SLAC-120
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TWO-MILE ACCELERATOR PROJECT

1 January to 31 March 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

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ABSTRACT

A status report on the Stanford Linear Accelerator Project covering the period January 1, 1970 to March 31, 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.
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INTRODUCTION

This is the thirty-first Quarterly Status Report of work under AEC Contract AT(04-3)-400 and the twenty-fifth 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 January 1, 1970 to March 31, 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 micro-amperes (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

Physics Beam Hours[1]	Jan.	Feb.	Mar.	Quarter
Machine Physics	32	45	21	98
Particle Physics	496	344	373	1,213
Total Physics Beam Hours	528	389	394	1,311
Nonphysics Hours				
Scheduled Downtime	16	16	16	48
Unscheduled Downtime Due to Equipment Failure	39	22	52	113
All Other (Machine Tuneup, etc.)	25	29	13	67
Total Nonphysics Hours	80	67	81	228
TOTAL MANNED HOURS	608	456	475	1,539

B. Experimental Hours[2]

1. Particle Physics

(3) Beam Line	Sched. Hrs. Electronic Experiments (a)	Electronic Experimental Hrs.		% $\left(\frac{b}{a}\right)$	Actual Bubble Chamber Hours	Actual Test And Checkout Hours	Total Experimental Hours	
		Actual Hours (b)	(4) Charged Hours				Actual Hours	Charged Hours
A	1,303	1,012	1,236	77.7	---	55	1,067	1,291
B_N	192	153	28	79.7	---	282	435	310
B_C	200	164	178	82.0	---	342	506	520
B_S	---	---	---	---	---	23	23	23
C	636	506	348	79.6	460	552	1,518	1,360
Total	2,331	1,835	1,790	78.7	460	1,254	3,549	3,504
2. Machine Physics							118	118
TOTAL EXPERIMENTAL HOURS							3,667	3,622

(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. 2 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	3,673
Hours charged during the quarter	1,790
New hours approved during the quarter	1,984
Approved hours remaining at end of quarter	3,867

2. Bubble Chamber Experiments

	40" BC	82" BC
Approved pictures at beginning of quarter	856 K	2,709 K
Pictures taken during the quarter	---	1,348 K
New pictures approved during the quarter	---	1,525 K
Approved pictures remaining at end of quarter	856 K	2,886 K

	Jan.	Feb.	Mar.	Quarter
D. Beam Intensity				
Peak	57 mA	45 mA	65 mA	65 mA
Average	6.7 μA	5.4 μA	8.7 μA	6.9 μA
E. Klystron Experience				
Total Klystron Hours	147,566	103,555	106,818	357,939
Number of Klystron Failures	11	6	15	32
F. Data Analysis				
Spark Chamber Events Measured	13,499	25,583	15,847	54,929
Bubble Chamber Events Measured	15,557	14,882	15,348	45,787
G. Computer Operations				
Manned Hours				
Computation Hours				
SLAC Facility Group	124	122	114	360
Users Groups	441	437	520	1,398
Total Computation Hours	565	559	634	1,758
Noncomputation Hours				
Scheduled Maintenance	93	100	79	272
Scheduled Modifications	9	---	---	9
Unscheduled Downtime and Reruns	24	3	9	36
Idle Time	10	7	8	25
Utility Failure	3	1	5	9
Total Noncomputation Hours	139	111	101	351
TOTAL MANNED HOURS	704	670	735	2,109

H. Special Operating Features

1. Beam Knockout

The beam knockout was used for 429 hours of experimental time and 29 hours of checkout time during the quarter at 10 and 40 MHz.

2. Power Supplies

The 3.4 MW power supply was run for 428 hours with the analyzer magnet in beam line 11, and for 277 hours with the 82" bubble chamber for a total of 705 hours during the quarter.

The 5.0 MW power supply was run for a total of 147 hours with the 54" spark chamber.

The 5.8 MW power supply was run for 246 hours with the two-meter spark chamber, and for 363 hours with the bending magnet for the 8 GeV spectrometer for a total of 609 hours.

The motor generator facility was run for 409 hours with the 82" bubble chamber, for 87 hours with the 40" bubble chamber, and for 35 hours of magnet testing for a total of 531 hours during the quarter.

II. RESEARCH AREA FACILITIES

A. C-Beam Developments

Test run T-6 demonstrated the feasibility of a separated proton beam (p=9.1 GeV/c) into the 82" HBC. See the report on T-6 for details.

B. Hydrogen Bubble Chamber Operations

On March 25, during BC-27's experiment, one of five lower magnet coils of the 82" HBC shorted out. This coil was bypassed and BC-27 was completed at ~8 percent less magnetic field. This lower field will be mapped in the future and until a new coil is made (one year) or a quick repair method is discovered for the shorted coil, the 82" chamber will be operated at reduced magnetic field. (Summary prepared by R. Rinta.)

C. Spectrometer Facilities Operations

It has been possible to operate the 1.6 GeV/c spectrometer simultaneously with either the 8 GeV/c or 20 GeV/c spectrometer for the last year or two.

During February 1970, the main portion of the work required to split the 5.8 MW power supply into two 2.9 MW power supplies was completed. Because of this split, and the completion of two tie lines from the 5.8 MW power supply building to the ESA spectrometer power supply building, it is now possible to run the 8 GeV/c and 20 GeV/c spectrometers simultaneously to full excitation. (Summary prepared by D. Coward.)

D. Liquid Hydrogen Targets

The E-49a liquid hydrogen target was put into operation in February. Since this is a unique target in many ways we will briefly describe it here. It has a deuterium filled cell, a hydrogen filled cell, dummy cells of each of these, and nine solid targets. The liquid cells can be exposed to high beam currents with a minimum of density change because each has forced circulation of the liquid through a heat exchanger. The temperature of each cell can be monitored by means of two hydrogen vapor pressure thermometers. The positioning of the targets is accomplished by rotating the whole top plate of the vacuum tank and by moving the reservoir up and down. The position repeatability is better than 0.005" vertically and 0.020" horizontally. Figure 1 shows the target and reservoir removed from the vacuum tank.

The target for E-40 gave some trouble during February. It is 2 cm in diameter and 50 cm long and had to be located 15 ft away from the liquid hydrogen reservoir.

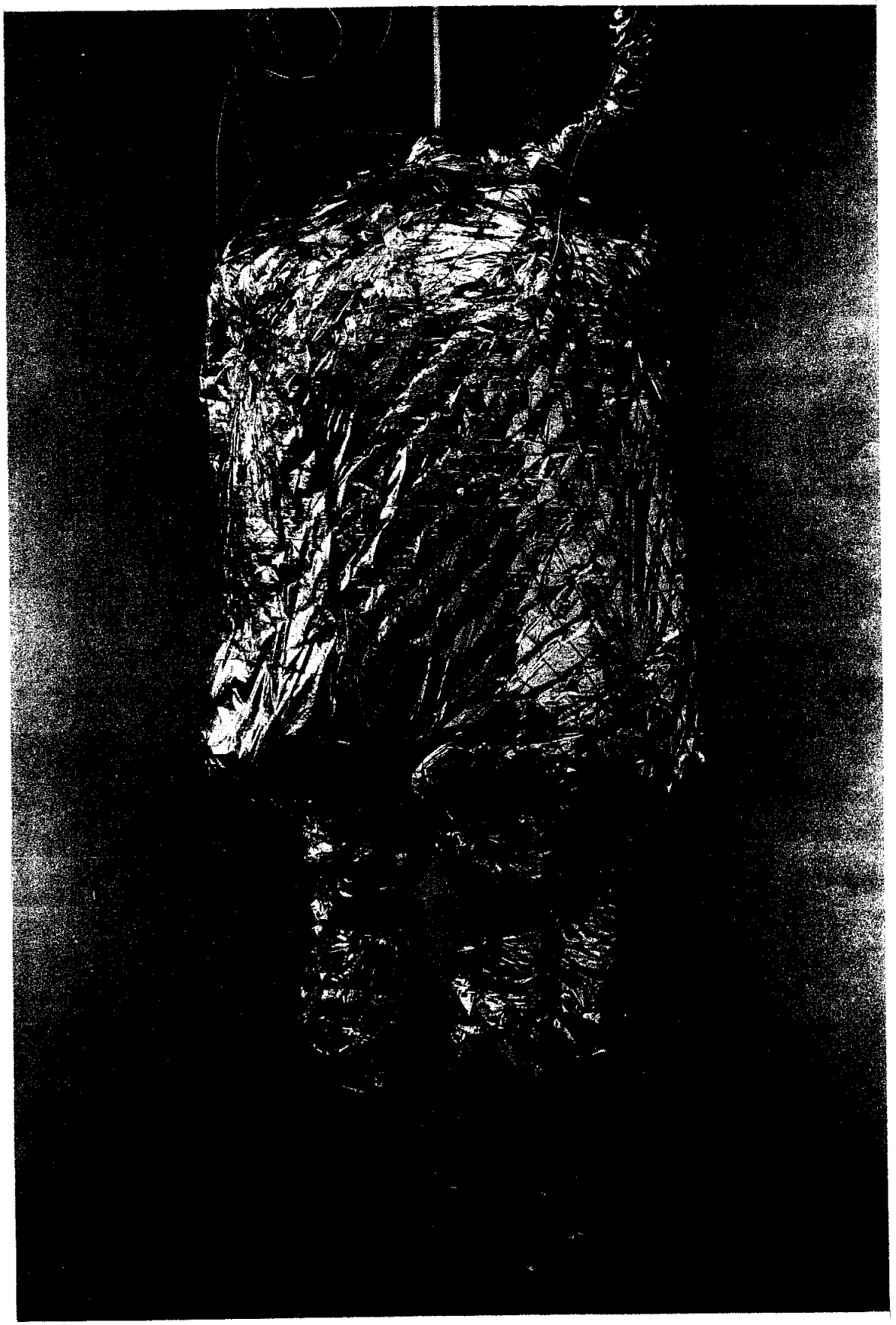

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FIG. 1--E-49a Hydrogen reservoir with LH_2 cell, LD_2 cell, 2 dummy cells, and holders for 9 solid targets.

It was found to be difficult to keep the target full of liquid because of heat leakage. A forced circulation loop was used to push out the H_2 gas and replace it with liquid. This solved the problem and the target was in use at the end of the month. (Summary prepared by J. Mark.)

E. Experimental Activity During the Quarter

Figure 2 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 3 is a tentative long-range schedule.

The prime users of the accelerator during the period were:

D-8 (Background Measurement, Spokesman G. Masek)

D-62 (Test of Total Absorption Detectors, Spokesman B. Hughes)

D-6b (Test of Solid State Detectors in 82" Bubble Chamber, Spokesman I. Pless and H. Lubatti)

CE-40 (Rho Production, Spokesman J. Tenenbaum)

E-41 (Neutral Rho Production, Spokesman B. Richter)

CE-48 (Measure of ξ Parameter, Spokesman M. Sakitt)

E-49a (Inelastic Electron Scattering from D_2, Spokesman R. Taylor)

E-50a (Compton Scattering at High Energies from H_2, Spokesman D. Ritson)

E-52 (γ_ρ^2 by Coherent ρ Photoproduction from Deuterium, Spokesman B. Wiik)

E-53 (Survey of Photon and π^0 Yields, Spokesman F. Murphy)

BC-11 (Polarized Photoproduction, Spokesman G. Wolf)

BC-14 (Study of πp Interaction, Spokesman I. Pless)

BC-27 (Study of "A_2" Problem, Spokesman K. Lai)

TBC-33 (4.5 GeV/c π^- Exposure in H_2 82" Bubble Chamber, Spokesman W. Selove)

BC-28 (5 GeV/c π^+p Exposure in the 82 Inch Hydrogen Bubble Chamber)

TBC-10 (Light Output of Bubble Chamber Trigger Counters)

D-6 (Sodium Iodide Counter Test)

D-9 (Production of High Quality Low Intensity $e^\pm$ Beams)

T-5 (University of Chicago Shower Counter Test)

NT-2 (Spectrometer Counter Tests)

BC-13 (7.5 GeV/c and 5.0 GeV/c π^- in H_2 82 Inch Bubble Chamber, Spokesman U. Kruse)

NT-3 (Rapid Cycling Bubble Chamber Tests, Spokesman H. Barney).

1. Status of Running Experiments

E-41 — Rho Production by Pions — A Test of Vector Dominance - B. Richter (SLAC)

During the January run cycle, the $\pi\rho$ group completed the data taking phase of the experiment. Most of the running was done with an incident pion energy of 15 GeV. Some data were taken in special configuration which increases the acceptance of the apparatus for high mass states. In addition, approximately four days were spent in the normal configuration and at an incident pion energy of 8 GeV. Approximately 300 reels of magnetic tape have been filled with data from the spark chamber system, and the analysis of this mass of data has begun.

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

The checkout phase of this experiment has been completed and the data taking phase has started. Data taking proceeded at the rate of about one picture every 1-1/2 to 2 seconds using pulse sharing with the E-41 beam. In this mode a beam of a high (about double normal) pulse repetition rate was used during the sensitive time; at the occurrence of an event these pulses were switched to E-41 during the dead time. The dead time was adjusted to give E-41 their proper number of pulses on the average. The same arrangement allowed the quick transfer of the E-48 pulses to the E-41 beam if technical problems or film changes required the data taking to stop. The pulse sharing worked very effectively for E-48, affording a considerable increase in data rate.

The beam was such that there were about one K^0 decay for every 5-1/2 triggers. Cuts in energy and fiducial volume will probably reduce this to one useful decay for every eight triggers. In addition, about 1/9 of the pictures were made with enhanced μ content for calibration purposes. The net result is about 1,000 K_L^0 in a $\sim$9,000-frame roll of film.

Some difficulty was experienced with the pulser but data taking continued with reasonable efficiency for about 18 good rolls or 18,000 K^0's. At that time, on the evening of January 23, accidental overvoltaging of the chamber caused arcing in two regions of the side. This could not be cured without major work on the chamber. In addition, there were indications that surface deterioration had taken place which would make other arcing very likely. As a result, data taking has stopped and rebuilding the chamber has commenced. Changes will be made to reduce the problems of side wall deterioration and prevention of overvolting. Additional changes will make it easier to replace wall structures if future problems occur. (Summary prepared by R. Mozley.)

E-49a — Inelastic Electron Scattering from Deuterium - R. E. Taylor (SLAC)

During February and March Group A completed an experiment to measure the inelastic electron scattering from deuterium and other nuclei at forward angles. The object of the experiment is to obtain a comparison of the structure functions for the neutron with those of the proton. During this period the inelastic cross sections were measured from hydrogen as well as deuterium in order to remove some potential systematic errors, and to check and extend the range of the proton data that have already been published. In February data were taken with the 20 GeV spectrometer set at 6° and with primary machine energies of 4.5, 7.0, 10.0, 13.5, 16.0, and 19.5 GeV. In March data were taken with the 20 GeV spectrometer set at 10° and with primary machine energies of 4.9, 7.0, 9.0, 11.0, 13.5, 15.1, 17.6, and 19.3 GeV. For each primary energy, data were taken at secondary momenta between that for elastic scattering and 2.5 GeV/c. Thus it should be possible to determine the inelastic cross sections over a wide range of inelasticity and momentum transfer. In addition, the inelastic scattering cross sections from beryllium, copper and gold were measured at 6° along with those from hydrogen and deuterium in order to obtain information about the A dependence of the inelastic process. (Summary prepared by D. Coward.)

E-50a — Compton Scattering at High Energies from Hydrogen - D. Ritson (SLAC)

During the January cycle data were collected on the Compton scattering on the proton out to large t-values and for photon energies of 6, 9, 12, and 18 GeV. The runs were very successful and, with the addition of these data, the experiment should be nearly finished. The first analysis of the data seems to indicate that the t dependence will be very similar to that observed in ρ photoproduction. As a check on the normalization elastic (e-p) scattering data were obtained in the same kinematical regions. (Summary prepared by B. Wiik.)

E-52 — γ_{ρ}^{2} By Coherent ρ Photoproduction from Deuterium - B. Wiik (SLAC)

During the cycle a large amount of data were collected on $\gamma d \rightarrow \rho^{o} d$. These data were taken using the new beam modulator system built by R. Miller and R. Koontz. The main virtue of this system as compared with the old system is the higher currents as well as the ease with which the modulation frequency can be changed. The data on coherent ρ photoproduction are in a t range from $-.15\ (\mathrm{GeV/c})^2$ to $-1.4\ (\mathrm{GeV/c})^2$ at 6, 12, and 18 GeV. An analysis of these data will give the coupling strength of a rho to a photon γ_{ρ}^{2}, as well as the total ρN cross section. During this cycle a successful test of $\gamma P \rightarrow \pi^{o} P$ was made by

measuring the γ's from the π^0 decay in coincidence with the recoil proton under polarized beam conditions.

