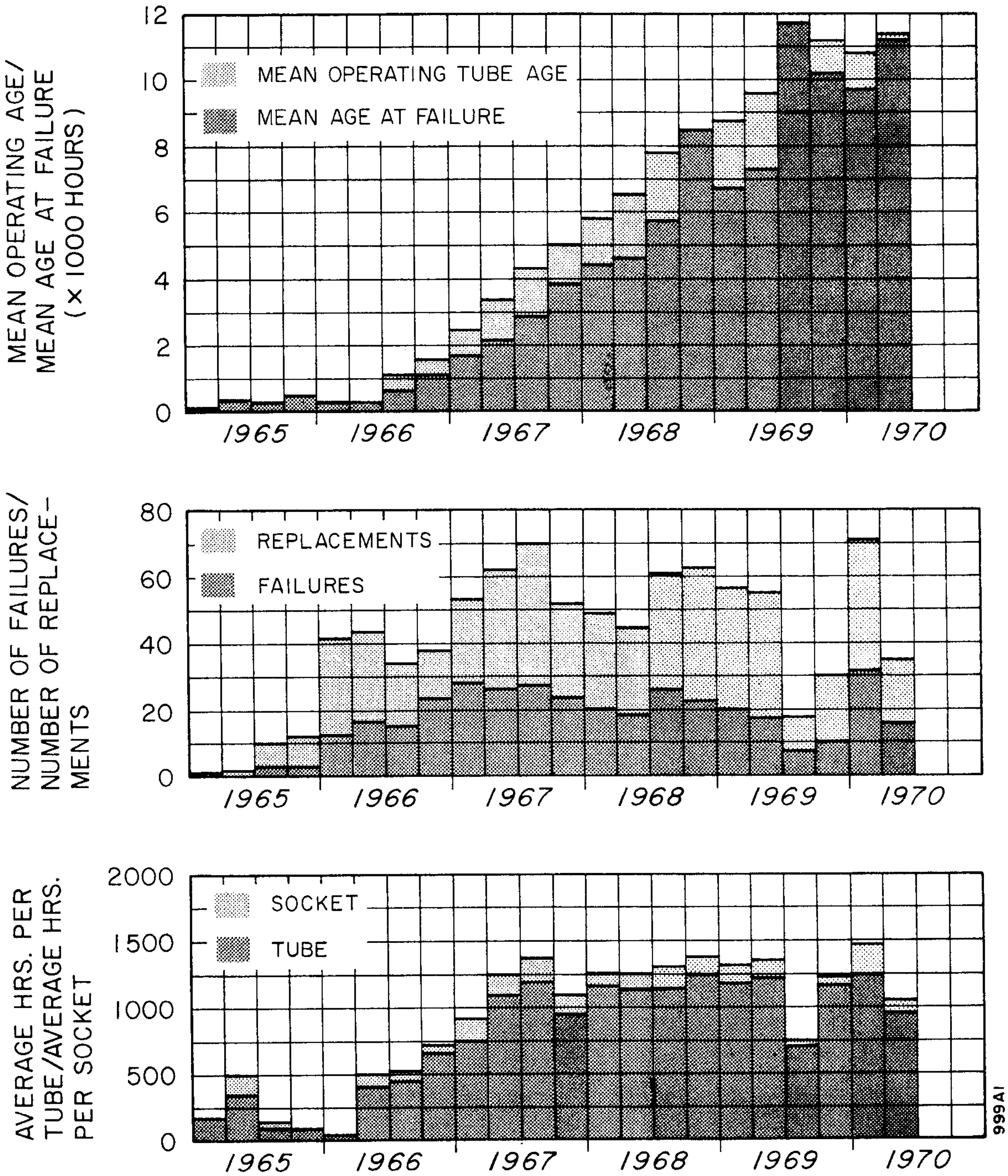

FIG. 7--High-power tubes: operating experience through June 30, 1970.