E-53 — Survey of Photon and π^0 Yields - F. Murphy (UC Santa Barbara)

The first part of E-53, π^0 and γ yields, was completed on checkout time in January 1970. Yield measurements were made at 18 and 16 GeV, at 6°, 8°, and 10°. This data is now being analyzed. About a week was then spent in disassembling the old shower counters, installing a new array of 14 lead-glass shower counters, and in rearranging the logic. The new counters provide better energy resolution, in a beam of up to 2×10^8 equivalent quanta per pulse. The last days of the cycle were used for checking out the new counters and logic and for four shifts of data-taking at 20.5 GeV at 120 pps, to extend the yield measurement to smaller cross sections. The running was successful but the data rate was limited by background radiation escaping into the yard. During the shutdown successful modifications were made to the beam lines in an attempt to remove some neutron sources, and shielding was also added. The experiment was completed in the first week of the February cycle. This required about nine shifts of 20.5 GeV electrons from 2.5 mA. The last four shifts were spent at 18 GeV to provide a comparison to the 20.5 GeV data. It is not yet possible to state the result, but the statistical level reached was probably more than sufficient to allow seeing the most favorable partons predicted by Bjorken and Paschos. Finally, three shifts were spent with positrons of 10, 12, and 17 GeV at $\sim$20 pps to calibrate the counters once more and to map in detail their response. (Summary prepared by F. Murphy.)

CE-40 — Production of Charged ρ Mesons by Pions - J. Tenenbaum (SLAC)

During the February period this experiment used a low pulse rate from the accelerator for checkout. All beam trigger and veto counters, 66 in number, were installed and checked out. These counters were plateaued and timed with the 54" magnet on and off and the final trigger electronics were aligned. The hydrogen target in and target out trigger rates were measured for the ρ^- trigger mode for incident pions of 15.0 and 8.0 GeV/c momenta. In addition, some shielding studies for beam backgrounds were started and three spark chambers were tested. During this period about 3000 pictures were taken dealing with the

following subjects: (a) backgrounds, (b) shower development in the shower chamber, (c) normally triggered pictures, and (d) beam phase space. In these preliminary measurements the trigger rates were close to the predictions with a target in-target out ratio of about 3 to 1.

During March the experiment primarily worked on trigger rates, set up so that the triggering is as it will be for the experiment. The optical chambers were operated on both charged particles and showers with varying voltage settings for efficiency comparisons. The clearing field was also varied to look for the effect of shorter memory time on background tracks. The background itself was reduced significantly by building two collimators, one at the second focus of the secondary beam and one immediately upstream of the hydrogen target. Studies of the effects produced showed both counter and picture backgrounds were decreased, principally by the upstream collimator. Data was taken using three chambers with 1.4×10^7 pions passing through the target. These events are currently being processed by a preliminary version of the analysis programs.

2. Bubble Chamber Exposures — (Summaries prepared by R. Gearhart)

TBC-11 — Laser Induced Polarized Photon Beam - G. Wolf (SLAC)

The second harmonic of the ruby laser was successfully generated in KDP crystals with conversion efficiency of ~20%. The energy of the backscattered photons produced by interaction with the electron beam is 9.65 GeV (E_{e^-} = 19 GeV). An engineering run produced some 57,800 pictures.

BC-13 — 7.5 GeV/c and 5.0 GeV/c $\pi^- p$ Exposure in the SLAC 82 Inch HBC - U. Kruse (U. of Illinois)

This experiment received 208,000 exposures of 5.0 GeV/c π^-. The exposure will be used in conjunction with other exposures in a study of $\pi^- p$ interactions being carried out by the University of Illinois.

BC-14 — 7.5 and 13 GeV/c π^+ and π^- Exposures - I. Pless (MIT)

An exposure of 144,000 pictures with 8 GeV/c π^- was obtained for this experiment.

BC-27 — Study of "A_2" Problem and Other Members of the $J^P = 2^+$ Nonet - K. Lai (BNL)

Kwan Lai of Brookhaven received 237,000 pictures in January and 272,500 in March, all at 4.5 GeV/c π^-. The 82" hydrogen bubble chamber used the 35 mm 3 strip film format.

BC-28 — 5 GeV/c π^+p Exposure in SLAC 82 Inch Hydrogen Bubble Chamber - Y. Eisenberg (Weizmann Institute)

This experiment is a high statistics study of π^+p interactions in the region of 5 GeV/c incident pions. This experiment progressed satisfactorily early in February. However, the experiment had to be discontinued after only 35,000 exposures because of a failure in the 82 inch bubble chamber.

In March the group obtained 291,000 exposures at 5.0 GeV/c π^+. The pictures will be used in a study of boson resonances and quasi-two-body final state events. The rf separated beam and a new beryllium target were successfully used. The film format was the 46 mm single strip.

TBC-33 — 4.5 GeV/c π^- Exposure in H_2 82 Inch Bubble Chamber - W. Selove (U. of Penn.)

In an engineering run in January for this experiment approximately 3,000 pictures were obtained with 4.5 GeV/c π^-.

In a test run in March, Selove obtained 58,000 additional pictures. The three-strip 35 mm film format was used. These pictures were taken to enable Selove to test his automatic sensing equipment. The pictures were taken at a low track density of about 8-12 tracks/picture.

D-6 — Sodium Iodide Counter Test - E. B. Hughes (Stanford)

During a test run measurements were made on a sodium iodide (thalium) spectrometer. This detector was larger than any previously tested and with a unique assembly. The resolution offered by this detector for electrons in the range 4-15 GeV varied from 1.4 to 0.9% (FWHM). These results are better than any previously obtained and probably do not represent the limit of this technique.

D-6a — Test of Total Absorption Detectors - B. Hughes (Stanford)

Design studies on total absorption detectors for strongly interacting particles were continued during the week of January 26, 1970. The development of 7500 cascades initiated by 15 GeV pions in sodium iodide was followed through a detector consisting of four segments, each approximately 0.5 absorption lengths thick. The energy deposited in each segment was separately measured for each cascade. These data will be compiled with design calculations and will provide information on the probability with which pion cascades can be confused with those of electrons.

D-6b — Test of Solid State Detection in 82 Inch Bubble Chamber - I. Pless (MIT) and H. Lubatti (U. of Washington)

Further tests of the solid state detector (SSD) were made. The object is to enable the bubble chamber to take a picture only if there is a single particle which

interacts. It is estimated that the system is approximately 70% efficient. Only 6500 pictures were taken but the test occupied seven calendar days.

T-5 — University of Chicago Shower Counter Test - P. Meyer (U. of Chicago)

During February a test run, T-5, was carried out in the π/e beam (line 6 of C) to calibrate balloon borne shower counters and associated systems for a group from the University of Chicago.

T-6 — Test of Feasibility of Separated Proton Beam - J. J. Murray (SLAC)

In this recent test it was found that a potentially useful proton beam can be delivered to the 82" BC. The rf separated beam is used at 9.1 GeV/c where π and K mesons can be separated from protons. With 18 GeV electrons, a 1 X_0 beryllium target, 1° production angle and ±1-1/2% momentum spread, the yield at the bubble chamber was ~1 proton/mA/per pulse primary beam with $\lesssim$ 1% contamination. The test was made at 9.1 GeV/c only; there are no other momenta at which conditions are as favorable.

NT-3 — Rapid Cycling Bubble Chamber Tests - H. Barney (SLAC)

The Bubble Chamber Development Group made initial tests of a small sonic-excited bubble chamber. Running time spanned four days.

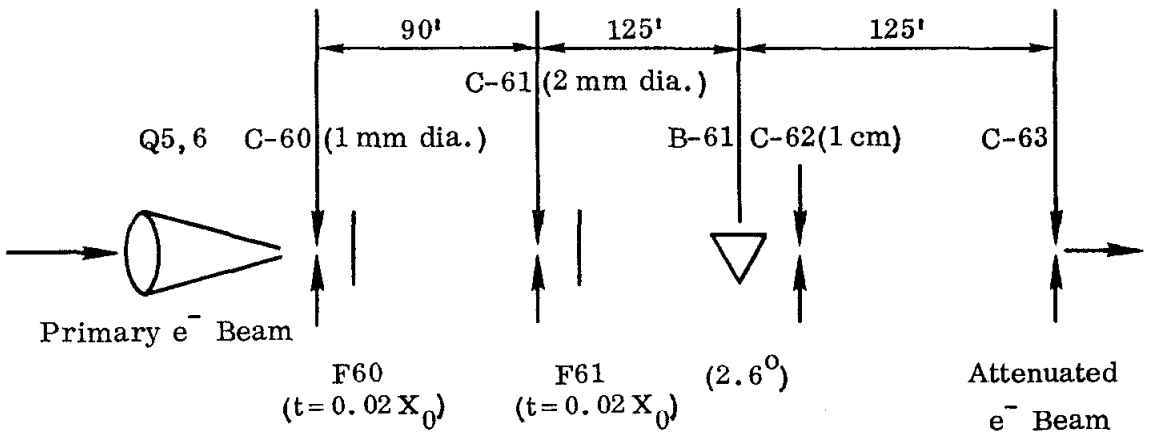
D-8 — Special Spectrometer Test Run - M. Granoff (UC San Diego)

The D-8 test was run to determine the ability of a magnetic spectrometer system to resolve the origin of particles along a beam line downstream of a target. This data will be useful in determining the feasibility of detecting short-lived particles ($\gamma c t = 1$ cm). The 8 GeV spectrometer was connected in a point-to-point focusing condition in both the horizontal and vertical planes with a double focus three meters from the end of the last quadrupole. A movable counter was placed inside the spectrometer shielding. During the parasite time all electronics were set up and an attempt was made to see the end of the 15 inch deuterium target that Experiment 52 was using. During the actual run four targets (.03, .1, .3, 1 radiation length of tungsten) were placed 2.25 cm upstream of the spectrometer pivot point. First the spectrometer was tuned for maximum resolution. Then the target image and tails were measured in the image plane looking at 12.5^o, 18°, and 29° and at .5, 1, 2, and 3 GeV/c positive particles. The spectrometer resolution and magnification determined from this data agreed with calculated values. Runs were taken with various targets including target out runs. Also, the target was moved 4.5 cm downstream so that the region upstream of the

target could be investigated. The run was entirely successful and preliminary results indicate that the rate away from the target is low enough to consider designing a system to be used in a very high intensity experiment.

D-9 — Production of High Quality, Low Intensity $e^{\pm}$ Beams - T. Erber (Illinois Institute of Technology)

There is a continuing need for e^+ or e^- beams at SLAC which have intensities much less than the minimum practical primary beam intensity and which are accessible to experimenters during operation. Secondary positron beams of excellent quality can and have been used, but the maximum intensity available is limited to $\sim 10^5$ e^+/pulse. There are now two experiments pending, each requiring $\gtrsim 10^6$ e^+ or e^-/pulse. Hence, a new technique has been adopted and was tested successfully during the February 1970 running period. An e^- beam of low intensity is produced by multistage attenuation of the primary e^- beam, at normal intensity, in a series of scattering targets and small size collimators. A two-stage version of such a beam was set up in the laser beam line of C and consists of the elements indicated in the sketch below:



F60 and F61 are the scattering targets and the only new elements added to the beam system. A final attenuated beam intensity $\sim 10^6$ e^-/pulse was obtained with 10^{10} primary e^-/pulse (1 mA, 1.6 psec), at an energy about 1% less than the primary energy and with an energy spread of about 1% FWHM. The attenuation can be controlled by varying the focus of Q5, 6 and/or the thickness of the scattering targets. The beam at C63 is 1 mm in diameter and contained in a cone of full angle 3×10^{-4} radians. This beam is to be used in an experiment to measure the magnetic bremsstrahlung spectrum produced in megagauss magnetic fields. (Summary prepared by J. J. Murray.)

F. New Experiments

During the 21 February 1970 meeting of the Program Advisory Committee E-61 was approved.

During the 20-21 March 1970 meeting of the Program Advisory Committee, some portions or all of Experiments E-50b, E-56a, E-62, E-63, E-64, E-65, E-66, E-67, BC-33a and BC-35 were approved and Experiments E-43 and BC-8 were granted extensions.

Summaries of Newly Approved Experiments

E-50b — Asymmetry in the Photoproduction of π^0 Mesons by Polarized Photons - D. Ritson (SLAC)

Theoretically, photoproduction of π^0 mesons at high energy is assumed to proceed through exchange of natural parity mesons (ρ, ω, ϕ's, etc.) and unnatural parity mesons (B^0, H^0, etc.). In a simple Regge picture, at the position of the nonsense zero of the ω trajectory at $t = -.5$ $(GeV/c)^2$ the cross section should be dominated by the exchange of the unnatural parity mesons (particularly the meson with $J = 1$, parity +, $C = -1$, $T = 0$).

Previously measurements of the production asymmetry of π^0 mesons have been made at CEA at 3 GeV. These measurements, interpreted in the above context, have shown that the production proceeds predominantly through "natural parity exchange" even at $t = \sim -.5$ $(GeV/c)^2$. However, s-channel effects may still be important at these energies and it is clearly of interest to extend these results to higher energies. In addition, of course, more complex theories involving absorptive effects have been proposed to account for the photoproduction cross sections, and measured asymmetries at higher energies will undoubtedly be necessary to check these predictions. We expect to be able to make precise measurements out to higher $|t|$ values than previously.

In principle the reactions $\gamma + P \rightarrow \gamma + P$ and $\gamma + P \rightarrow \pi^0 + P$ can be measured by observing the recoil proton yield as a function of missing mass. In practice, however, due to the experimental resolution, only the sum of the Compton effect and π^0 photoproduction can be determined with this technique. We have done this successfully with the 1.6 GeV spectrometer for incident photon energies between 6 GeV and 16 GeV and to t values between $-.2$ $(GeV/c)^2$ to -1.4 $(GeV/c)^2$. However, by further observing the scattered photon in a shower counter in coincidence with the recoil proton the two reactions should be easily separated. In this experiment we are initially interested in the range $0.1 \leq |t| \leq 1.0$ $(GeV/c)^2$.

The recoil proton as measured with the 1.6 GeV spectrometer defines the t value, and together with the incoming photon, the plane of the scattering. π^0 mesons decay within a cone with an opening angle m/E, and hence by making the photon detector very small compared with this decay cone and placing it in the scattering plane, the observation of π^0 production will be strongly suppressed. Conversely, by increasing the size of the detector and moving it out of the scattering plane the π^0 cross section can be measured without contamination from Compton scattering. The main event selection will thus be made by the 1.6 GeV spectrometer via the recoil protons, and the shower counter will simply provide an additional kinematic constraint, largely geometric in nature and not strongly dependent on the quality of the energy resolution of the counter.

E-56a — A Search for Short-Lived Sources of Neutrino-Like Particles - M. Schwartz (SLAC)

This is a speculative experiment which has a high probability of yielding no significant result. But the total investment involved in both money and effort is sufficiently small and the possibilities sufficiently exciting to warrant its implementation.

Specifically, this experiment will search for sources of hitherto unknown neutrino or neutrino-like particles which can be produced at SLAC. The electron beam will be allowed to enter Beam Dump East on a parasitic basis. A large, sixty ton, spark chamber, lead-wall array will be set up behind enough earth to stop all muons and other known debris (except neutrinos).

Background events in this experiment will consist of neutrino events (originating mainly from π decay) and accidental cosmic rays. Both of these backgrounds will have a characteristic appearance and should be easily recognizable. The data reduction process will be to look for a significant number of events which do not resemble either of these backgrounds.

E-61 — Forward Angle Electron Scattering - R. E. Taylor (SLAC)

The approved portions of this experiment consist of two distinct features:

a. π Production Near Threshold. Soft π calculations have been made relating the cross section for π production near threshold to the axial vector form factor, g_A. About a year and a half ago Group A reached the conclusion that the systematic errors in their 6° data were too large to allow meaningful results to be obtained for g_A. Since this data is now being used for this purpose in the literature, it appears desirable to attempt a more careful study of the threshold region with regard to spectrum shape, and the exact location of threshold in the spectrum, for a range of q^2 values.

b. Inelastic Scattering. Present data at 1.5° and 6° can be improved with a "triangle" at an intermediate angle. A triangle consists of a spectrum of the double differential scattering cross section from elastic scattering to scattering with a final energy of around 3 GeV, for each of several initial energies from ~4 to 20 GeV. This data will provide information on the behavior of the resonance at values of q^2 where the resonance cross sections are increasing relative to the elastic peaks. The q^2 dependence of σ_T for low values of q^2 is of some interest and is not very well defined by present data. The cross sections for large W should cover the transition region of q^2 and ν where "scaling" is not valid and will be programmed to overlap part of the 6° line in q^2 and ν.

E-62 — Particle Spectra at High Energies - Y. Nagashima (Cal Tech)

This experiment will measure the differential cross section $\frac{d^2\sigma}{dXdQ^2}$, where X = fraction of available longitudinal momentum and Q = transverse momentum, in the reactions

$$\gamma + p \longrightarrow \left\{ \begin{matrix} \pi^{\pm} \\ K^{\pm} \\ p^{\pm} \end{matrix} \right\} + \text{anything}$$

as a function of X and Q at several photon energies. (Negative X means the particles are going backward in the center-of-mass.) This measurement will be performed on the 8 GeV spectrometer, using time-of-flight and a single Cerenkov counter to separate charged secondary particles. The counting rates have been estimated from Be yield measurements; the rates should be feasible for $Q \leq 1$ GeV/c using a bremsstrahlung subtraction of $\Delta k/k = 0.10$. The region $-1.0\ X \leq +0.1$ will be covered.

It is known that in p-p collisions at high energies pions are emitted preferentially with small longitudinal momentum in the center-of-mass. This phenomenon, called "pionization," is believed to account for the largest fraction of meson production at cosmic ray energies. Various theoretical models have been put forth to account for the effect, but good experimental data which covers zero longitudinal momentum is lacking. This experiment will determine whether pionization is a process which contributes strongly to the photoproduction of π's and K's up to 20 GeV. In addition the data will be compared against available theoretical models that predict the quantitative behavior of the particle cross sections. In particular,

the following measurements will be done:

(a) the cross section as a function of transverse momentum to determine if this has the same exponential dependence observed in p-p;

(b) the cross section as a function of longitudinal momentum to determine whether this has the simple 1/X behavior predicted, and if so, the range of validity; and

(c) the dependence on energy of the function describing the longitudinal momentum distribution.

E-63 — Measurement of K_L^0 and Neutron Total Cross Sections on Nuclear Targets - E. B. Hughes (Stanford)

In recent parasite work this group has studied the feasibility of distinguishing, using time-of-flight, between the K_L^0 and neutron components of the secondary neutral beams at SLAC, and made preliminary measurements of the K_L^0 and neutron total cross sections on certain nuclei. On the basis of this work this experiment initiates a precision measurement of these two hadron-nucleus total cross sections at GeV energies for a broad range of nuclear targets. The experiment would also provide limited information on the variation of both cross sections with hadron energy. For selected targets the total absorption cross section for both neutrons and K_L^0's will be measured. These experiments are the simplest ones using this technique. They would also provide the beam information necessary to design other experiments in an optimum way. The available neutral hadron intensities at SLAC are not large and it is of interest to determine the ranges of flight time, or momenta, within which the K_L^0 and neutron components can be separately tagged.

E-64 — Study of the Decay $K_L^0 \rightarrow \pi^{\pm}\mu^{\mp}\nu$ - M. Schwartz (SLAC)

This experiment is a high statistics study (5×10^7 events) of the neutral K meson decay mode $K_L^0 \rightarrow \pi^{\pm}\mu^{\mp}\nu$ as the initial experiment for the large magnet and wire chamber spectrometer facility now being assembled in ESB. This data would be used to study the charge asymmetry in the decay and the details of the Dalitz plot distribution, and to search for rare decay modes, such as $K_L^0 \rightarrow \mu^+\mu^-$.

The existence of a charge asymmetry in the $K_{\mu 3}$ decay is prima facie evidence of CP violation. In 1967, a large fraction of this group measured this asymmetry to be $\delta_\mu = \frac{N_{\mu+} - N_{\mu-}}{N_{\mu+} + N_{\mu-}} = (4.05 \pm 1.35) \times 10^{-3}$. Two experiments on K_{c3} decay have found $\delta_e = (2.24 \pm 0.36) \times 10^{-3}$ and $\delta_e = (3.15 \times 0.3) \times 10^{-3}$. It is therefore of

interest, since all theories of CP violation predict $\delta_\mu = \delta_e$, to provide a second measurement of δ_μ with higher precision. With 5×10^7 events, we would expect to measure δ_μ to a precision of better than 10%.

Further, with this large sample of $K_{\mu 3}$ decays, a study of the Dalitz plot distributions, for example, to place a limit on the possibility of a $\pi\mu$ resonance in this mode will be done. In addition, a limit on the branching ratio for the decay $K_L^0 \rightarrow \mu^+\mu^-$, which is of the order of 10^{-8}, can be set. This is in the range of values predicted if the decay proceeds via two virtual photons. This experiment represents a substantial improvement over the previous $K_{\mu 3}$ experiment.

E-65 — A Proposal for an Experiment to Study Electroproduced Hadrons - W. T. Toner (SLAC)

This experiment will study the hadrons produced in inelastic electron scattering in which the scattered electron and forward hadrons are detected in a large spark chamber spectrometer. It is planned to study some 350, 000 events, of which more than 14, 000 will be fully analyzable ρ^0. Roughly equal amounts of hydrogen and deuterium data will be taken. A preliminary run on complex nuclear targets will be made.

The following studies of the data will be made:

(1) Transverse and longitudinal momentum distributions of forward produced hadrons, with π/p discrimination up to 3 GeV/c for a subset of the data. Comparison will be made with photoproduction data from bubble chambers. Any H_2/D_2 differences will be studied.

(2) Detailed study of ρ^0: Determination of transverse/longitudinal amplitudes and phase. q^2, t, ν dependencies will be studied. Coherent production from deuterium and heavy nuclei at high q^2 will be studied. The q^2 dependence of π-π mass spectrum will be examined.

E-66 — Inelastic Photoproduction of Charged Pi and K Mesons in the Forward Direction - S. Ecklund (SLAC)

Measurements of inelastic scattering of hadrons, where only one of possibly many reaction particles is detected, have revealed several interesting facts. One is that the cross section at high energies and moderate inelasticities is a function only of the transverse momentum Q, typically with an e^{-3Q^2} dependence. Another interesting feature is the presence of forward peaks for $Q < 0.4$ in $pp \rightarrow \pi^\pm$. However, these peaks may be explained by N* decay.

While there is no very good or complete theory of such inelastic processes, attempts to understand the existing data and to predict new features are being made.

Feynman asserts that the important parameters are the transverse momentum Q and the center-of-mass (c.m.) longitudinal momentum divided by the incident c.m. momentum $x = P_\ell/P_i (-1 < x < 1)$. The cross section $d^2\sigma/dQdx$ is expected to have simple properties; at high energies $d^2\sigma/dQdx \rightarrow f(Q, x)$ independent of energy. For not too large but finite x, the x dependence is 1/x. For x near 1, the dependence is expected to be $(1-x)^{1-2\alpha(t)}$ where $\alpha(t)$ is the highest Regge trajectory which could contribute to the process.

Other more quantitative models have been proposed with a Regge framework; "thermodynamic" models have also been used.

Since the photon is found to behave very much like a hadron in collisions with hadrons, it is of interest to study inelastic photoproduction to compare with inelastic pion and proton production in hadron collisions. Measuring photoproduction of π or K plus anything is different enough from other photoproduction measurements to warrant investigation. Up to now, no one has specifically set out to measure inelastic photoproduction at high energies although some information is available as a by-product of some test runs.

Several features appear unusual and demand investigation.

1. The π^+ and π^- yields are not equal at large Q.
2. The K^+ and K^- yields are not equal at any of the measured points.
3. Measurements at different momentum and angle seem to depend only on Q and have an $e^{-5.5Q^2}$ dependence for $Q < 1$. The π data appear to have a break in the Q dependence near $Q = 1$.

The difference in π^+ and π^- is probably understandable in that the multiplicity of pions is still small enough to favor π^+ over π^- for a proton target. The difference in K yields seems more interesting, especially in view of the beam survey results from Be which gave K^+/K^- ratios of typically 2.4. This seems to imply that K production is dominated by associated K-hyperon production which might not be expected at large inelasticities. To sort out the causes for the differences in π^+ vs π^- and K^+ vs K^- measurements with deuterium will be important.

This experiment will measure inelastic cross sections for π^+, π^-, K^+, K^-, off hydrogen and deuterium for the several values of the three kinematic variables, photon energy, angle, and momentum. The photon energy will be determined by a bremsstrahlung subtraction of 1 GeV. The charged mesons will be detected in the 20 GeV spectrometer system. A range of values of Q, longitudinal c.m. momentum ($p_{c.m.} = xk_{c.m.}$), and missing mass (M_x) will be covered.

E-67 — Study of $\pi N \rightarrow N\bar{N}N$ at 15 GeV/c - D. W. G. S. Leith and H. L. Lynch (SLAC)

This experiment is a study of the process $\pi N \rightarrow NNN$ at 15 GeV/c. Little or no information exists on this reaction, which includes the interesting meson decay channel into nucleon antinucleon pairs. A survey of such decay processes in the mass region up to 2600 MeV will be done and, in particular, a study of the properties of the four "known" resonances observed in this range by the CERN Missing Mass Group (since little is known about their spin, parity or decay modes) will be performed. The experiment will be sensitive to $N\bar{N}$ decays at a level of $\geq .2\%$ of the total cross section of these resonances. For decay rates $\geq 10\%$ of the total, analysis of the decay distribution will provide information on the spin parity of the resonances. (The decay angular acceptance is rather uniform in the range $|\cos\theta_{N\bar{N}}| \leq 0.95$, over the whole mass region.) The experiment employs the wire spark chamber spectrometer system previously used in the study of $\pi^- p \rightarrow \pi^+\pi^- n$, $\pi^- p \rightarrow K^+K^- n$ at 8, 15 GeV/c (E-41).

BC-33a — 300,000 Pictures, 4.5 GeV/c π^- in H_2 82 Inch Bubble Chamber - W. Selove (U. of Pennsylvania)

The principal objectives of this experiment are to study $\pi\pi$ scattering, to investigate the feasibility and validity of extrapolation techniques for getting cross sections for collisions with virtual particles, and to study ρ production in the reaction $\pi^- p \rightarrow \rho^0 n$ with sufficient data and sufficiently broad angular sensitivity so as to determine specific polarization components accurately. These principal objectives involve primarily the one-pion exchange process.

In the pursuit of these objectives, the best data come from bubble chamber experiments. Presently available data at suitable beam energies, however, are statistically too limited to draw completely clear conclusions, and there is a serious need for much improved statistics. This experiment would give about 5 times more data than any single existing experiment at comparable energies.

The relevant events for these principal objectives are the 2-prong events. In the course of measuring these events, data will also be obtained which promise to be useful in the study of various resonance properties; that study forms a secondary objective of this experiment, though not a minor one. At the same time 4-prong events and also events of higher multiplicity will be measured. These also promise to add to present knowledge of various resonance properties.

BC-35 — γ-d Interactions at 3.5 and 5.5 GeV with Polarized Photon Beam - R. T. Poe (UC Riverside) and R. W. Birge (UC Berkeley)

Photoproduction reactions in the GeV range have become feasible and have been fruitfully studied only in recent years. The study of these reactions not only yields results of inherent interest such as the direct photon-vector meson couplings, but it also makes possible the study of certain aspects of strong interactions which are difficult or even inaccessible in the usual hadronic collisions.

The recent experiments at SLAC using the laser-induced polarized photon beam in the 82" hydrogen bubble chamber have resulted in a detailed study of the mechanisms involved in the photoproduction reactions. Such investigations of exchange mechanisms will provide better understanding of high energy reactions, and are quite important in assessing the range of validity of various theoretical models, in particular, vector meson dominance and Regge-pole theory.

This experiment is to be a large-statistics experimental study of photoproduction reactions with polarized photons in deuterium. A total of one million pictures in the LRL 82 inch bubble chamber filled with deuterium were requested, and an initial approval of 300K pictures has been granted. The exposure is to be equally divided between two photon energies, 3.5 GeV and 5.5 GeV. In a 100K exposure this will yield 250 events per μ-barn cross section at each energy.

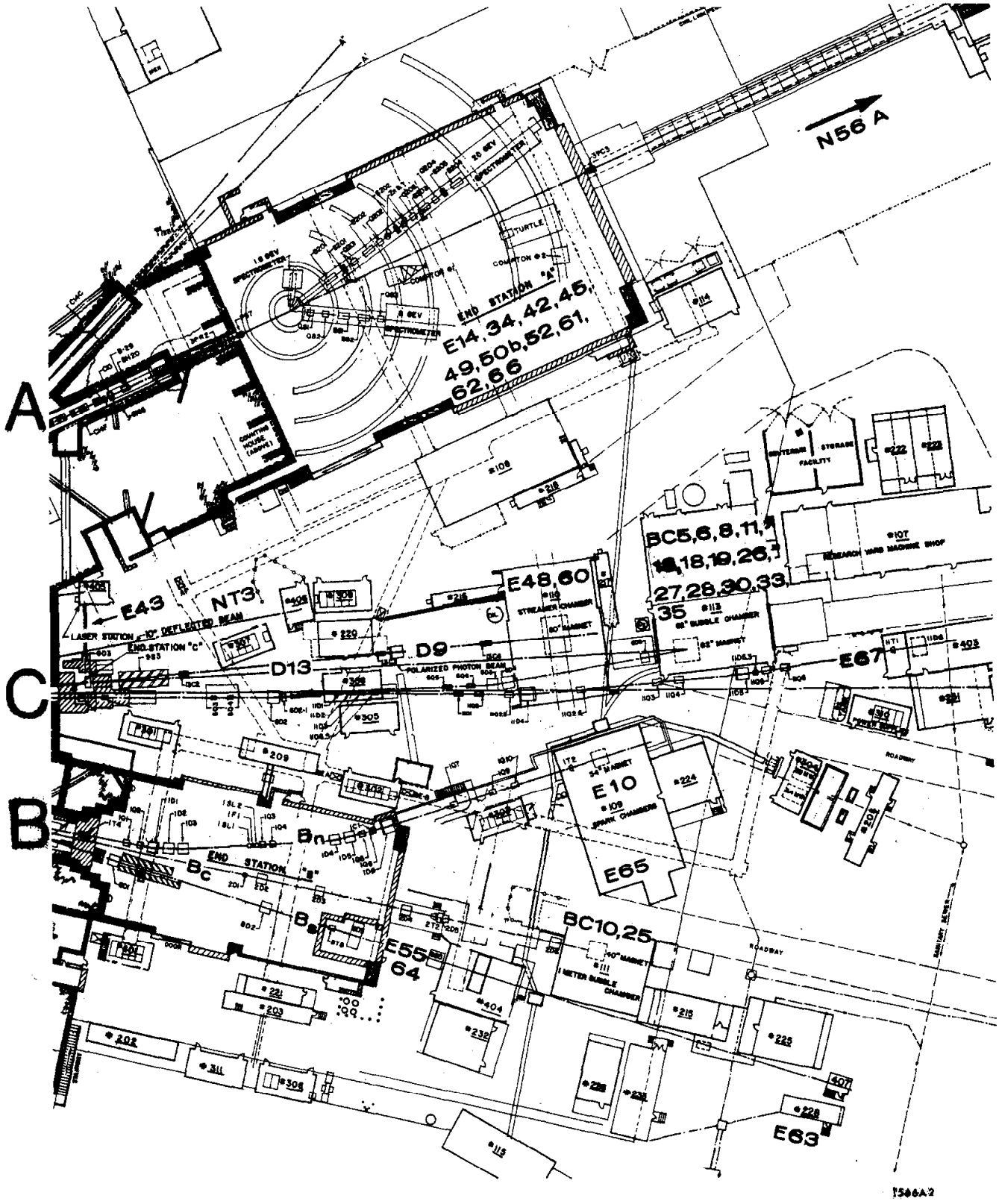
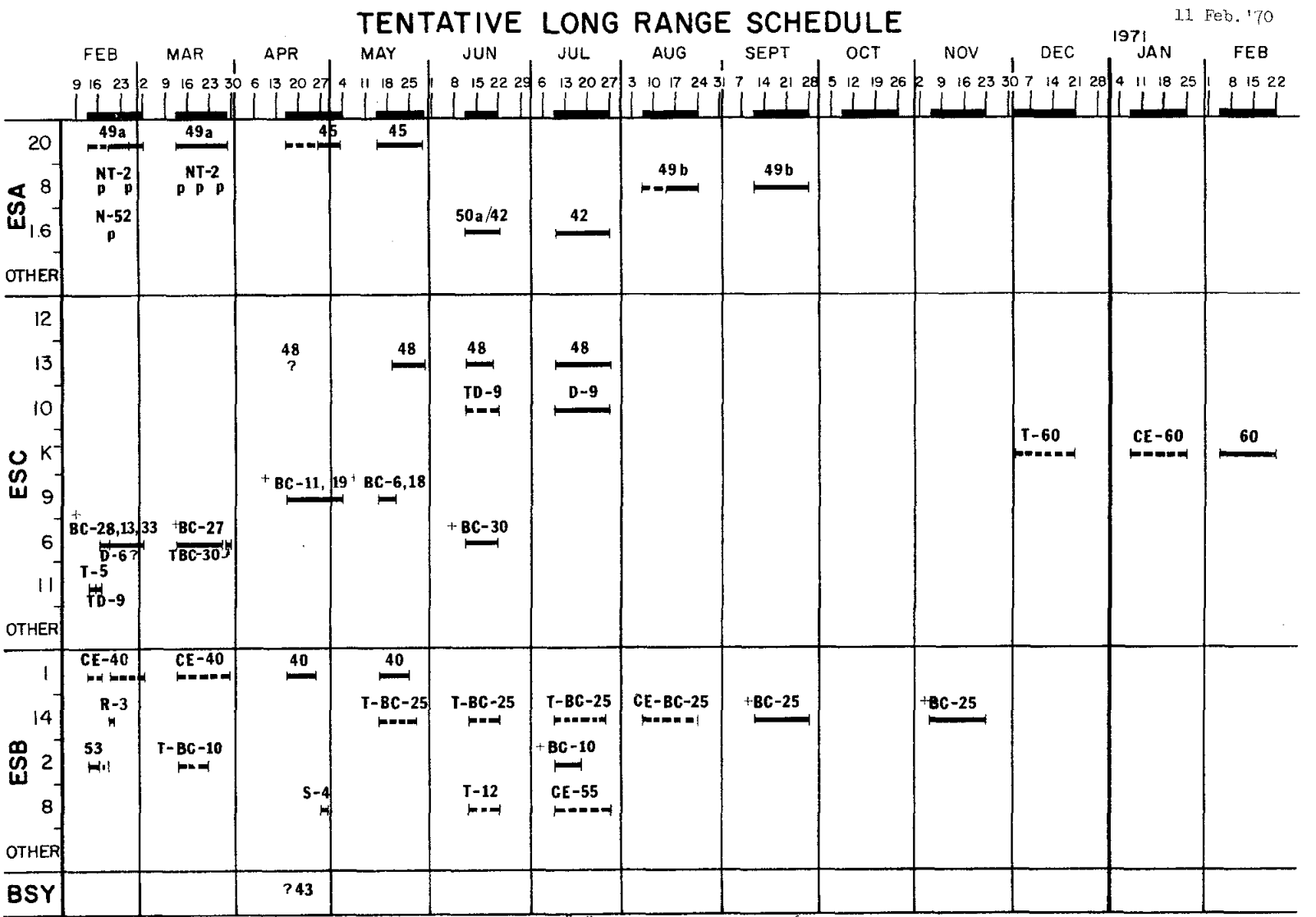