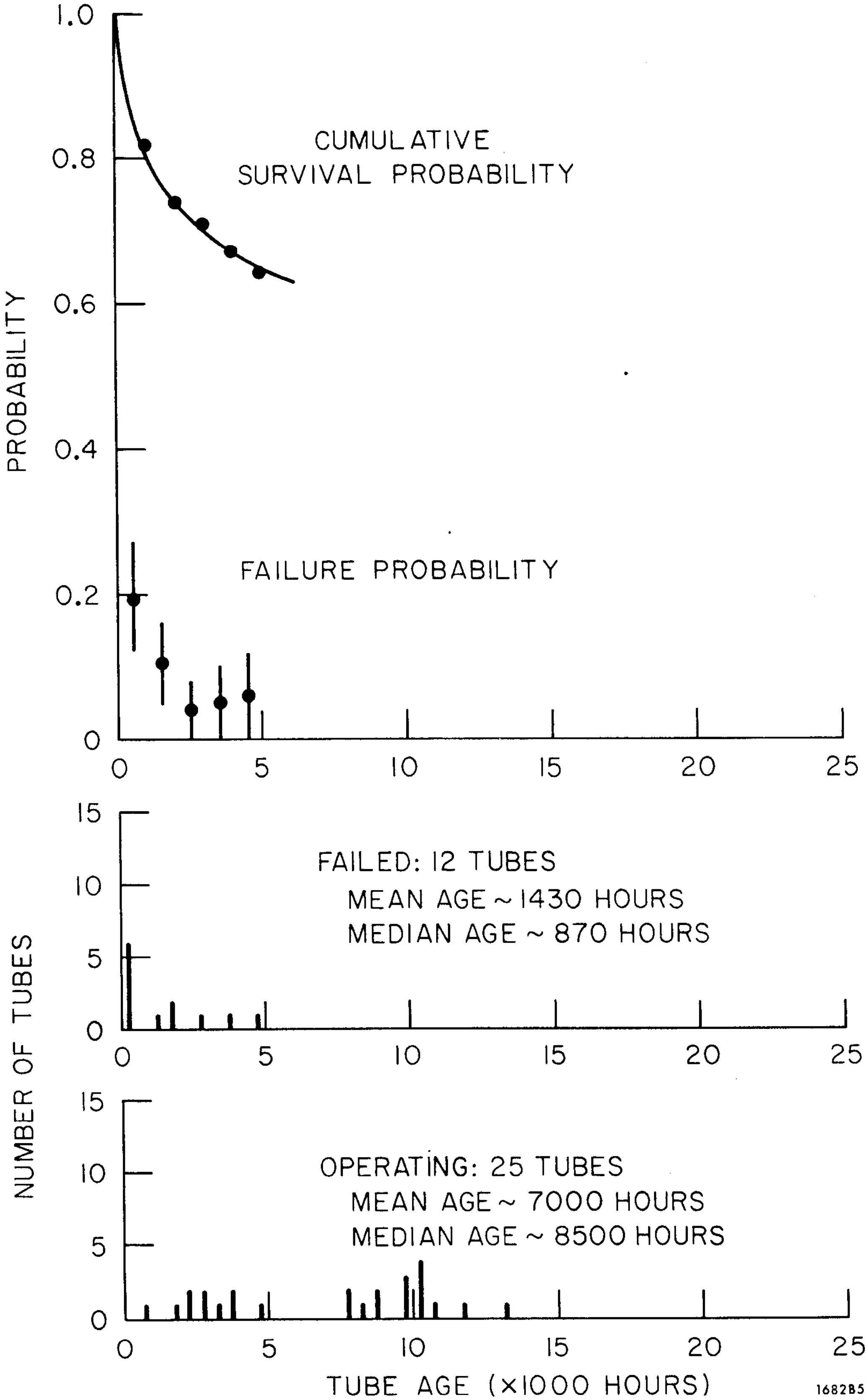

FIG. 8--Driver amplifier tubes: age distribution of operating and failed tubes, and survival and failure probability, June 30. 1970.

The parameters examined indicated that the slow saw tooth oscillation (< 10 per second) with an amplitude of less than 0.1 db of the total rf signal had at most a barely discernible affect on the accelerator beam.

A fast noise component (from 100 kHz to 10 MHz) was discovered on the klystron in station no. 1 (D7-124B). Presence of this noise even for amplitudes less than 0.1 db of total rf signal caused instabilities in the sector 1 phasing system and on the accelerator beam. While drive power and cavity tuning affected the fast noise, focus magnet current had the greatest control. Adjustments of focus current, drive power, and cavity tuning could minimize the noise but the adjustment did not have long term stability.

Further investigation of the fast noise is planned together with efforts to overcome it by changing the operating mode.

5. Vacuum System

No changes in performance of the gallery vacuum system have occurred during the quarter, with the main manifold gage pressure averaging about 1.5×10^{-8} with klystrons operating.

Maintenance and modifications included changes in tightening of a few leaky gaskets, and specifically a change in the bellows of a 3-inch valve in sector 15 penetration. As a result of this last change the gas bursts at stations 15-1 and 15-3 have stopped.

Five ion-pumps were completely disassembled, chemically cleaned, reassembled, pumped down, and pinched off. On three pumps the stainless steel bodies were oxidized by baking in an air atmosphere at $300^{\circ}C$ for 24 hours. These pumps exhibited a considerably shorter pump downtime to reach a base pressure and a somewhat lower pressure was achieved.

VIII. ACCELERATOR INSTRUMENTATION AND CONTROL
(January 1 - June 30, 1970)

A. CCR Console Improvements

A new alarm panel was installed in the recently rearranged Central Control Room (CCR) console, to accommodate several alarm indicators and reset buttons. In contrast with the annunciator panel which usually signals the operator about momentary or benign malfunctions, the new alarm panel is concerned with cooling tower failures, modulator overtemperature and other similar problems. Each alarm has a continuously operating audible alarm which can now be turned off and a red alarm indicator which flashes until the trouble is corrected.

A new "Beam On" indicator system for CCR has been designed and is being fabricated. The new panel will show which beams are running normally and will show repetitive rate of each beam. This panel will also identify some sources of abnormal operation by comparing pattern and permissive pulse rates as well as comparing status information.

A new injector control panel was installed which provided easier access to beam pulse parameters for the operator in the new operating position.

The dc steering current meters, which were originally installed in the back-up console, have been moved to the operator's console.

B. DAB Improvements

A 1000-square-foot addition was completed in the Data Assembly Building (DAB) to house magnet power supplies, main distribution frame and coaxial termination facilities.

Regrouping and removal of unused electronics in the old console area has been started. This area contained some operational equipment as well as some equipment still remaining from a recent experimental run. This reorganization will permit cleanup as well as proper documentation to proceed.

The following systems and panels have been recently modified or newly installed in the Main Control Console:

1. End station roof-fan status
2. L.C.W. status summary and alarm
3. Average current monitor system
4. C-beam safety status and control
5. Buffer (fan-out) amplifiers for DAB signals

6. 12-channel coaxial patching system
7. Fire alarm and smoke detector system
8. dc supply status, readout and alarm system
9. C-12 D.V.M. and temperature interlock
10. Toroid selector system
11. Video monitor system additions.

C. Beam Guidance

Installation of pulsed quadrupoles and pulsed steering is continuing. In January a simpler version of the pulsed quadrupole power supply was installed in sector 11. This unit and one in sector 28 could then be operated at two current levels (to satisfy the requirements of two independent beams).

In April, all existing pulsed quadrupole and steering supplies in sectors 11, 25, 28, and 29 were converted to six-level operation. A control selector system allows CCR to control levels 1, 2 ... (normally corresponding to a beam line) for each pulsed device.

A monitoring selection system was installed to allow CCR to read the pulsed quadrupole magnet currents, or the vertical or horizontal pulsed steering magnet currents along the machine in place of the unused Log Q signals. These signals are transmitted to CCR and displayed as a histogram on an oscilloscope at the control console.

Linear Q system improvement is continuing. At present the signal conditioning and transmission units in different sectors have different saturation characteristics. As a result, when multiple beams of differing currents are run (as displayed by CCR oscilloscopes) the dots of the higher current beam do not line up at the top of the display at saturation. Clipper circuits are being installed in the sector transmitters to eliminate this problem.

D. Beam Loading Delay

At the end of January, a prototype of a continuously variable time delay was installed in the Sector Trigger Generator at sector 18. This unit replaced the original stepwise delay circuit.

A pulsed version of this delay was built for six-level operation and installed in sector 25 in late April. It is operated by the pulsed quadrupole-steering control panel in CCR. Level selection and beam line assignments are similar to the guidance controls so that the desired beam loading delay which is inserted in the sector trigger can be selected for each beam. Four additional units are being constructed and will be installed next quarter.