FIG. 2--Experiment locations.



+Due to a malfunction in the 82" Bubble Chamber on 16 February, the Bubble Chamber schedule will be revised.

FIG. 3

TABLE I

TABLE OF PROGRAMMED EXPERIMENTS

Number	Title	Authors	Date Approved	Status (See Key)
E-14	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 CALTECH B. C. Barish	7/2/68	Inactive
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	SLAC J. Cox, B. Dieterle, W. Kaune, M. Perl, J. Pratt, J. Tenenbaum, W. Toner, T. Zipf	8/5/68	Checkout
E-41	Rho Production by Pions - A Test of Vector Dominance	SLAC F. Bulos, W. Busza, G. Fischer, E. Kluge, R. R. Larsen, D.W.G.S. Leith, B. Richter, H. Williams IBM M. Beniston	8/5/68	Completed
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	Inactive
E-43	Velocity of Light Experiment	UCSD G. Masek	12/14/68	Inactive
E-45	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	Setup

Table of Programmed Experiments (cont'd) - 2

Number	Title	Authors	Date Approved	Status
E-48	Measurement of the ξ Parameter in the Decay $K_L^0 \rightarrow \pi\mu$	BNL D. Hill, R. Palmer M. Sakitt, N. Samios SLAC D. Fries, F. Liu, R. Mozley A. Odian, J. Park, W. Swanson, F. Villa	2/8/69	Running
E-49a	Inelastic Electron Scattering From D_2 and Other Nuclei	SLAC E. Bloom, L. Cottrell, D. Coward, H. DeStaebler, C. Jordan, R. E. Taylor MIT J. Elias, J. I. Friedman, H. W. Kendall, M. Sogard, K. Tsipis, M. Breidenbach, R. Verdier	2/8/69	Setup Checkout Running
E-49b	Inelastic Scattering From D_2 and Other Nuclei: Large Angles	SLAC D. Coward MIT J. Elias, J. I. Friedman, H. W. Kendall, M. Sogard, K. Tsipis, M. Breidenbach, R. Verdier	8/6/69	Inactive
E-50a	Compton Scattering at High Energies from Hydrogen	SLAC R. Anderson, D. Gustavson J. Johnson, I. Overman, D. Ritson, B. Wiik HARVARD UNIV. J. Walker NORTHEASTERN UNIV. R. Weinstein	3/22/69	Running/ Checkout
E-50b	Asymmetry in the Photoproduction of π^0 Mesons by Polarized Photons	SLAC R. Anderson, D. Gustavson, J. Johnson, I. Overman, D. Ritson, B. Wiik HARVARD UNIV. J. Walker NORTHEASTERN UNIV. R. Weinstein	3/21/70	Inactive
E-52	Determination of γ_ρ^2 and the Total πN Cross Section From Coherent ρ- Photoproduction of Deuterium	SLAC R. Anderson, D. Gustavson, R. Johnson, I. Overman, B. H. Wiik NORTHEASTERN UNIV. R. Weinstein	8/6/69	Checkout/ Running
E-53	Survey of Photon and π^0 Yields	U.C. SANTA BARBARA D. Caldwell V. Elings, D. Fancher, A. Greenberg, G. Jahn, A. Kaushal, B. Kendall, R. Morrison, F. Murphy, S. Tyler B. Worster	6/11/69	Setup Checkout Running Complete

Table of Programmed Experiments (cont'd) - 3

Number	Title	Authors	Date Approved	Status
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	8/6/69*	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 UNIV. OF CALIFORNIA SANTA CRUZ D. Dorfan	3/21/70	Inactive
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		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	CALIF. INSTITUTE OF TECHNOLOGY B. C. Barish, A. Dzierba W. Ford, R. Gomez, Y. Nagashima P. Oddone, C. Peck, J. Pine, F. Sciulla, A. V. Tollestrup	3/21/70	Inactive
E-63	Measurement of K_L^o and Neutron Total Cross Sections on Nuclear Targets	STANFORD UNIVERSITY J. Crawford R. Ford, E. B. Hughes, L. Middleman, L. H. O'Neill, J. Otis	3/21/70	Inactive
E-64	Study of the Decay $K_L^o \rightarrow \pi^{\pm} \mu^{\mp} \nu$	SLAC D. Fryberger, D. Litlin, J. Liu, M. Schwartz, S. Wojcicki U.C. SANTA CRUZ D. Dorfan	3/21/70	Inactive

Table of Programmed Experiments (cont'd) - 4

Number	Title	Authors	Date Approved	Status
E-65	Study of Electroproduced Hadrons	SLAC B. Dieterle, W. Lakin, F. Martin, E. Petraske, M. L. 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 $\pi N \rightarrow N\bar{N}N$ 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
BC-5	Study of Many Particle Final States Produced by 12 GeV/c π^- Mesons at SLAC	UNIVERSITY OF HAWAII A. Kohya, M. W. Peters, V. Peterson, V. Stenger, A. Johnson, N. Rogers, P. Wohlmut	12/16/67	Inactive
BC-6	Study of the One Pion Exchange Contribution to γ-Nucleon Scattering (in 40 Inch Deuterium Bubble Chamber)	OAK RIDGE H. O. Chon, R. D. McCulloch UNIV. OF TENNESSEE G. T. Condo, W. M. Bugg	9/28/68	Inactive
BC-8	Exposure of the 82-Inch Hydrogen Chamber to a Beam of π^+ Mesons at 7.0, 11.0 and 14.0 GeV/c.	PURDUE D. D. Carmony	Ext. 3/21/70	Inactive
BC-10	Investigation of K_2^0p 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 Special Test
BC-11	A Bubble Chamber Experiment with the Polarized Laser Induced Photon Beam (Extended 10/3/69)	SLAC J. Ballam, G.Chadwick, Z. Guiragossian, P.Klein, A. Levy, M. Menke, J. Murray, G. Wolf TUFTS UNIV. C. Sinclair UC-BERKELEY H.Bingham, B.Equer, K. Moffeit UCLRL M.Rabin, W. Podolsky, A. Rosenfeld	5/11/68 Ext. 10/3/69	Running

Table of Programmed Experiments (cont'd) - 5

Number	Title	Authors	Date Approved	Status
BC-13	7.5 GeV/c $\pi^- p$ Exposure in the 82" HBC	UNIV. OF ILLINOIS G. Abrams G. Ascoli, B. Crawley, B. Eisenstein, R. Hanft, U. Kruse, D. Mortara, T. O'Halloran, R. Sard	8/5/68 Ext. 12/12/69	Running Complete
BC-14	7.5 and 13 GeV/c, π^+ and π^- Exposures in the SLAC 82" HBC	MIT P. L. Bastien, D. Brick, T. Dao, B. T. Feld, R. I. Hulsizer, L. Kirkpatrick, V. Kistiakowsky, H. Lubatti, D. Miller, A. Nakkasyan, G. Ouannes, I. Pless, A. Sheng, T. Watts, F. Winkelmann, J. Wolfson, R. Yamamoto	8/5/68	Running Complete
BC-18	4.25 GeV γ-Deuterium Experiment in the SLAC 40" Bubble Chamber	WEIZMANN INSTITUTE Y. Eisenberg, B. Haber, U. Karshon, L. Lyons, E. E. Ronat, A. Shapira, G. Yekutieli	9/28/68	Inactive
BC-19	γ-d Experiment with an Annihilation Beam of 7.5 GeV in the SLAC 40" Bubble Chamber	TEL AVIV UNIV. G. Alexander I. Bar-Nir, A. Brandstetter, S. Dagan, J. Gunhaus, A. Levy, Y. Oren	9/28/68	Inactive
BC-25	Study of Pomeranchon, Meson and Baryon Exchanges by Triggering the SLAC 40" Bubble Chamber on Fast Forward Particles	CAL TECH B. Barish, W. Ford, R. Gomez, C. Peck, J. Pine, F. Sciulli, B. Sherwood, A. Tollestrup, G. Zweig	6/18/69	Inactive
BC-26	Determination of Quantum Numbers for Resonances in the R,S,T, and U Region Using π^++d Interactions at 12 BeV	DUKE UNIV. M. Binkley, D. Carpenter, L. Fortney, C. Rose, E. Fowler, J. Elliot, G. Golson, F. Joshi, J. Kronenfeld, T. Snow, W. Yeager	6/11/69	Inactive
BC-27	Study of the "A_2" Problem and Other Members of the $J^P = 2^+$ Nonet	BROOKHAVEN NAT. LAB. D. Crennell, U. Karshon, K. Lai, R. Kinsey, J. O'Neall, W. Sims, J. Scarr	6/11/69	Running Complete

Table of Programmed Experiments (con't) - 6

Number	Title	Authors	Date Approved	Status
BC-28	5 GeV/c π^+p Experiment in the SLAC 82 Inch HBC	WEIZMANN INSTITUTE OF SCIENCE Y. Eisenberg, B. Haber, U. Karshon, E. Ronat, A. Shapira, G. Yekutieli	8/6/69	Running
BC-30	Λp in the Momentum Interval 1-5 GeV/c	LRL-BERKELEY G. Trilling J. Kadyk, G. Goldhaber, J. Hauptman	12/12/69	Inactive
BC-33	4.5 GeV/c π^- Exposure in H_2 82" Bubble Chamber	UNIV. OF PENNSYLVANIA S. Barish, J. Bensinger, E. Bogart, P. Jacques, W. Selove	12/12/69	Running
BC-33a	4.5 GeV/c π^- Exposure in H_2 82" Bubble Chamber	UNIV. OF PENNSYLVANIA S. Barish, J. Bensinger, E. Bogart, P. Jacques, W. Selove	3/21/70	Special Test
BC-35	γ-d Interactions at 3.5 and 5.5 GeV with Polarized Photon Beam	UNIV. OF CALIFORNIA-RIVERSIDE S. Fung, A. Kernan, R. Poe, T. Schalk, B. Shen UNIV. OF CALIFORNIA-BERKELEY R. Birge, R. Ely, G. Gidal, D. Grether, G. Kalmus, W. Michael	3/21/70	Inactive
NT-3	Rapid Cycling Bubble Chamber Development	SLAC H. Barney, R. Blumberg, A. Rogers, S. St. Lorant	12/15/68	Parasiting
D-6	Charpak Wire Chamber Tests	SLAC E. Bloom, K. Doty, G. Johnson, R. Siemann	9/15/69	Special Test
D-6a	Sodium Iodide Counter Test	HEPL E. B. Hughes	12/15/69	Special Test
D-6b	Test of Solid State Detectors in 82" BC	MIT and UNIV. OF WASHINGTON I. Pless, H. Lubatti		Setup Complete
D-8	Background Measurement	U.C. SAN DIEGO G. Masek		Completed
D-9	Magnetic Bremsstrahlung	ILLINOIS INSTITUTE OF TECH. T. Erber, F. Herlach, H. G. Latel	2/8/69	Inactive

Table of Programmed Experiments (con't) - 7

Number	Title	Authors	Date Approved	Status
D-13	Low Mass Particle Search	SLAC J. Murray	3/21/70	Special Test

(Key)

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

*Approved for checkout only.

III. ACCELERATOR IMPROVEMENTS

Installation of pulsed steering and focusing in four sectors of the accelerator neared completion during the quarter. The last of four quadrupole doublets was installed in February and the second pulsed quadrupole power supply was installed and made operational during the quarter. The parts shortage which had delayed completion of the final two power supplies was cleared up, and fabrication was nearly completed at the end of the quarter. Installation of the last two power supplies and the final controller and logic chassis will be accomplished during the April shutdown. Fabrication of four pulsed steering power supplies and installation of three of them was completed prior to the quarter. The last of those power supplies will be installed in April. Additional funds were released during March to cover the fabrication and installation of pulsed quadrupoles and power supplies and pulsed steering power supplies in four additional sectors. This will increase the total number of sectors capable of pulsed steering and focusing to eight.

Work on pulsed beam loading compensation continued during the quarter. A prototype of a delay control circuit was completed in January and successfully tested during the February run. Based on results of the tests, fabrication of a pulsed system for six channels was begun in March and will be installed and tested in April. It is planned to provide five sectors with this facility.

Shielding methods were developed and tested in January and February to protect the off-axis injector from the high field main injector solenoid. Use of a bucking coil and an arrangement of shielding apparently solved the problem. The off-axis injector was used exclusively for the March experimental run to prove its compatibility and the results were satisfactory. It now appears feasible to make the conversion necessary to permit simultaneous use of the on-line and off-axis injectors on a pulse-to-pulse basis. Work is continuing on a new pulsed gun modulator and a pulsed alpha magnet is being designed to replace the dc alpha magnet presently being used with the off-axis injector.

Yield comparison tests were conducted in January on material to be used in a new positron source target. A yield of 9% was recorded at the entrance to the beam switchyard with 3/4" tungsten compared to a yield of 3.5% with copper.

Work on the B-beam slit continued during the quarter and is now about 20% complete. The fixed aperture collimator and the copper-tungsten modules were

completed in March and the slit modules and the precision shafting coder were about 50% complete at the end of the quarter.

Engineering was started in March 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 in March on the Data Assembly Building (DAB) rack and cabling expansion. Material is being ordered for the fabrication of an additional main cable frame in the data assembly building. Additional cables and coaxial terminations will be provided to handle the normal expansion of experimental requirements.

The first phase of consolidation of the two control rooms got under way during the quarter. Extensive use of the two presently installed computers is planned. Depending upon allocation of additional funds, consolidation will require about two years to complete.

IV. RESEARCH DIVISION DEVELOPMENT

A. Physical Electronics

Glass Semiconductors

A glass composition reported by D. Adler of MIT was compounded, and two devices were fabricated with this material. Results were erratic due to evaporation problems. The possibility that the material is decomposing rather than evaporating is being investigated.

Secondary Emission Detector

A method of lowering the work function of the GaAs photoemitter by surface treatments of Cs-CsI-Cs was investigated. To develop techniques, the Cs-CsI-Cs treatment was first applied to silver substrates. The work function of cesiated silver was lowered by 0.1 eV by the process, while the photoelectric yield was lowered with CsI films thicker than about 200 Å.

The Cs-CsI-Cs techniques were then applied to polished GaAs crystals with no success. Neither the work function nor the photoelectric yield were as good as that for simple cesiated GaAs. Surface contamination, which has plagued workers on similar problems, is suspected of poisoning the low work function. The contamination problem will be circumvented by using a vacuum cleaved GaAs sample.

In the measurement of photoyield from pure silver samples, a peak was discovered at 3.9 eV, which is well below threshold. Since this corresponds to the plasmon energy, it was proposed that the peak is due to multiple excitation with a plasmon intermediate state. It was found that the photoyield at 3.9 eV varies linearly with intensity. Also, no increase in the photoyield was found when the sample was excited by an auxiliary electron beam. Therefore, it is concluded that the peak below threshold results from a simple photoexcitation.

Gallium-Arsenide Statistics Tube

The efficiency of the electronic optical system has been measured to be greater than 95%. An oxygen source is being prepared and will be tested early next month.

Several quadrupole gas-analyzer problems have been solved, and the gallium-arsenide crystal-heating system has been modified and checked out.

General Techniques

Plexiglass and cement transmission measurements have been temporarily suspended to acquire techniques for cataphoretic deposition of lanthanum boride and alumina on heater filaments.

Rhenium filaments coated with lanthanum boride are very useful as low temperature emitters for ionization systems, while alumina sintered to tungsten provides electrical insulation for high-temperature filaments used in the proximity of conductors. Both of these types of filaments were needed for the GaAs statistics tube.

B. Magnet Research

Short-Sample Tests

The Airco samples have been tested to obtain their short-sample characteristics. Two of the samples were cylindrical with twisted and nontwisted superconductors. At 65 kG, they both carried a current of 3500 A in stable mode. When shaped into a configuration of .25" × .375", the conductor carried a current of 3100 A at 65 kG. This conductor appears to be adequate for the conversion of the bubble chamber magnet. We are expecting the 1200 ft conductor in May, and preliminary preparations for coil winding have been undertaken.

Thermal Conductivity and Electrical Resistivity of Niobium

We have obtained to date thermal conductivity data from 1.5 to 6°K with and without an external magnetic field of 6 kG.

Magnetization and Susceptibility Measurements

A series of 1/8" diameter, 2" long, niobium rods will be obtained in order to study susceptibility and the H_{c1}, H_{c2}, and H_c, as well as Maki's parameters as a function of temperature and impurities. The test equipment has been prepared, and a few preliminary measurements at 4.2° comparing susceptibility and magnetization data have been performed.

Magnetic Field Investigation

The SLAC program NUTCRACKER has been improved from Version III in order to accommodate odd shaped coils and iron in two-dimensional configurations. Also, a double-precision calculation has been incorporated to determine the magnetic field of high homogeneity coils. The effect of iron in high-field magnets was investigated, and a summary of this work is given in a paper to be presented at the Third International Magnet Conference under the title, "High-Field Magnets with and without Ferromagnetic Return Yokes."

Superconducting Magnet Tests

A report* summarizing our work with the 100-kG, 4.5-MJ, SLAC-Max Planck-Vanderbilt magnet is completed. In this report, problems encountered with a system of concentric and eccentric modules are treated in detail.

C. Conventional Data Analysis Activities

Maintenance

Vanguard Measuring Machines. Machine "MA" returned to service with factory reconditioned encoders. This machine was down for 2-1/2 months waiting for encoders during which time the engine, film transport, and keypunch were overhauled. Machine "MC" is now in the technicians' shop undergoing the same treatment while awaiting one encoder which is at the factory for reconditioning. This machine is expected to be returned to service in mid-April.

NRI. Home group construction on NRI updating is 90% complete. As soon as prewire-wrapped IC boards are received, modification of the second machine will begin. Design of the new NRI card reader interface is started. The old unit will be available as backup.

Spiral Reader. A new AGC card, using an IC multiplier, is being constructed. This card will have a wide background range and should be able to do a precise scaling of the pulse height.

Programming-Hummingbird

After a trial run of the Hummingbird on the UCRL(B)-SLAC cosmic ray experiment, production was stopped for program improvements. The processing rate of 700 events/hour was satisfactory, but the fraction (15%) of incompletely analyzed or "unresolved" events was too high. Changes are being made which may reduce the fraction of unresolved events to 5% or so.

Scanning and Measuring

In January about 420,000 frames were scanned in 2600 man-hours; 34,000 events were measured in 3000 man-hours. The breakdown of events measured by machine is as follows:

NRI System (5 tables in operation)	19,366 events
Hummingbird — not in operation during January	0 events
Spiral Reader	6,100 events
SPVBs (one machine in operation)	2,100 events
Vanguards (two machines in operation)	6,200 events

*H. Brechna, "Testing of a large-volume, 10-T, composite superconducting coil system," Report No. SLAC-TN-70-1, January 1970.

The increase in the number of events measured on the NRI system compared to the December work was over 30%; this was mostly due to a decrease in downtime on the 6020 computer from 36% in December to 16% in January.

During February 330,000 frames were scanned in 1900 hours; 33,000 events were measured in 2600 hours. Nearly 14,000 of these events were measured on the six machines in the NRI system. The Spiral Reader produced 8700 events in 220 hours. Presently both operational and maintenance personnel are being trained on the Spiral Reader, since it was recently turned over to CDA. This will probably limit the number of hours available for production work during March, but by April we expect to have a significant increase in the production hours on the Spiral Reader. The other automatic measuring machine, the Hummingbird, was used this month on a trial production run on cosmic ray film. The 20,000 events measured in this test run are not included in the totals given above.

During March 450,000 frames were scanned in 1900 hours; 40,000 events were measured in 3000 hours. About 22,000 of these events were measured on the six NRI tables; this is significantly more than the preceding month. Part of the increase is due to a simpler event type being measured on one of the experiments, and part of it is due to the fact that the EMR computer that drives the NRI tables was down only about 13% of the time, compared to 26% in February. Spiral Reader production increased by about 35% in March; in February 8700 events were measured in 220 hours as compared to 12,050 events in March in 335 hours. This increase is a direct result of the increased number of hours used for production, which is a consequence of better operational and preventive maintenance scheduling.

D. SPEAR Activities

Main Magnet System

This quarter the final design criteria for the standard bending and quadrupole magnets have been established. Working drawings are being prepared for release to the shop. It is presently intended that we shall build one prototype bend magnet.

Preliminary magnetic measurements of the model sextupole magnet show satisfactorily low harmonic content. The model pole pieces have been shifted into an asymmetric arrangement and additional measurements have been made. Even though the poles have been shifted 1/16", the harmonic content of the field is still within tolerance. These measurements confirm theoretical studies made

on the computer. The computer program can now be used to predict the "best" geometry for the pole and the maximum tolerance to pole shifting.

Vacuum System

Aluminum extrusions completed 20 thermal cycles from room temperature to 200°C with no indication of permeability to helium. Sensitivity of the leak detector was 2×10^{-10} standard cc per second of helium. The base pressure of three 33-foot extrusions after bakeout with one eight-liter-per-second ion pump is on the order of 5×10^{-9}.

Tests continued on aluminum diaphragms. Thermal testing is currently in progress, along with mechanical cycling. Ribbing tests continued on the 33-foot extrusion and appear promising. Testing for flanges from 2-3/4" OD to 8" OD was completed this quarter.

The prototype distributed sputter ion pump has been fabricated and assembled and is currently being placed within a 12-foot test extrusion for vacuum pumping speed measurements. Speed measurements should take place the first week of April.

Electron desorption tests will take place in April. Two aluminum test chambers have been fabricated for this purpose.

Radiofrequency System

The solid-state rectifiers have passed operational tests in a transmitter. A rearrangement of the air flow in the cooling system of the prototype transmitter has insured that, at full load, the rectifiers will operate at temperatures which give 100 percent of the manufacturer's specified characteristics. Also, the rearrangement results in only one exhaust air duct per transmitter.

The drawings for the 42.35 MHz prototype cavity have been completed and released to the fabrication shop.

Beam-loading simulation studies are being performed on the 47 MHz cavity built for the earlier storage ring R and D program. The probable effects of higher order cavity modes on beam stability are being investigated.

Beam Transport System

The design of the six-degree bending magnets has been modified per the review committee recommendations plus changes necessary to fit the stand design. Preliminary design of the 3-5/8" × 3-5/8" quadrupole magnets is complete.

A meeting has been held to review the design of the collimating slits, and the engineering layouts have been approved in principle. Some modifications are

required to accommodate greater momentum spread. Design of a single-screen ZnS profile monitor is complete. It is a simplified version of the existing beam switchyard monitors and will handle all profile monitoring requirements except for the monitor in the splitter complex.

Injection System

On February 12, 1970, a test run demonstrated for the first time the SLAC accelerator's positron production capability under conditions closely approximating those necessary for injection into the SPEAR 1/2 configuration. Using the E.G.&G. pulser in connection with the grid on the primary gun, peak currents of 3.6 mA of positrons with pulse lengths of 7 nanoseconds were produced into an analyzed momentum spectrum of ± 0.5 percent and into a phase space approximately one-half that of the injection aperture of the ring. It is expected that the peak current of the gun may be increased by another factor of two. This superior performance at a positron energy of 1.5 GeV, a beam energy that had never been tried before, implies that SPEAR 1/2 may be filled with positrons in the one-bunch mode without the necessity of having to build a low-frequency rf rebunch system. The filling time of the ring to a 1/2-amp circulating current, extrapolated from this test run, will be approximately three minutes.

Instrumentation and Control System

General system design continued during the quarter. A prototype of the magnet power supply controller was built and tested. Prototypes of the several versions of the digital-to-analog converters for magnet control were started as were prototypes of the synchrotron light monitors and the beam position monitors. A new version of the current-to-frequency converter for the ion pumps, capable of handling the short-circuit current of the ion pump power supplies, was built and tested.

Two versions of an electronic relay were built and tested satisfactorily, one for ordinary relay replacement and the other for high speed (> 1 MHz) data transmission. A suggestion to use voltage-to-frequency converters to integrate the output of flux loops on the magnets (thereby producing fast magnet-field readback during ramping) is being tested.

V. PLANT ENGINEERING

The relocation of the SLAC Library within the Central Laboratory was completed during the quarter and the new facilities were placed in use. The former location on the third floor is now being modified for office occupancy.

Field work is in progress on a number of projects, the principal ones being as follows:

1. Central Utility Building Expansion — two 50-ton chillers are on hand and a ten-foot westward extension of the building to house them has been started.

2. Modifications of Radioactive Water Services — this installation in the end station "B" target room is well along and should be completed during the planned outage of the accelerator in April, 1970.

3. End Station "A" North Wall — concrete blocks have been procured for an 800 gross square foot triangular extension of the shielding wall. Installation is scheduled for early in the next quarter.

4. Front Entryway Improvements — construction of the information booth is under way. Most of the landscaping and the exterior lighting at the new entryway are in place.

5. Upgrading of Buildings 102 and 104 — incorporation of offices, rest room and work shop space in these research yard buildings is 75% complete.

6. Utility Improvements — construction of two improvement projects in the research yard has started. One of these extends the utility tunnel east of end station "B" approximately 90 feet. The other is an extension of the 4160 volt electrical service to buildings 102 and 232. Both jobs will be completed in the next quarter.

Preliminary work on a number of items, as stated below, is under way:

1. SLAC 230 kV Tap Line — consideration is being given to the deadending of pole structure number 35 as a preventive maintenance measure.

2. Neutral Particle Facility — this will provide a 35-foot deep steel-lined pit approximately 240 feet northeast of beam dump east in the end station "A" beam line (Experiment 56 — Search for Unknown Sources of Neutral Particles Having no Strong Interactions). Preliminary design has started.

3. Building Number 403 Extension — two additional bays (600 square feet) are to be added to this research yard facility. The project has been scoped and procurement will be initiated in April.

4. Superconducting Accelerator — an engineering study for the conversion of the SLAC two-mile machine is being continued.

Services to other SLAC groups were provided throughout the quarter, chiefly in the extension of utilities and the adaptation of buildings in the research yard for changing experimental requirements. The ongoing program of plant utility operation and minor modifications to buildings as a general service to SLAC was continued.

VI. KLYSTRON STUDIES

A. Development

1. High Power Klystrons

Litton Subcontract. The delivery and acceptance of Litton tubes continued satisfactory during the quarter. Litton has begun work on tube improvements to allow operation at 270 kV. Arrangements were also made with Litton to allow for operation of some of their tubes under the present warranty contract at beam voltages in excess of 250 kV. This operation will enable us to acquire some additional experience for high level operation from which to determine the budget implications of changes in the operating level of the whole machine.

RCA Subcontract. RCA has delivered some additional tubes for operation at 270 kV, 30 MW. However, we have been unable to complete acceptance tests because of lack of special lead and other accessories.

SLAC. Some work directed to an understanding of the oscillation problems which have been observed in the 21 MW tubes is continuing. Indications are that the main culprit is a mode at 6140 MHz in the third cavity which can transmit down the drift tube and excite modes at a coincident frequency in the gun package. The third cavity geometry in the new 30 MW tubes is substantially different and no serious oscillation problems have been observed to date with those.

Minor improvements are still being introduced in the design of the 30 MW tubes. One is the optimization of the drift length between cavities within the total length allowed by the permanent magnet; the second is a reduction in the output Q (from 19 to 17). The reduction in Q should further increase efficiency at the higher operating voltage; its main purpose, however, is to decrease the output gap voltage and hopefully eliminate the rf output breakup which has been observed on some tubes when the output exceeds 33 MW.

Figure 4 gives the results obtained with the best tube designed and built to date. It indicates a maximum efficiency of 50.8% at 260 kV, and a power output of almost 38 MW at 270 kV.

2. Superconducting Accelerator Klystrons

The first klystron for potential use with a 2856 MHz superconducting accelerator has been built. The tests were terminated during the quarter and the tube returned for rework after the cathode was accidentally misaligned during tests. The tube was initially tested at very low duty using the test equipment available

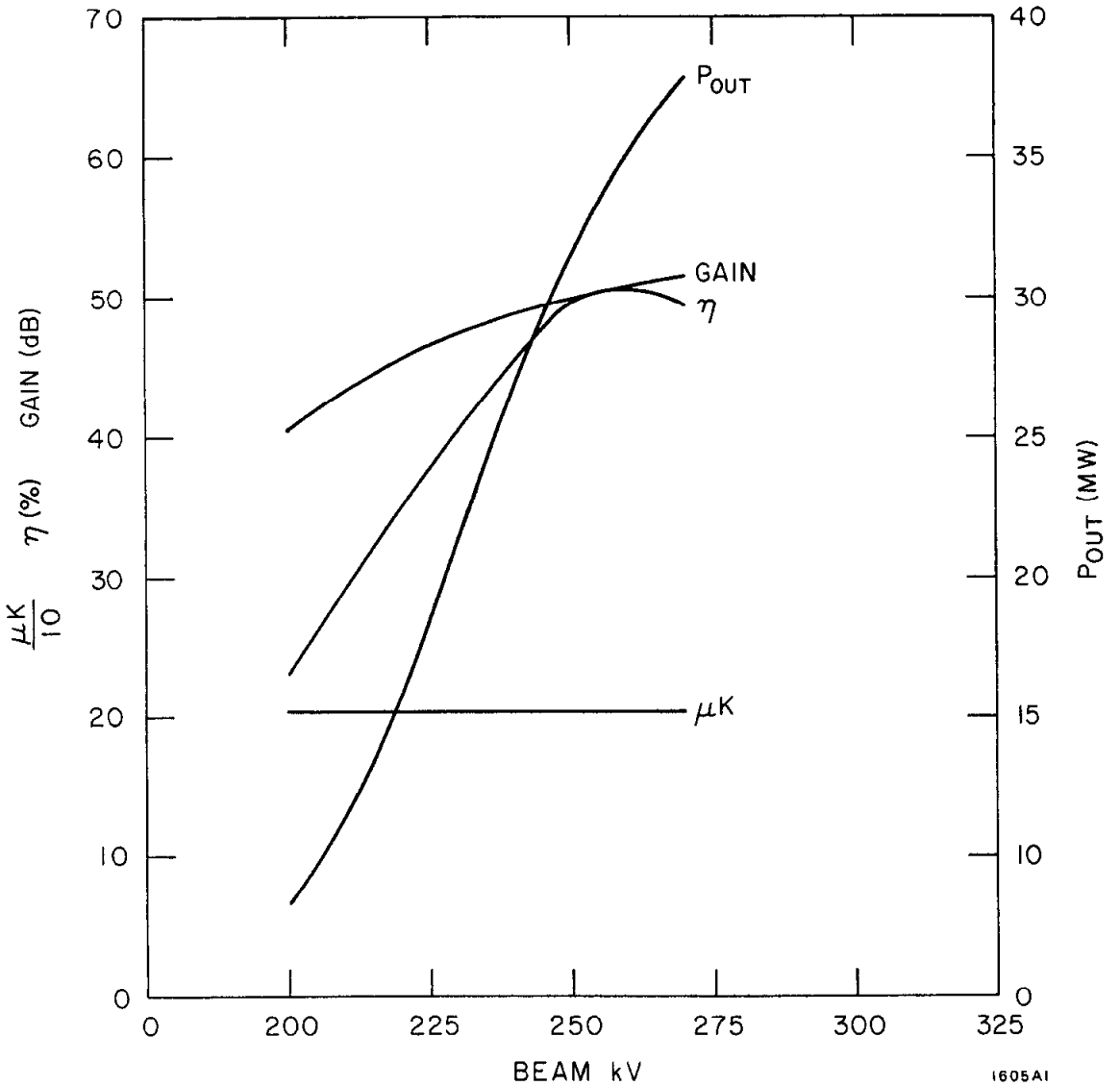


FIG. 4--Acceptance test results with best tube designed to date.

for the driver amplifier klystrons. Operation in both electromagnet and permanent magnets was very satisfactory with an efficiency of the order of 30%. All high duty ratio tests to date have been performed in electromagnet only. A maximum efficiency of 34% has been observed at 20 kV; the efficiency appears to peak near 22 kV. The maximum power output is achieved at 2860 MHz. Because of leak during the bake and conversion cycle the cathode activation was not as clean as desirable and emission from the focus electrode of the gun obscured many of the results obtained.