E. Video Transmission System

During the last reporting period, a study was made to pinpoint the cause of the poor pulse rise time. The major cause was found to be a stepping switch in each channel which changes the local input gain, selects local input channels and reverses the signal flow through the system. This remotely operated stepping switch was added, for operating convenience, after the initial installation. One channel of the system was modified so that for normal operation (input at the injector and output at CCR) all of these selectors were bypassed, but it was found that the operations group required selection capability on both channels more than they required the fast rise time.

F. Radio Communications

During the last six months we have made several improvements in the operations radio equipment. During the radiation area search, prior to beam startup, extensive use is made of 1 watt "handie talkies" by the search teams. During operating periods, the operations radio equipment is used by the chief operators 24 hours per day and by control room operators when they leave the control consoles. In addition, Health Physics surveys the many beam lines regularly and checks each area when experimental equipment or beam parameters are changed. Finally, communications must be maintained with various technician groups which service vacuum, water, hydrogen targets, power supplies and other experimental equipment. Most base stations have moderate power transmitters (25 watts) and all of the protable radio equipment has a maximum of 2 watts rf power output. Due to the radiation shielding requirements, communication is very difficult or impossible from many shielded areas. These include the klystron gallery and housing, the beam switchyard (BSY), the cable tunnels under the various experimental buildings, and shadow areas at ground level around several of the end stations.

In the past many solutions have been tried but we now are following a definite plan which will improve communications to and from these shielded areas. We have installed passive antennas in pairs to bridge the radiation shielding of the BSY. Quarter wave ground plane antennas cut to our operating frequency have been installed on the top of the BSY and on the ceiling of the BSY. These pairs are connected by a coaxial cable which has been precut to an integral number of half wavelength at our operating frequency. Communications are now possible from virtually every area of the BSY with only 5 pairs of antennas. This has decreased the search time considerably and in addition has provided the emergency services (Fire Department and maintenance technicians) with on the spot communications. We plan to install passive antennas in the klystron housing in the near future since radio communications are impossible from this 10,000 foot-long shielded area.

We have installed a high gain antenna on the East Alignment Tower which is the highest spot on the project. This tower is 35 feet high on the machine center line just east of the research area and affords an excellent line of sight path to most of the project. At present, we have a single 25 watt transmitter/receiver operating at the base of the tower and a control point in the Health Physics department. Additional control points will be added at CCR and DAB in the near future. Each control point will be able to communicate with any other control point via the audio lines and with any portable unit in the area. Emergency power will be available at the tower transmitter as well as at each control point.

G. Personnel and Machine Protection

The personnel protection system logic for end station B was rebuilt. The system had been modified regularly to accommodate experimental requirements. The original logic philosophy was maintained but the hardware is now built so that maintenance is easier and changes can be readily made. The personnel and machine protection was also rebuilt in DAB and CCR.

New logic was installed in the BSY personnel protection system so that operators could immediately determine which beam lines were safe for beam.

Circuits were installed along the Klystron Gallery so that the area secure tone loop can be tested by the computer. When the keybank release control is operated, the sector secure tone loop is interrupted.

Several switchyard elements have failed during this report period. In order to satisfy the safety requirement of having at least three beam stoppers between an operating beam and personnel, other elements were connected to the associated personnel protection system.

A number of jobs have been accomplished during this period to upgrade the personnel and machine protection systems. The "B" target room door was upgraded to a full remote entry control module, a gate was installed in sector 11 near the positron source and added to the area protection system, and incandescent flashing (warning) lights were added within end station C. AN-2 door to end station A (ESA) was eliminated and was removed from the personnel protection system when the north wall of ESA was moved to allow greater angular movement of the 20 GeV spectrometer.

H. PLIC System

The Panofsky long ion chamber (PLIC) system suffered a series of faults during a 29-hour period between March 14 and March 16. The trouble evidently was caused by transients due to arcing in the high voltage components. Some damaged HV components have been replaced, but there is some lingering anxiety that the faulty component that started the trouble may not have been identified. New high voltage blocking capacitors have been ordered for evaluation. Zener diodes and a fuse have been installed to protect semiconductor signal components. A study is under way to determine if the system can fail in an unsafe manner.

I. Control Room Consolidation

Consolidation of the two control rooms (CCR and DAB) will be accomplished through extensive use of the two existing computers (an SDS 925 in DAB and a DEC PDP9 in CCR). This is in contrast to physical consolidation by moving entire control consoles. The essential step is to establish a data communications link between the two computers. As soon as data can be transferred, the programmers can start check out of interpretive routines to decode the information transmitted by the other computer.

The second step is to use this information in the creation of oscilloscope display panels. To implement this step, a touch panel system is being developed which will allow an operator to use the oscilloscope displays as if they were physical panels. The touch panel consists of a glass sheet over the face of a computer-generated push-button display. A matrix of highly collimated sound waves is transmitted across the surface of the sheet. Finger pressure on the glass absorbs the wave and the X-Y coordinates are fed to the computer. A production model is being designed with simplified electronics and a curved faceplate to eliminate parallax. (See Fig. 9.) A Data Disk system will be used to refresh the several scope displays.

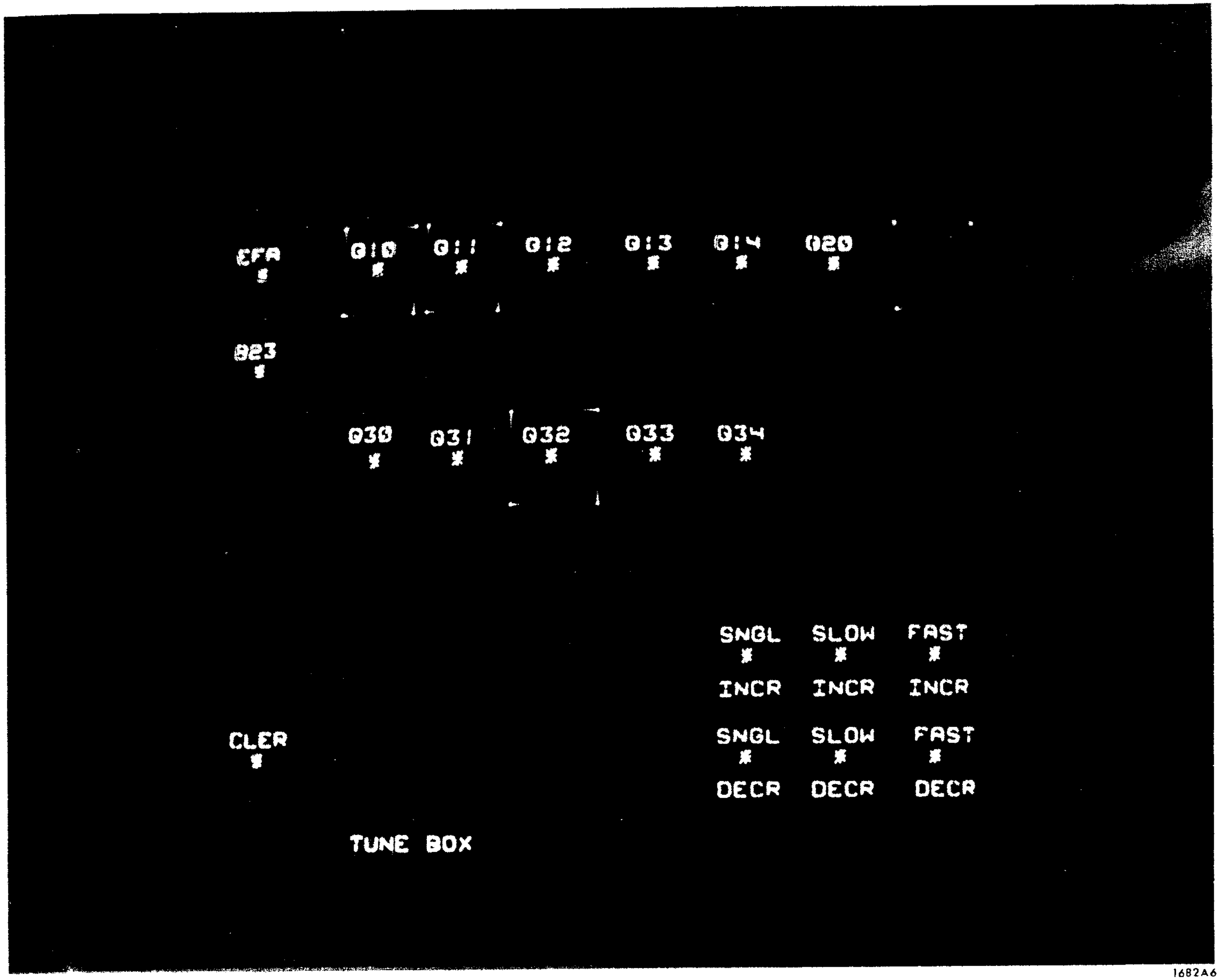

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FIG. 9--Touch panel.

The third step is to transfer existing video information on coax cables to the other control room.

During the last reporting period, new controls and monitoring have been connected to each control room computer. These additions are described below in the Computer section. The operating (software) systems are being modified so that they will be compatible with the link, the man-machine interfaces at DAB and accelerator interface at CCR. Maximum use is being made of the PDP9 8K core by providing a roll-in roll-out program to swap routines between the core and the million word disk. Accelerator control will be maintained within the PDP9 (for example klystron replacement and quadrupole set). We plan to do more closed loop control in the future within both computers for the area that each serves; however, programs will be written in such a way that primary control of both the accelerator and the beam switchyard will be centered in the existing DAB computer.

A key part of the control room consolidation plan is the CCR-DAB data link. The DPO9 exists for the CCR end of the link. A Data Set Interface has been designed as the DAB end of the CCR-DAB computer link. It is completely compatible with EIA I/O formats and is capable of full-duplex operation up to 50 kc. Since the computers will be about 2500 cable feet apart, we have decided not to use data sets but have chosen instead to build the necessary line drivers and receivers as well as a synchronizing clock as part of the communications interface. Coax cables will be used to transmit the clock to DAB and data in both directions. Wire pairs will connect the units in order to insure that each end is ready to transmit and receive data. We intend to send about three data words per beam pulse. The maximum clock rate will be 10 kc. The signals levels will be kept between ± 6 volts so that the system will be compatible with future data sets if they are required.

J. PDP9 Solid State Accelerator Control and Monitoring Interface

A solid state driver has been built which takes its inputs from the solid state part of the DRO9 (an 18-bit output relay buffer). The output of the driver has levels of 0 and -3 volts (100 mA at ground) and 0 and -24 V (2 amperes at ground). The former will drive DEC logic and the latter output will drive 24 volt relays.

Three other solid state units are being built to allow the computer to select an area of control, to select an analog to be digitized and read and to send a command to a selected area. These three units, called "area selector", "analog selector" and "channel repeater", are the second step in our plan to speed up the computer-accelerator interface. Another unit which was described in our last report (Sector Memory) is a solid state unit (to be located in each sector) which will receive, store and execute commands in each sector. These units will allow the computer to send a command to a sector and receive an acknowledgement within 50 μsec and move on to another task. At present, the computer must set and hold a command up to 10 seconds (quadrupole set program).

The Analog Selector will allow the computer to read all of the sector analogs instead of the four analogs per sector which are now possible. Injector control is not possible now with the computer. These new units will allow access to all controls and analogs in the injector area including the existing gun modulator and a new gun modulator to be installed later this year. The control of these functions is an absolute requirement for control room consolidation.

K. Log Q, x, y Interface

The Log Q - DMA interface which was mentioned briefly in the last report has been installed and checked out. The Log Q transmission channel to CCR from each sector is not used by Operations. Beam current measurement in the machine has always been accomplished using Lin Q. We decided to use the Log Q part of the Log Q, x, y channel to transmit pulsed beam guidance signals to CCR. These signals are now available in CCR from four sectors as explained above in the Beam Guidance section.