The only thermal problem observed to date has shown up as excessive temperature of the output coupling loop and coax line at high duty cycle. An average power output of 3 kW appears to be the limit of the present design. Redesign with improved cooling is being undertaken.

The 2 CW diodes are still in test, one with an oxide cathode, the other with a dispenser cathode. They have operated approximately 1300 and 2600 hours respectively. Neither shows signs of emission slump or arcing problem.

3. High Power Windows

During the quarter four SLAC klystrons failed due to cracked windows in accelerator operation. Three of these were installed in sectors operating at 265 kV. Of these three, two were on tubes built prior to the decision to operate at more than 250 kV. One was on a tube built last year and intended for operation at the higher power level. It is not certain that the failures actually did take place as a result of the change in operation level (it is suspected that one of the windows had actually cracked more than a year ago). However, a general trend of increased window temperatures at the higher operating level in tests has caused sufficient concern to require evaluation of several new programs of window improvements.

Two main approaches are being taken for further improvement of window life. One is the reduction of total window heating. It is suspected that the main cause of heating at the present time is the titanium coating, and a maximum effort will be put on further coating studies. However, we will not neglect such other areas as seal loss heating and dielectric loss in the ceramic. The other proposed method of decreasing the number of window thermal failures is by increasing the heat transfer from the window assembly. Marked improvement has already been achieved by water cooling the waveguide on either side of the window. We are

not proposing at this time to water cool the edge of the window directly because this approach would introduce, on a long term basis, the possibility of water leaks in the output system. Additional improvements are being considered by increasing the radiation and convection characteristics of the window assembly.

4. Driver Amplifier Klystrons

A new cathode heater package has been designed to increase filament efficiency. Focus electrode emission which has appeared on a number of tubes should be decreased by the new package and a slightly different conversion schedule on bake. Some tubes have experienced magnet interchangeability problems in the crucible magnets. A careful review of the magnetic field and investigation of the difference should resolve the gain problem which has been observed.

5. Special Problems

RF Loads. All components for an rf load of new design have been machined and we expect the load to be assembled and tested early next month.

Computer Program. Work with the klystron computer program obtained from Los Alamos Scientific Laboratory has continued; there appears to be disagreement between computer and actual results. Checks of the beam loading and cavity impedance formulas, especially with respect to relativistic corrections, will probably resolve the discrepancies.

In addition material has been received from Wessel-Berg on large signal klystron theory. This material is being reviewed to adapt it to computer use and give us valuable information as well as a comparison between the two programs.

B. Operation and Maintenance

The number of klystron hours reached a record of almost 360,000 during the quarter. However, we experienced 32 klystron failures which is also a record for a single quarter. The number of stations operating at 265 kV was increased to 32 early in February. There were six operating subbooster klystron failures this quarter.

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. 5 in which we have added the mean age of operating tubes and the cumulative hours average per socket since the beginning of operation.

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

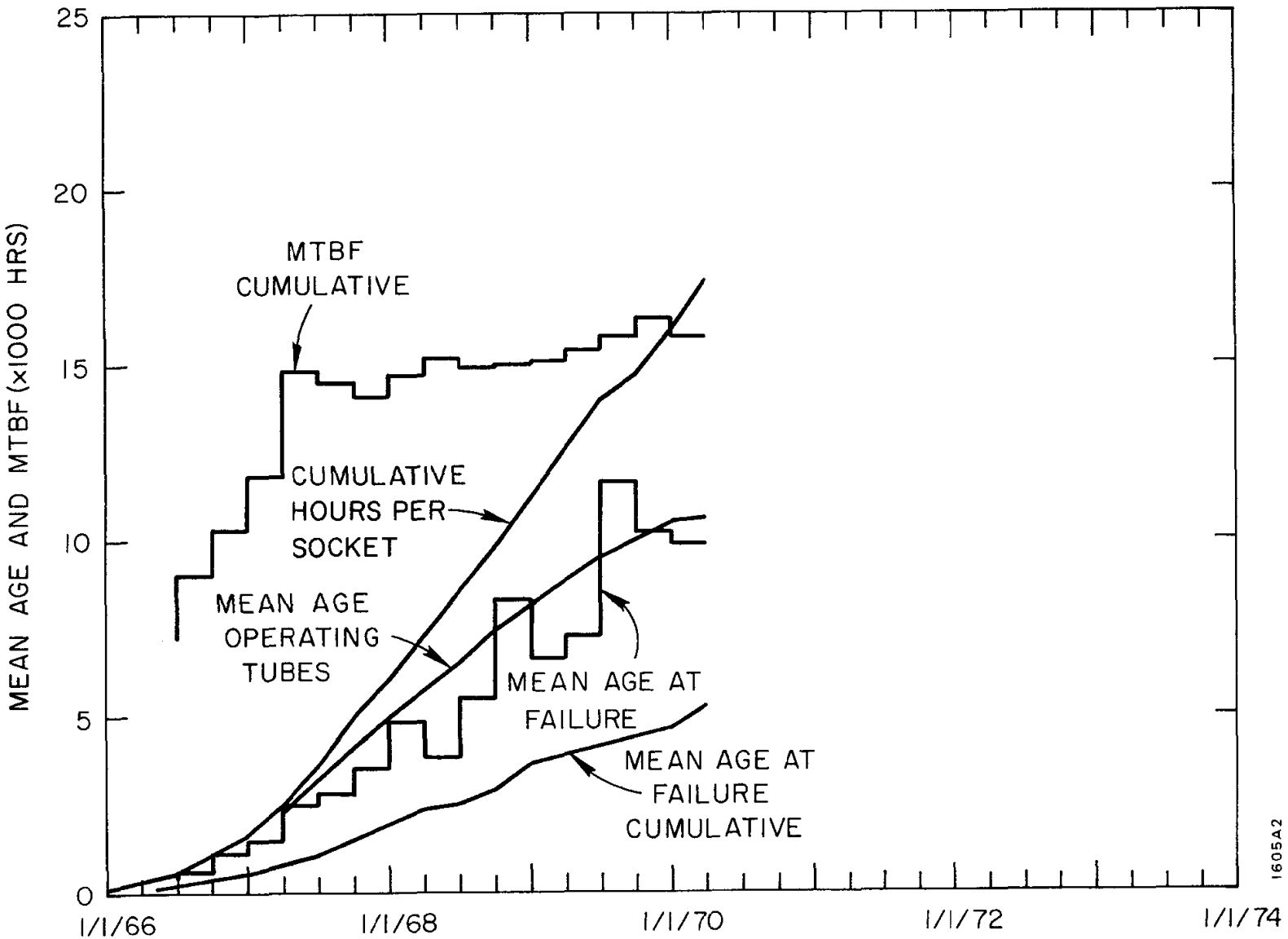


FIG. 5--High power tubes: cumulative MTBF, mean age at failure, mean age of operating tubes, and cumulative hours per socket, March 31, 1970.

The tube age distribution of both living and failed tubes for all vendors is shown in Fig. 6. For tubes now living the mean age is 10,700 hours and the median age is 13,000 hours. Forty-two percent of the tubes have operated in excess of 15,000 hours.

The data presented in Fig. 6 has been analyzed to determine the failure and survival probability. The results are shown in Fig. 7.

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 70% of the average MTBF. Six out of 32 failures (18.5%) occurred at high operating level stations, which comprise 13% of the whole machine. If the trend continues during next quarter a reassessment of the cost of high voltage operation should be conducted.

The causes of failure have been analyzed again and are tabulated below by vendor by percentage.

OPERATION FAILURES

Causes of Failures	RCA	Litton	SLAC
Windows	65 %	20 %	27 %
Vacuum (including droop)	20	23	23
Overcurrent faults	7	50	25
High voltage seal	6	2	13
Cathode (heater emission)	1	4	11
Miscellaneous	1	1	1
Total	100 %	100 %	100 %

2. High Power Klystron Maintenance

Increased emphasis on accelerator beam stability has resulted in increased emphasis on klystron power output stability. As a result, tubes with questionable performance were reviewed carefully and it is probable that the substantial increase in window failures experienced during the quarter is due at least in part to this more careful check into power output instabilities. Whether because of this additional emphasis in stability or for other reasons the average rate of klystron replacement rose from 1 to 1.6 per 10,000 klystron socket hours between last quarter and this quarter.

The operating experience for all high power klystrons since the beginning of operation is shown in Fig. 8.

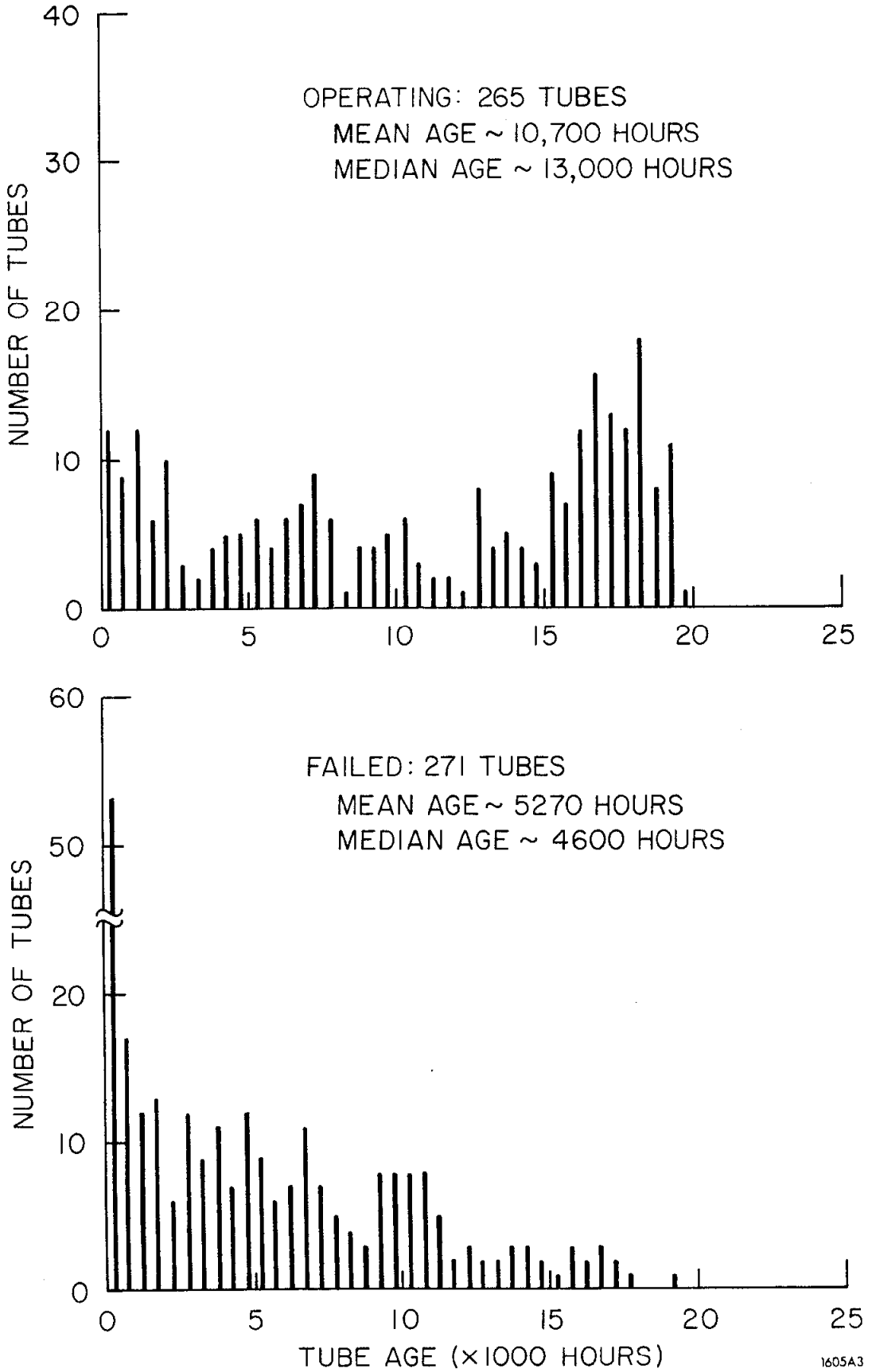


FIG. 6--High power tubes: tube age distribution of both operating and failed tubes, March 31, 1970.

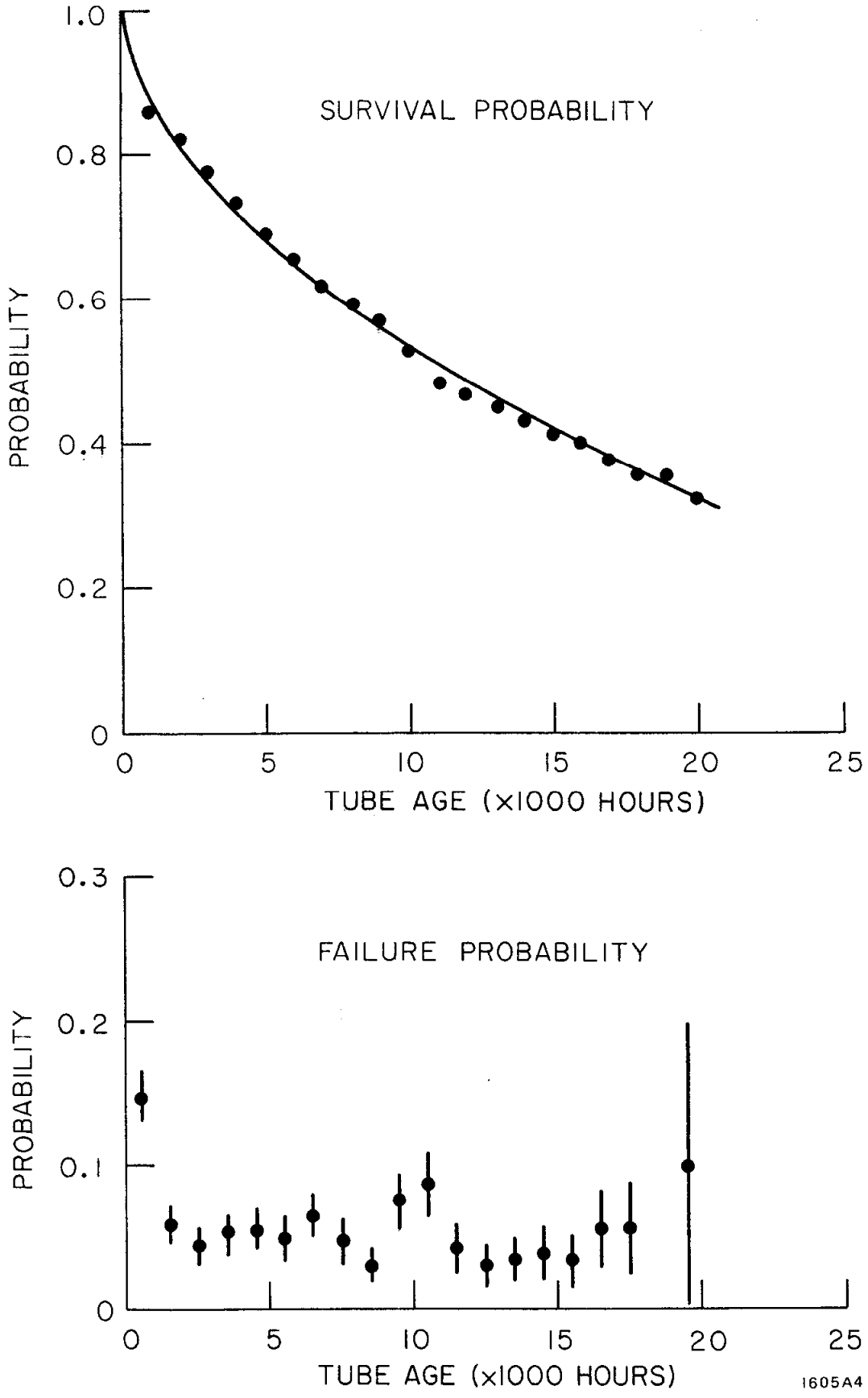


FIG. 7--High power tubes: survival and failure probability, March 31, 1970.