For consolidation, the computer must be able to read and display these pulsed signals in DAB. The Log Q - DMA interface was designed to digitize and to load memory on a cycle stealing basis. The interface contains a Word Count Register and a Memory Address Register both of which must be initialized before each transfer. Depending on requirements, thirty, sixty or ninety words can be transferred just after each beam pulse. Log Q (or pulsed beam guidance information) is contained in the first 30 words; the second 30 words contain the horizontal beam information (x position) and the last 30 words contain the vertical position information. Each word is composed of 8 binary bits and is derived from a ± 5 volt input signal. Pulsed beam guidance signals have a range of 0-5 volts dc whereas beam position information is in the range of ± 1 volt. Each dc analog is sampled for 4 μsec during which time the analog is reduced in range by one half and offset to 2.5 volts, digitized (in gray code) to 8 bits, gray to binary converted and strobed into a data buffer for transfer to memory. A high speed ADC and level shift amplifier are used and a fast gray to binary converter was developed to meet the timing requirements.

L. Pattern Scanner Interface

The pattern scanner system for the PDP9 was enlarged and modified to improve reliability. The original 12 × 64 bit 3-volt scanner was replaced with one using higher voltage levels (15 volts) to sense pattern switch positions. A new 18 × 64 bit scanner was installed to accommodate more binary signal inputs. The 12-bit slow ADC was connected in parallel to 8 "word" inputs of the new scanner, so that it is read more often then before. It is now read 8 times at uniform intervals in the 64 × 2.78 msec scan period. The ADC system does not yet give consistently good results because of noise pickup in the klystron gallery. Work is proceeding on cleaning up the systems.

M. Pattern System

It is planned to install a new sector 27 and 28 pattern control system for CCR. This system will enable the CCR computer to switch sector 27 and 28 klystrons between the "standby" and "accelerate" mode in one 2.78 msec interpulse period. The system also provides for monitoring and push button control by CCR operators. These units are part of a system designed for very fast response to malfunctions which cause the beam energy to change suddenly, for example, whenever an active klystron or modulator suffers a fault. In some cases, depending on beam power, slit opening and other parameters, this may trip an ion chamber circuit that shuts off the beam. Appreciable time is required for the operators to notice and identify the trouble, to correct the energy loss, and to restore the beam. The fast computer operated klystron switching system will examine the beam spectrum after each pulse and when necessary, will switch a "standby" klystron to the "accelerate" mode before the next pulse.

The system will require a new low noise circuit for processing spectrum monitor data on a pulse-to-pulse basis, signal transmission channels between DAB and CCR, and an analog digital computer input. Spectrum acquisition elements are now being developed which will filter and amplify signals from the existing systems. Existing transmission channels, originally intended for "Log Q" signals, can be adapted for transmitting the signals to CCR. These channels are already connected to the CCR computer through the Log Q - DMA interface.

N. DAB Computer

The following jobs are in progress or were completed during this period for SDS 925 computer.

A new flip-coil interface to provide field strength data from both A & B bends. Hardware is complete and checked out.

A Contact-Closure Pulse Generator which produces standard interrupt signals from noisy contacts, e.g., push buttons, relays, etc. The prototype has been in service for 2 months; further cards are in production.

A Digital Input Interface to handle status and interlock signals (capacity $2^8 \times 24$ bits). This is presently under construction.

A new DVM-Scanner to read low level dc voltages from magnet shunts under direct computer control is being designed. This will have a maximum resolution of 1 μV and each channel will be directly addressable.

Digital Output Device (DOD). The DOD is a word addressable output multiplexer for the SDS 925 computer. The DOD system consists of:

1. Computer-DOD interface
2. Up to 32 8-word (24-bits/word) DOD output buffer card bins.

The interface and 8-word DOD output buffers were designed, fabricated, installed and checked out. Presently, one 8-word DOD output buffer chassis is installed.

Computer-Clock Interface (CLK). This unit gates 2 DAB trigger-systems 360 pps clock pulses into the SDS 925 computer for basic system timing. It also contains an internal line-synchronized oscillator that generates pulses simulating the trigger system pulses. These pulses are available (under program control or manually selected) in the event that the trigger system is turned off.

Serial Data Device (SDD). Preliminary design of a serial (4 wire) clocked half duplex data I/O system for the SDS 925 has started. The system is planned as data I/O from the new DAB operations console and magnet power supply DAC controls.

Digital to Analog Converter (DAC). A new DAC using a stepping motor-driven potentiometer as the reference element is being designed. The general design criteria were developed in cooperation with the Experimental Facilities Department power supply group.

The SDS 925 hardware has been improved as follows:

1. The CPU and interface racks have been moved into one long row to improve the working space and allow fragile computer cables to be rerouted inside cabinets instead of under the floor.

2. The SDS 925 I/O bus wiring is being reworked.

3. A new SLAC interface cabinet has been designed and is being fabricated.

4. Additional panel space was installed on the SDS 925 operations console for planned diagnostic controls.

5. An adjustable CRT (or TV) stand was mounted on the SDS 925 operations console.

6. New cable ways were installed in the SDS 925 CPU. There is now less strain on cables when card frames are swung out and there is better access for servicing.

7. All interface I/O cabling has been checked and repaired as needed.

The result of the relevant improvements has been to make the SDS 925 operation more reliable over the last six months.

O. DAB Trigger System

The Beam Definition system consists of a Beam Trigger Selector and a Beam Definition Logic chassis. During this period the system was enlarged so that any one of the CCR beam lines could be routed to 21 destinations. The logic chassis can be easily modified so that it can be controlled by the SDS 925.

P. CCR Computer Summary of On-Line Operations

The computer has been used consistently for logging klystron data, modulator recycles, and modulator states (Mod. off and Mod. not available). RF drive conditions and subbooster recycles are also tabulated by sector. The final tabulation on this Recycle Log is a sequential list of fast valve (sector vacuum isolation valve) closures. This log is printed out once each 24-hour period.

A Beam Pulse Log is printed out every 8 hours which lists the number of pulses per beam line, the length of time each beam was on (gun pulses), the average pulse rate for each beam line and the summary of Tone Interrupt Unit Operation (gun permissives).

In addition, the CCR operator can request the computer to print out the pattern switch positions (number of sectors contributing to each beam), a summary of all klystrons on standby or those not on, and a calculation of energy per klystron. The summary of klystrons on standby or off is updated every 5 minutes so if the variable voltage substations (VVS) shut off due to a power failure or an interruption of the personnel protection system, beams can be reestablished in a minimum of time.

The energy per klystron calculation is computed when the beam line, beam current and beam energy have been entered. This resultant figure is a useful measure of klystron phase.

The VVS reference voltage is measured every half hour and compared with a standard value. A "too low" or "too high" statement is printed out if comparison is not within a specified range.

During startup, a program checks the machine protection and personnel protection tone loops. Each tone loop is broken (at each sector) and the result is printed out if a circuit malfunctions.

Q. CCR Computer - Operating Program

The disk monitor operating system for the PDP-9, consisting of the disk monitor and a timed sequence scheduler, was completed and checked out. The various user programs such as klystron replacement, logging, quadsetting are rewritten and will be incorporated during the accelerator downtime June 25 - July 10. The next accelerator cycle then should run under the new systems. This system has a 32K virtual memory in 512-word page increments, which will allow new functions (such as CCR/DAB consolidation) to be added without requiring additional hardware core memory.

The software I/O handler for the fast ADC system (providing the computer with pulse-to-pulse values of Log Q, x, y for all 30 sectors) was also written and checked out during this period.

Work is continuing on the software aspect of the CCR/DAB consolidation project. Hardware specifications for the computer link are firm enough to begin programming the I/O handlers. Formats for link messages have been agreed upon and data structures for the internal representation of the touch panel images are being developed.

IX. PLANT ENGINEERING

Three utility modification projects were completed during the quarter and the facilities were placed in use. These were: extension of the 4160-volt electrical service in the research yard: a 90-foot-long extension of the utility tunnel near end station B: and modification of the radioactive water service system in the "B" target room.

Two additional bays were added to building 403 to accommodate the expanded experimental program planned for that facility. A major extension of the north shielding wall in end station A to permit extended use of the spectrometer facilities was completed.

Construction of a new information booth was finished in June. A minor amount of landscaping and exterior lighting remains to be done and this will be accomplished early in the next quarter. This virtually finishes the relocation of SLAC's front entryway incident to the widening of Sand Hill Road at the north boundary of the Laboratory site. A view of the new facility is shown in Fig. 10.

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

1. Central Utility Building Expansion. Two 50-ton chillers have been installed and will be placed in operation next month. A small amount of electrical work remains to be done.

2. Neutral Particle Facility. Excavation and lining of this 38-foot deep pit located on the end station A beam line have been finished. Mechanical and electrical utilities will be installed in July.

3. Upgrading of Buildings 102 and 104. Incorporation of offices, rest rooms, and work shop space in these research yard buildings is 95% complete.

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

1. North Yard Expansion. Design has started on the expansion of utilities to serve the north yard of SLAC research area.

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

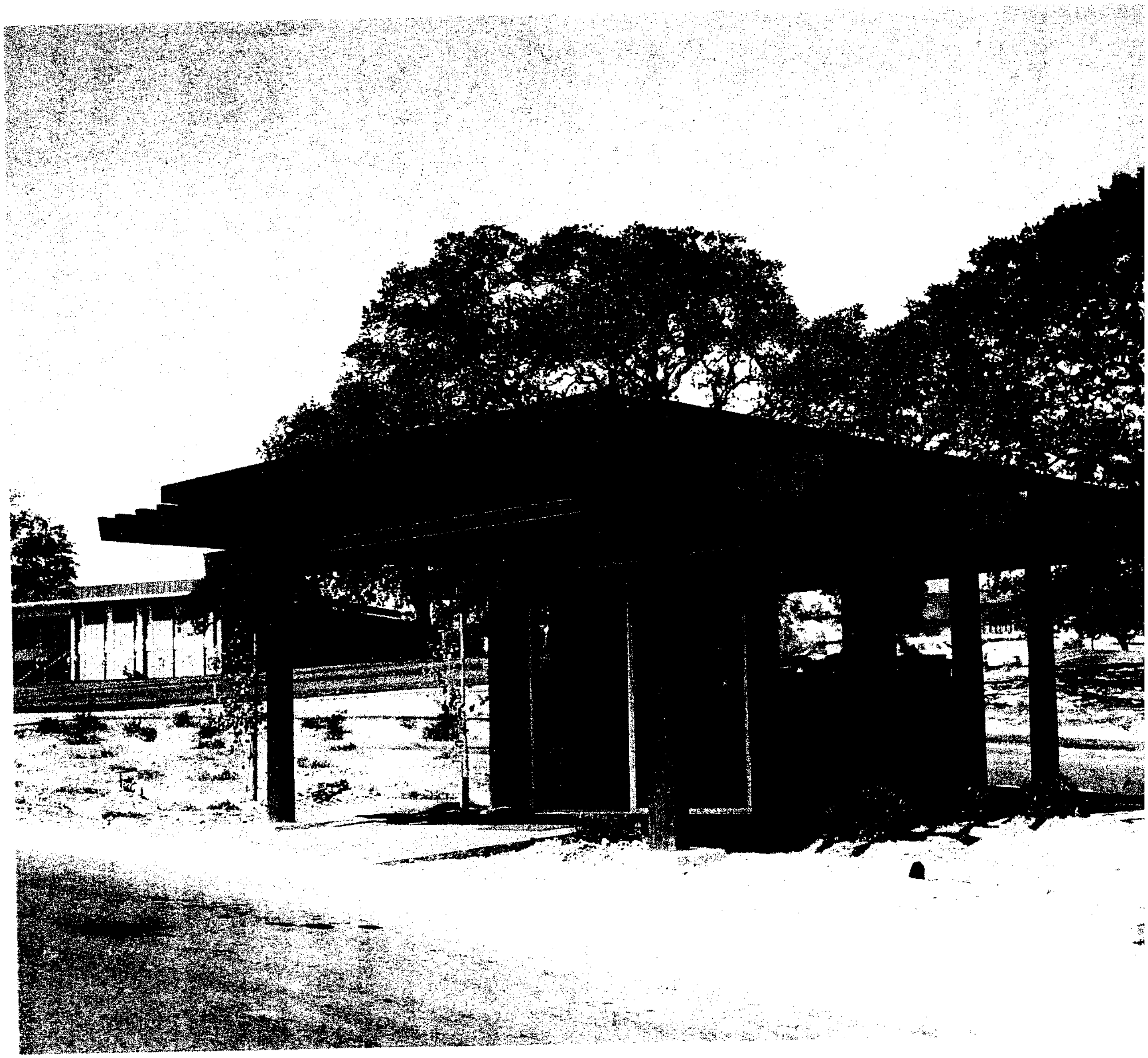

FIG. 10--Information booth, SLAC front entryway.