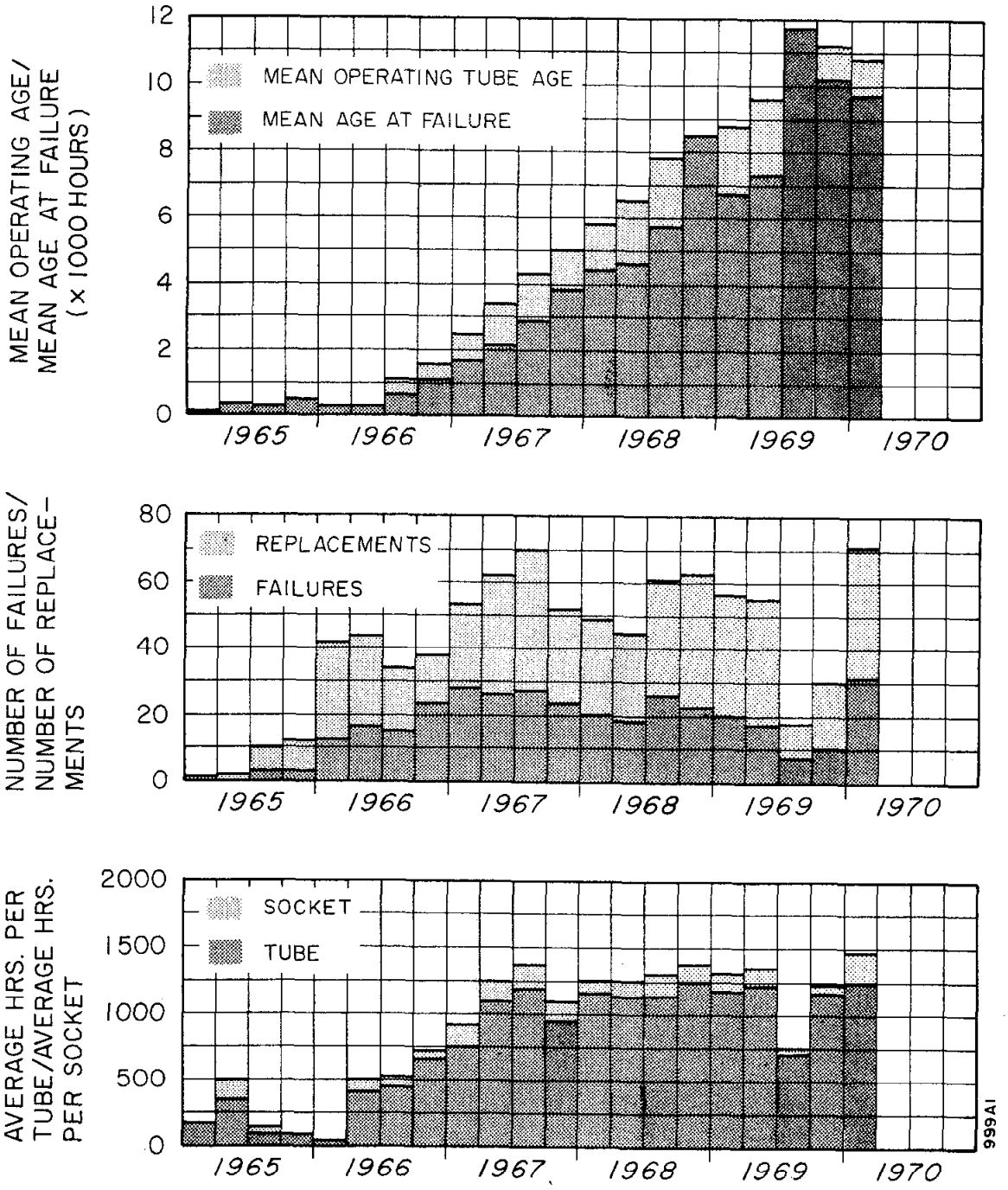


FIG. 8--High power tubes: operating experience through March 31, 1970.

3. Driver Amplifier Klystrons

Of the six driver amplifier klystron failures during the quarter four were Eimac tubes with a mean age at failure of approximately 15,000 hours and two were SLAC with a mean age at failure of 1300 hours. There are still six Eimac tubes in the gallery and three in the test laboratory. All remaining Eimac tubes have a mean age in excess of 23,000 hours with a minimum age of 16,500.

The SLAC tubes have now accumulated sufficient operation to give us some meaningful analysis on the failure rates. The results are given in Fig. 9 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 1000 hours of operation and 6% per 1000 hours thereafter. This is very similar to results obtained for the high power klystrons.

4. Main Booster Klystrons

A main booster klystron in station number 2 failed with an open filament during the quarter. Several failures occurred within the focus coil power supply of station no. 1. Both problems were overcome and little loss of accelerator operating time resulted.

Because of beam instabilities observed during the quarter, particularly when very narrow slits are used, we are continuing a record of the power output of the main booster stations and drive line system. These records do not show instabilities exceeding .1 db. However, there appear to be combinations of operating parameters of the main boosters which can result in amplitude modulation in the output at a frequency of 1 Hz (within one order of magnitude). Some investigations have been started to obtain and achieve the best possible overall stability, and discussions will be undertaken with the tube vendors to insure that we are obtaining the best possible tube.

5. Vacuum System

There were no major vacuum problems during the quarter. Some ion pump instabilities have been observed at stations 15-1 and 15-3. A leak has been detected at station 15-6 and if the leak can be successfully repaired we expect the pump instabilities to disappear.

Otherwise a normal amount of maintenance was performed during the quarter.

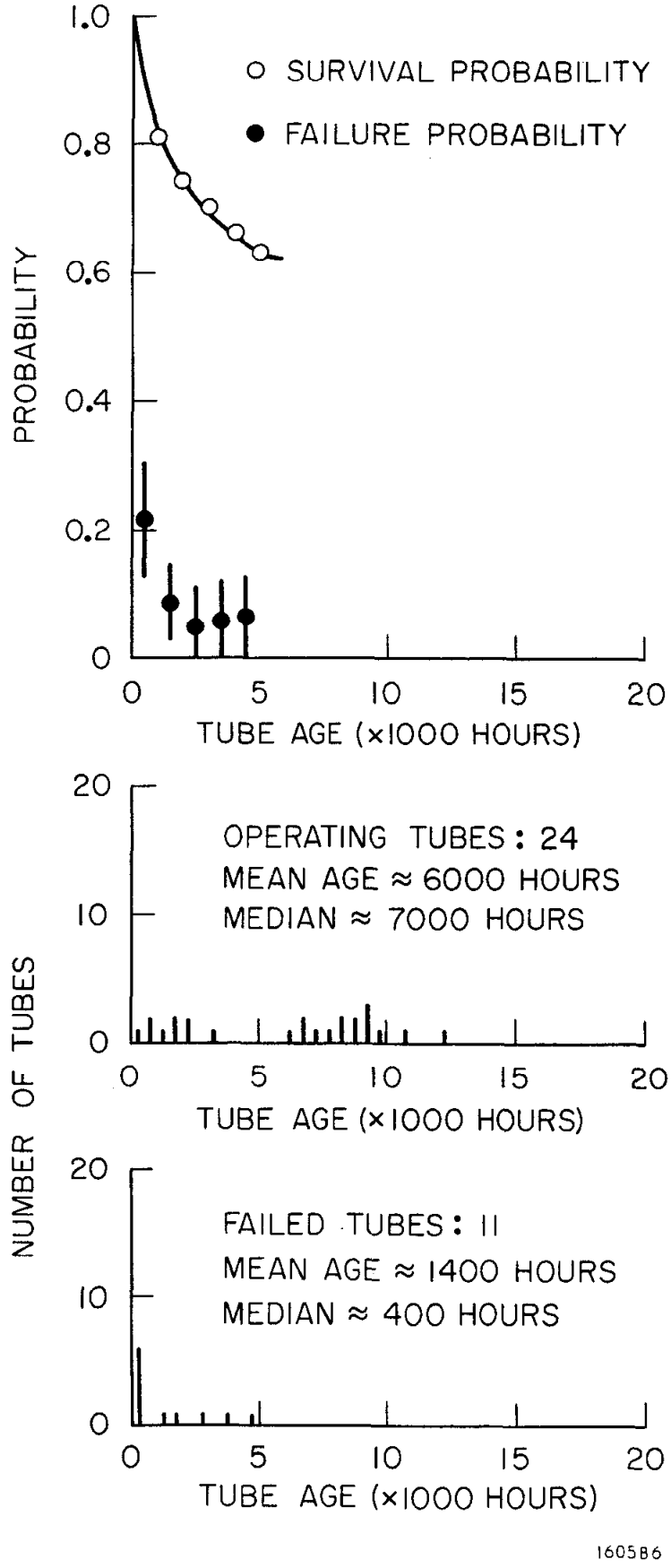


FIG. 9--Driver amplifier tubes: age distribution of operating and failed tubes, March 31, 1970.

VII. ACCELERATOR ELECTRONICS GROUP

April 1, 1969 - March 31, 1970

A. Main Modulators

These units are operating satisfactorily with an average of 17,500 hours recorded running time. We have improved them in various areas over the past year which has increased reliability and reduced maintenance. We have watched our large, expensive components for indications that they might be reaching end-of-life but have not noticed anything serious other than the usual problems we had last year. Those problems are as follows.

1. Pulse Capacitors

These units continued to be our most troublesome area in the modulators. The old original capacitors are continuing to fail with a rate that increases steadily with time. We have instituted backup source programs over the past several years and have procured new, improved capacitors from various manufacturers. Nearly all those units have been installed on the machine in place of the old units so the proportion of old capacitors to new is steadily dropping. We now have about 50% old capacitors and 50% new, improved ones.

We had a total of 789 capacitor failures from April 1, 1969 to March 31, 1970 as compared with 644 in the same period the previous year (22.5% increase). The average monthly failures were as follows:

Period	Average failures per month
7/1/67 to 3/31/68 (9 months)	46
4/1/68 to 3/31/69 (12 months)	54
4/1/69 to 3/31/70 (12 months)	66

From the above chart it is apparent that our failure rate is increasing in spite of the fact that we are running less hours this fiscal year than last and the number of old, original capacitors on the machine is steadily decreasing.

Figure 10 shows the percentage of survival against age for those capacitors.

At one time during the past 12 months we ran out of new spares and had to install old, used ones. They were useful in keeping the accelerator running but we are experiencing high failure rates among them. It appears they are only good for another 1000 to 2000 hours. Therefore, we must continue to order new capacitors to keep the machine running.

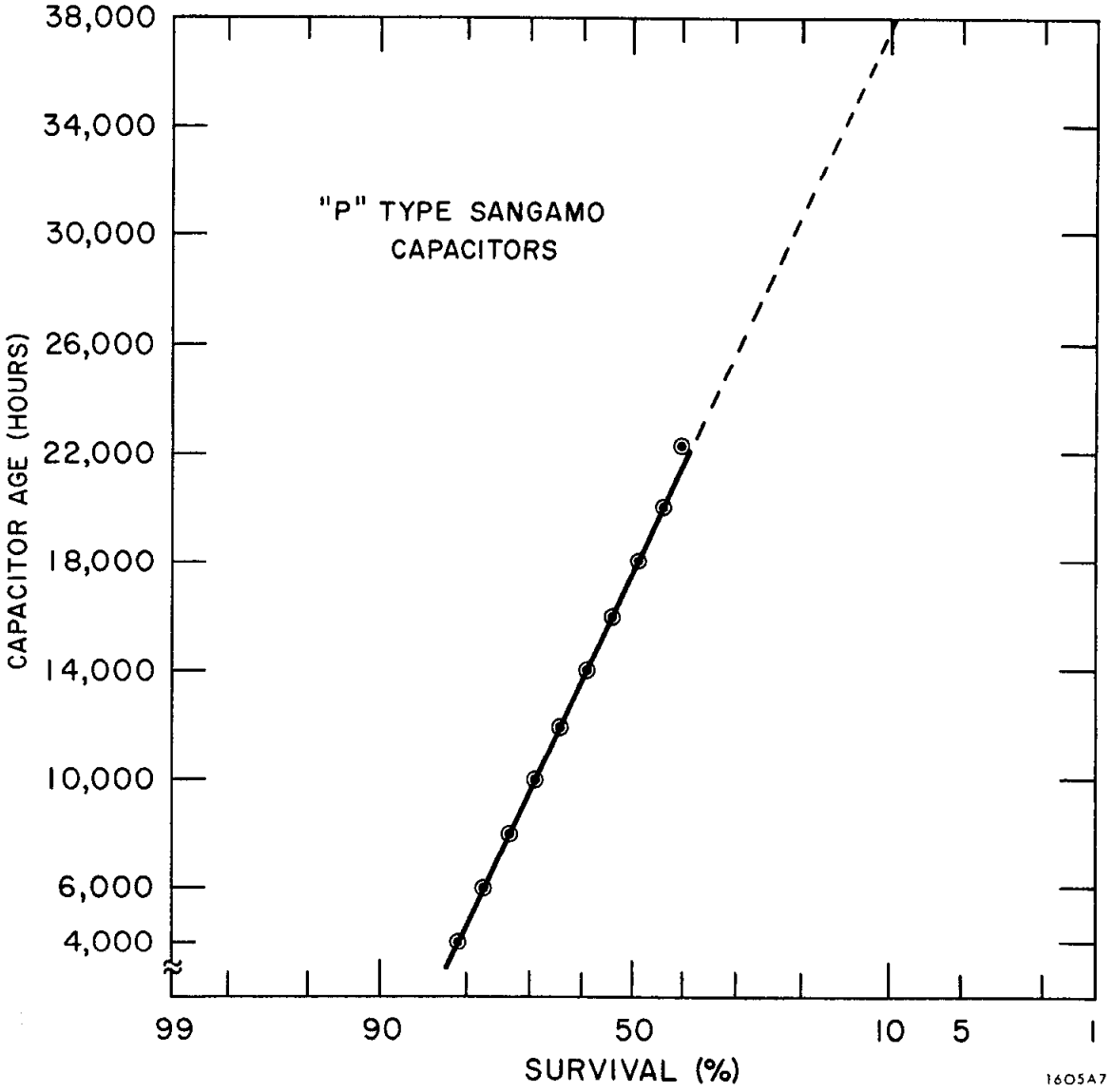


FIG. 10--Pulse capacitors: percentage of survival versus age.

2. Rectifier Transformers and Charging Chokes

We continued to have problems with some of these units. Out of 245 operating we had 50 transformers that developed oil leaks around the high voltage bushings or had cracked ceramic insulators around the low voltage studs. This compares favorably with 60 during the previous 12 months. These units were repaired in our shop and put back on the line.

We had 21 failures among the 245 charging chokes running on the accelerator. The main problem was corona damage in the windings causing gas formation and slightly swollen cases. In some cases we had turn-to-turn shorts which resulted in overheated units and, of course, faulty modulator operation. One choke got so hot from this type of failure that it exploded and caused a small fire. In order to prevent such occurences and help locate faulty units, we installed an over-temperature interlock switch on the case of each choke and tied it into the over-temperature circuit in the modulator which, in turn, turns off the modulator in case of an overheated choke. These problems are internal and necessitate re-building the units. All 21 were rebuilt by a local company.

Another problem caused by failed charging chokes is de-Q'ing SCR failures. The faulty chokes can overvoltage those silicon controlled rectifiers (SCR's) and cause them to fail prematurely.

3. Main Rectifiers

Thirteen main rectifiers failed during the past twelve months as compared with 24 the previous 12 months. It appears we are weeding out the weak ones.