3. SLAC 230 kV Tap Line. Pole structure No. 35 is to be dead-ended as a plant reliability project. Preliminary planning indicates the existing pole can be used as one of three in a design configuration to preclude disconnecting the high voltage lines.

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

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

The department's sizeable program of plant utilities operation and minor modifications to buildings as a general service to SLAC was continued.

X. PUBLICATIONS

Journal Articles

SLAC-PUB-715
GENERALIZED IBM SYSTEM 360 SOFTWARE MEASUREMENT. R. H. Johnson, T. Y. Johnston. Submitted to Datamation.

SLAC-PUB-717
EVALUATION OF THE π-π SCATTERING LENGTHS USING ON-MASS-SHELL PIONS. A. A. Golestaneh (Mount Union Coll.); C. E. Carlson (SLAC). Submitted to Phys. Rev.

SLAC-PUB-722
UP-DOWN ASYMMETRY IN INELASTIC ELECTRON-POLARIZED PROTON SCATTERING. Robert N. Cahn (UCRL, Berkeley); Y. S. Tsai (SLAC). Submitted to Phys. Rev.

SLAC-PUB-729
STUDY OF $\gamma p \rightarrow p\omega$ WITH LINEARLY POLARIZED PHOTONS AT 2.8 AND 4.7 GeV. J. Ballam, G. B. Chadwick, R. Gearhart, Z.G.T. Guiragossián, M. Menke, J. J. Murray, P. Seyboth, A. Shapira, C. K. Sinclair, I. O. Skillicorn, G. Wolf (SLAC); R. H. Milburn (Tufts U.); H. H. Bingham, W. B. Fretter, K. C. Moffeit, W. J. Podolsky, M. S. Rabin, A. H. Rosenfeld, R. Windmolders (UCRL, Berkeley). Condensed version published in Phys. Rev. Lett. 24: 1364-8, 1970.

SLAC-PUB-730
DIFFRACTION DISSOCIATION AND THE REACTION $\gamma p \rightarrow \pi^+\pi^- p$. Jon Pumplin. Submitted to Phys. Rev.

SLAC-PUB-733
A MODEL OF COUPLING CONSTANT RENORMALIZATION. Kenneth G. Wilson (SLAC and Cornell U. LNS). Submitted to Phys. Rev.

SLAC-PUB-734
OPERATOR PRODUCT EXPANSIONS AND ANOMALOUS DIMENSIONS IN THE THIRRING MODEL. Kenneth G. Wilson (SLAC and Cornell U. LNS). Submitted to Phys. Rev.

SLAC-PUB-735
K-MATRIX MODEL FOR POMERANCHUK EXCHANGE. Wolfgang Drechsler. Submitted to Phys. Rev.

SLAC-PUB-738
THE FORWARD COMPTON SCATTERING AMPLITUDE AS A SIMULTANEOUS ANALYTIC FUNCTION OF COMPLEX PHOTON MASS AND ENERGY. Ashok Suri (SLAC and UC Santa Cruz).

SLAC-PUB-740
A LINEAR CURRENT-FREQUENCY CONVERTER FOR ION PUMP CURRENT READOUT. R. Scholl. Submitted to Rev. Sci. Instrum.

SLAC-PUB-741
ANOMALOUS DIMENSIONS AND THE BREAKDOWN OF SCALE INVARIANCE IN PERTURBATION THEORY. Kenneth G. Wilson (SLAC and Cornell U. LNS). Submitted to Phys. Rev.

SLAC-PUB-742
ON DIRECT METHODS FOR SOLVING POISSON'S EQUATIONS. B. L. Buzbee, C. W. Nielson (Los Alamos); G. H. Golub (SLAC). Submitted to SIAM J. on Numer. Anal.

SLAC-PUB-743
UNITARY THREE-PARTICLE ON-SHELL T-MATRIX. H. Pierre Noyes. Submitted to Phys. Rev. Lett.

SLAC-PUB-744
PHOTOPRODUCTION OF $\pi^{\pm}\Delta(1236)$ FROM HYDROGEN AND DEUTERIUM AT 16 GeV. A. M. Boyarski, R. Diebold, S. D. Ecklund, G. E. Fischer, Y. Murata, M. Sands. Submitted to Phys. Rev. Lett.

SLAC-PUB-747
METHODS FOR THE BETHE-SALPETER EQUATION I: SPECIAL FUNCTIONS AND EXPANSIONS IN SPHERICAL HARMONICS. David Kershaw, Herschel Snodgrass (UC, Berkeley); Charles Zemach (SLAC). Submitted to Phys. Rev.

SLAC-PUB-748
METHODS FOR THE BETHE-SALPETER EQUATION II: BRACKETS AND THE N/D METHOD. David Kershaw (UC, Berkeley); Charles Zemach (SLAC). Submitted to Phys. Rev.

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

SLAC-PUB-755
MASSIVE LEPTON PAIR PRODUCTION IN HADRON-HADRON COLLISIONS AT HIGH ENERGIES. Sidney D. Drell, Tung-Mow Yan. Submitted to Phys. Rev. Lett.

SLAC-PUB-756
FOURTH ORDER ELECTRODYNAMIC CORRECTIONS TO THE LAMB SHIFT. Thomas Appelquist, Stanley J. Brodsky. Submitted to Phys. Rev.

SLAC-PUB-757
IS THERE ANY "SCALING" IN ELASTIC PROTON-PROTON SCATTERING? Fritjof Capra.

SLAC-PUB-761
THE PRESENT STATUS OF QUANTUM ELECTRODYNAMICS. Stanley J. Brodsky, Sidney D. Drell. Submitted to Ann. Rev. Nucl. Sci.

SLAC-PUB-766
Δ PRODUCTION VIA $\gamma p \rightarrow \Delta\pi$ BY LINEARLY POLARIZED PHOTONS AT 2.8 AND 4.7 GeV. H. H. Bingham, S. B. Fretter, K. C. Moffeit, W. J. Podolsky, M. S. Rabin, A. H. Rosenfeld, R. Windmolders (UCRL, Berkeley); J. Ballam, G. B. Chadwick, R. Gearhart, Z.G.T. Guiragossián, M. Menke, J. J. Murray, P. Seyboth, A. Shapira C. K. Sinclair, I. O. Skillicorn, G. Wolf (SLAC); R. H. Milburn (Tufts U.). Submitted to Phys. Rev. Lett.

Conference Papers

SLAC-PUB-731
AN IMPROVED TLD READER. G. K. Svensson, R. C. McCall, G. L. Babcock. Submitted to 2nd Int. Congress of Int. Radiation Protection Assoc., Brighton, U.K., May 3-8, 1970.

SLAC-PUB-736
ELECTROMAGNETIC INTERACTIONS AT VERY HIGH ENERGY. J. D. Bjorken. Invited paper, Int. Conf. on Expectations for Particle Reactions at the New Accelerators, Univ. of Wisconsin, Madison, March 30-April 1, 1970.

SLAC-PUB-737
BROKEN SCALE INVARIANCE AND ANOMALOUS DIMENSIONS. Kenneth G. Wilson (SLAC and Cornell U. LNS). Submitted to Midwest Conf. on Theoretical Physics, Notre Dame Univ., Indiana, April 3-4, 1970.

SLAC-PUB-739
HIGH-FIELD MAGNETS WITH AND WITHOUT FERROMAGNETIC RETURN YOKES. H. Brechna (SLAC); J. Perot (Saclay). Presented at 3rd Int. Conf. on Magnet Technology, DESY, Hamburg, Germany, May 19-22, 1970.

SLAC-PUB-745
IMPORTANT PROBLEMS AND QUESTIONS FOR THE NEW ACCELERATORS. S. D. Drell. Invited paper, Int. Conf. on Expectations for Particle Reactions at the New Accelerators, Univ. of Wisconsin, Madison, March 30-April 1, 1970.

SLAC-PUB-746
NEW RESULTS ON HIGH ENERGY ELECTROMAGNETIC INTERACTIONS. R. E. Taylor. Invited paper, Int. Conf. on Expectations for Particle Reactions at New Accelerators, Univ. of Wisconsin, Madison, March 30-April 1, 1970.

SLAC-PUB-750
A NEW PRECISION MEASUREMENT SYSTEM FOR BEAM TRANSPORT TYPE MAGNETS. J. K. Cobb, D. Horelick. Presented at 3rd Int. Conf. on Magnet Technology, Hamburg, Germany, May 19-22, 1970.

SLAC-PUB-752
STATUS OF HUMMINGBIRD FILM DIGITIZERS. John L. Brown. Presented at 2nd Int. Colloquium on PEPR, MIT, May 5-7, 1970.

SLAC-PUB-753
THE SLAC LH_2 TARGET CONTROL SYSTEM. W. B. Pierce. Presented at 3rd Int. Cryogenic Engineering Conf., West Berlin, Germany, May 25-27, 1970.

SLAC-PUB-760
NUMERICAL TECHNIQUES IN MATHEMATICAL PROGRAMMING. R. H. Bartels (Texas U.); G. H. Golub (SLAC); M. A. Saunders (Stanford U. Computation Center). Presented at Nonlinear Programming Symposium, Madison, Wis., May 4-6, 1970.

Technical Reports

SLAC-117
THE FORMULARY MODEL FOR ACCESS CONTROL AND PRIVACY IN COMPUTER SYSTEMS. Lance J. Hoffman.

Publications by SLAC Authors on Research not Related to SLAC

THE FILLING FACTOR OF SHIELDED DIELECTRIC RESONATORS. Jean-Louis Pellegrin. IEEE Trans. on Microwave Theory and Techniques MTT-17: 764-768, 1969.

A MAGNETIC MONOPOLE DETECTOR UTILIZING SUPERCONDUCTING ELEMENTS. Luis W. Alvarez, Maurilio Antuna, Jr., Roscoe A. Byrns, Philippe H. Eberhard, Robert E. Gilmer, Egon H. Hoyer, Ronald R. Ross, Hans H. Stellrecht, John D. Taylor (UCRL, Berkeley); Robert D. Watt (SLAC). (UCRL 19756). Submitted to Rev. Sci. Instrum.

PROPOSAL TO MEASURE THE TOTAL HADRONIC PHOTOPRODUCTION CROSS SECTION AT THE SERPUKHOV IHEP ACCELERATOR. A. I. Alikhanian, G. L. Bayatian, K. A. Ispirian, S. H. Matinian, A. H. Oganessian (Yerevan Physical Inst.); I. A. Alexandrov, A. M. Frolov, R. A. Rzaev, A. V. Samoylov, Yu. M. Sapunov, V. I. Voronov (IHEP, Serpukov); Z.G.T. Guiragossián (SLAC). (EFI-E4-170)

Publications Issued Elsewhere, Based Upon Research Performed at SLAC

DOUBLE-REGGE ANALYSIS OF THE REACTION $\pi^+p \rightarrow \pi^+\rho^o p$ AT 13.1 GeV/c. J. W. Lamsa, J. A. Gaidos, R. B. Willmann, C. Ezell (Purdue Univ.). (COO-1428-170)

OBSERVATION OF N*(1720) DECAY TO $\Delta(1236)\ \pi$ FROM π^+p INTERACTIONS AT 13.1 GeV/c. R. B. Willmann, J. W. Lamsa, J. A. Gaidos, C. R. Ezell (Purdue Univ.). (COO-1428-75)

PHOTOPRODUCTION OF MULTI-PION FINAL STATES IN γd REACTIONS AT 4.3 GeV. Y. Eisenberg, B. Haber, E. Kogan, E. E. Ronat, A. Shapira, G. Yekutieli (Weizmann Institute of Science, Israel).

POLARIZED PROTON TARGET FOR USE IN INTENSE ELECTRON AND PROTON BEAMS. Michel Borghini, Owen Chamberlain, Raymond Z. Fuzesy, William Gorn, Charles C. Morehouse, Thomas Powell, Peter Robrish, Stephen Rock, Stephen Shannon, Gilbert Shapiro, Howard Weisberg (Lawrence Radiation Lab., UC, Berkeley). (UCRL-19724)

TOTAL HADRONIC (γ, p) AND (γ, n) CROSS SECTIONS FROM 4 TO 18 GeV. D. O. Caldwell, V. B. Elings, W. P. Hesse, R. J. Morrison, F. V. Murphy, B. W. Worster (Physics Dept., UC Santa Barbara); D. E. Yount (SLAC). Submitted for publication.