As in the past, the mode of failure is a diode on one of the 60 cards making up a complete rectifier which opens up and arcs with subsequent heating to the point where a small fire develops. The fire in turn overheats the temperature sensitive wires placed over the rectifiers which, in turn, removes high voltage, stops fans and turns in an alarm. In all cases the fire extinguishes by itself and only two or three cards of the 60 are damaged. The damaged cards are replaced and the rectifier placed back in service.

Over two years ago we obtained 29 backup source rectifiers from several manufacturers for evaluation on the accelerator. They are still operating satisfactorily and since we have been able to repair the old units no further purchasing of such units has been necessary.

4. De-Q'ing SCR Assemblies

During the past 12 months we had 51 SCR assembly failures compared with 40 the previous 12 months. The distribution of failures is shown in Fig. 11. Most of the failures were among the old series-connected dual SCR circuits. We have been incorporating single SCR-diode circuits with improved transient suppression circuits in more and more modulators as the old units fail. They are proving more reliable and should result in decreasing failure rates; however, the charging chokes are getting older and are failing a little faster which tends to increase our failure rate among these units. It is not a bad failure rate considering the rest of the high power units in the modulator and the much higher failure rate we would have had if we used thyratrons to do their work.

Another improvement that was incorporated in the modulators during the past 12 months was a new mounting for the de-Q'ing load resistors. The old method often resulted in broken ceramic insulators and subsequent shorting between adjacent resistors. The new method places the weight on the insulators in compression rather than in shear and has eliminated the trouble.

5. Pulse Cable Assemblies

These units, which transfer pulsed power from the modulator cabinet to the pulse transformer tank, had 43 failures during the past 12 months, 13 of which were repairable.

The reasons for failure were erosion at the finger stock on the connectors and cable failure due to corona damage in the major dielectric consisting of layered polyethylene and silicon oil. The problem is that air pockets occur between the layers of polyethylene and the air in those pockets develops corona discharges which, in turn, deteriorates the polyethylene. In extreme cases the damage goes through all the layers and shorts out the cable.

During the past 12 months we obtained and placed on test seven new, improved, all-silicon-rubber cable assemblies. The major insulation in the cable is solid silicon rubber which if molded properly has no air pockets. The cable connector and other end termination are molded of silicon rubber thus making one solid void-free assembly. The cable for those assemblies was a short run and really not long enough to get the cable making machinery adjusted properly so the corona starting voltage was lower than we would like to have had, but after six months of running time on the accelerator they are still operating satisfactorily. In fact, the corona starting voltage actually increased during that time.

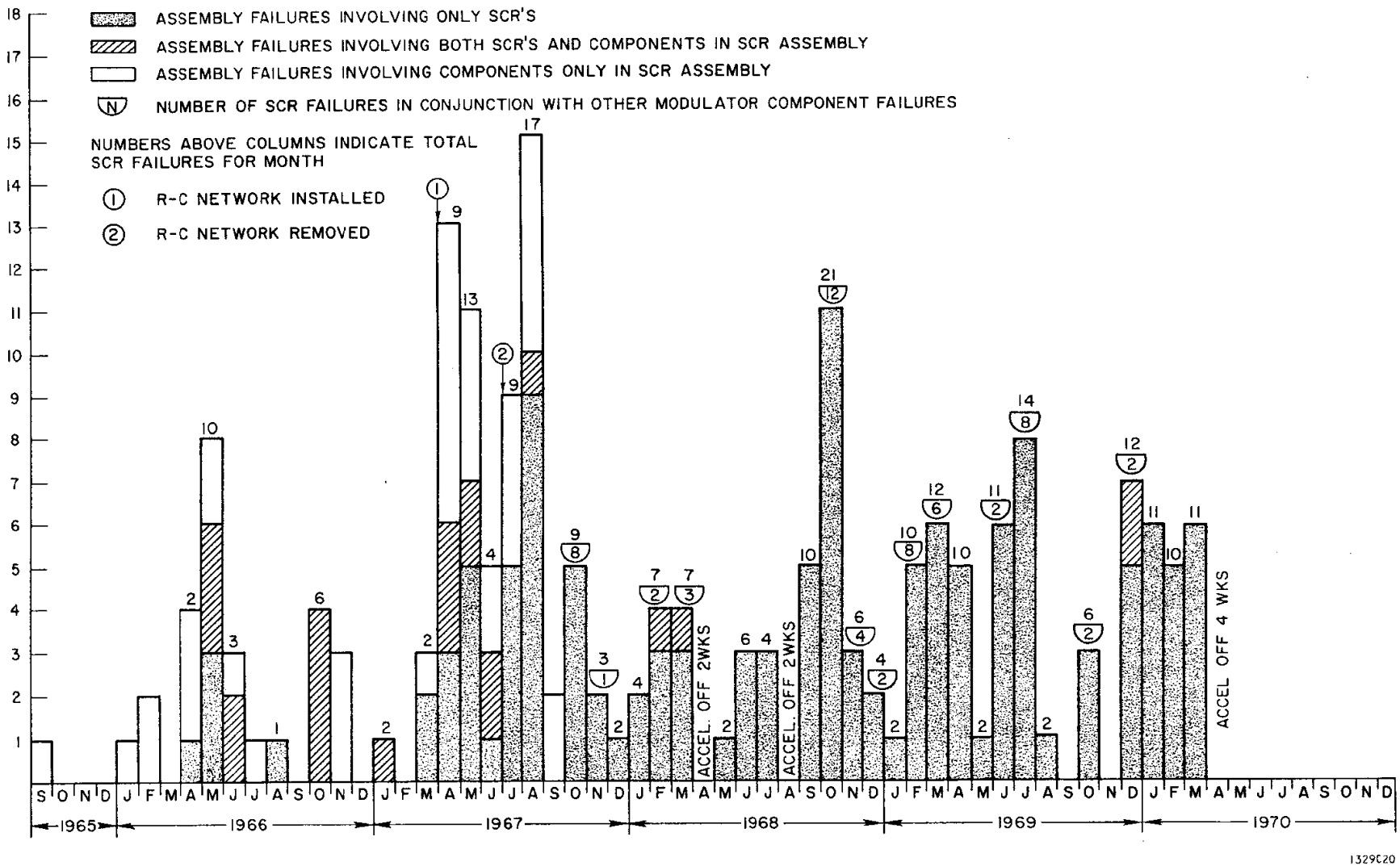


FIG. 11--SCR assemblies: failure distribution.

Our tests revealed two small problems. One was arcing at the inner conductor connection ring because the outer diameter of the ring was 0.005" too small. That problem was solved by plating the ring up to the proper diameter. Another problem was separation between the silicon rubber insulation and the inner shield connection ring. A design change in that area should solve the problem; however, it does not cause a problem during running because those parts are pressed together when the connector is made up in its socket.

6. Hydrogen Thyratrons

During the past 12 months Wagner Electric Company continued to be our main supplier with their CH1191; I.T.T. supplied the last of their KU275B tubes and swung into an improved version, the KU275C.

As reported last year, many of the KU275B tubes had short lives because they would occasionally go into sieges of kickouts, or faulting, which make their operation on the accelerator impossible. A few of them lived 8,000 to 10,000 hours but many of them died early giving them a low average life.

In order to produce tubes with longer lives, I.T.T. redesigned their cathode giving them 800 cm^2 of active surface. We received 88 and by the end of the quarter we had 29 running on the machine. The remainder were in spares awaiting sockets on the accelerator. We have experienced 11 failures among those tubes with an average life of 1270 hours. The average life at failure is increasing steadily, but it is too early to predict what it will be. The average age of those tubes operating on the accelerator is 2318 hours and increasing. There are a few of them that have 3000 to 4000 hours on them. Another year at least is needed to determine the average life of this new design.

Wagner, on the other hand, has an average life that climbed to about 8000 hours (averaged over 80 tubes that failed around December 1968) then dropped down to about 6000 hours (averaged over 50 tubes that failed around December 1969), climbed to over 9000 hours (averaged over 20 tubes that failed around February 1970) and dropped 4500 hours for the last ten tubes that failed this quarter. This is shown in Fig. 12, in which the lives of failed tubes are averaged in blocks of 10 (in the order of failure). This type of presentation still has some statistical variation in it but it is a sensitive indicator of what is happening to the lives of most recent tubes. Incidentally, the two points at 9000 hours and up, which seem so out of line, were as a result of a rash of very old tubes that happened to fail during that period. Figure 13 shows the average life of all the tubes failed

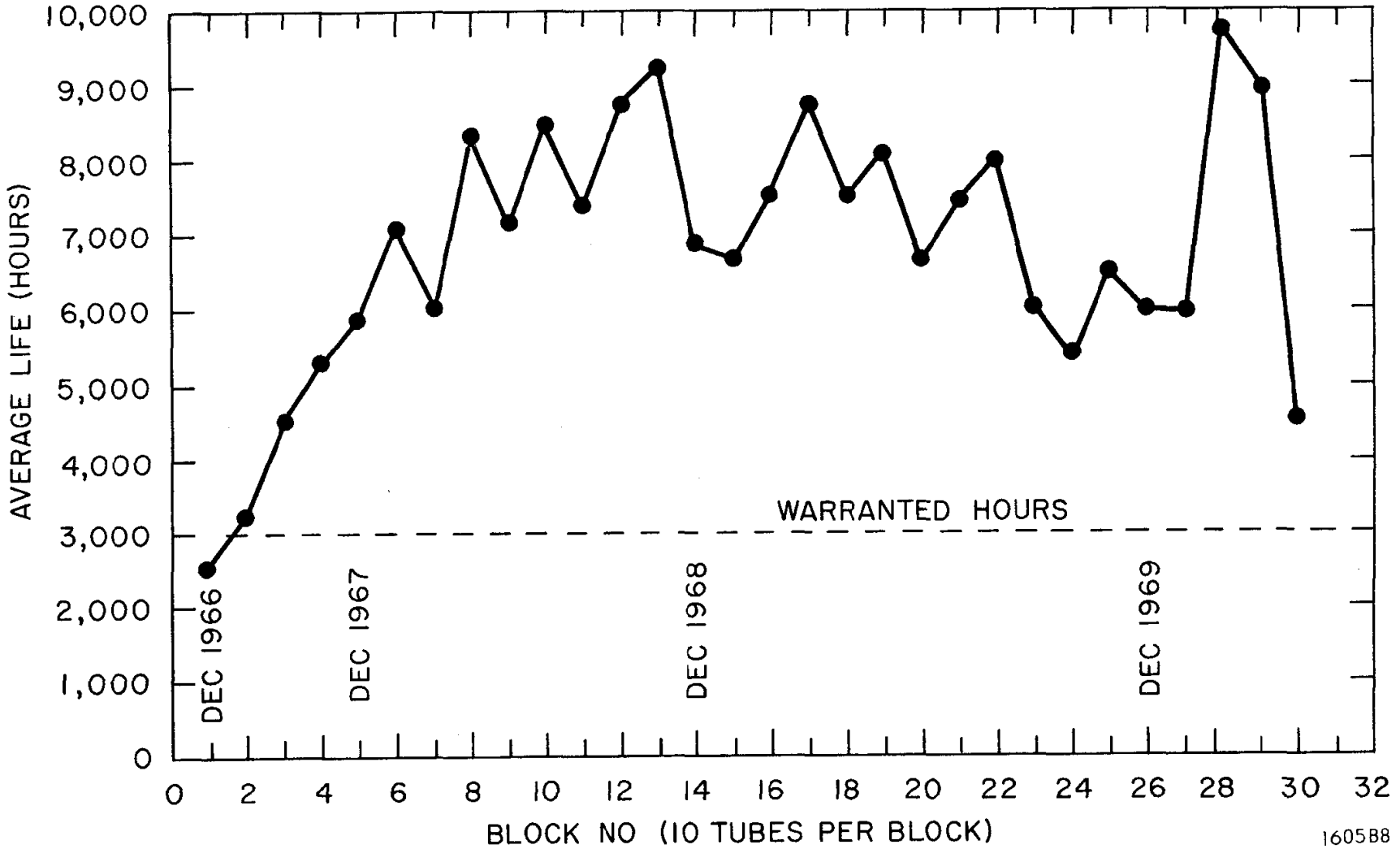


FIG. 12--CH1191 thyratrons: average life in 10-tube blocks, in order of failure.

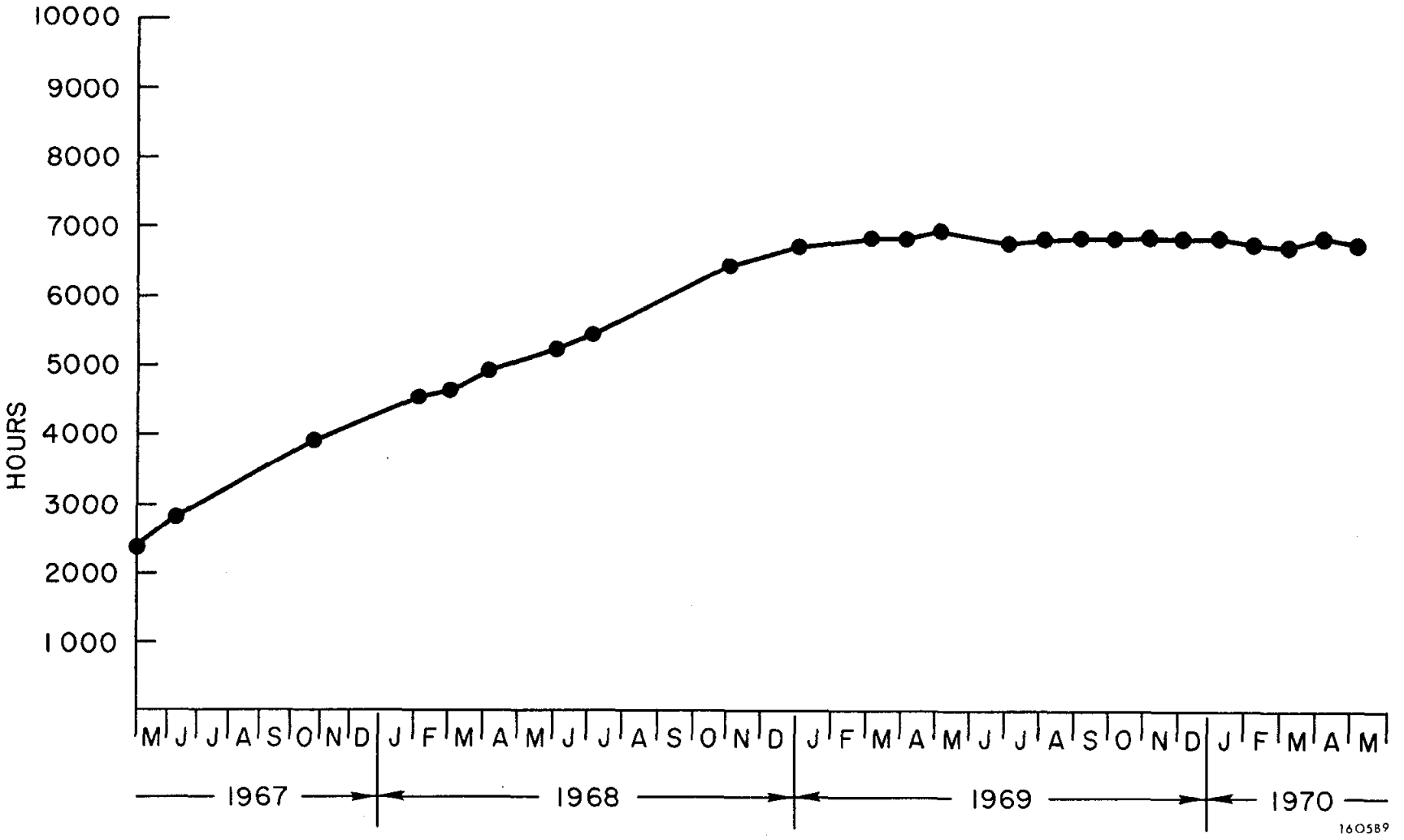


FIG. 13--CH1191 thyratrons: average life of failed tubes.

to a given point in time. It is interesting to note that the overall average life is about 6800 hours; however, the chart in Fig. 12 indicates a tendency toward shorter life for the more recent tubes. Another indication of this is in the chart in Fig. 14 in which the number of operating tubes is plotted against age. Here we see two blocks of tubes with none existing between 8000 and 12,000 hours. There seems to be an old generation that is dying off and a newer generation which has not yet caught up. Indeed, the longest lived thyratron on the machine died during this report period, serial number 35, with 19,255 hours on it!

We are doing everything possible to increase the lives of these tubes. One modification we made enabled us to feed as high a reservoir voltage to the old tubes as they required by simply connecting in series the outputs of two reservoir transformers which were originally put in the modulators for dual tubes. Another was to replace many of the old, faulty reservoir meters with new, more accurate ones so that we might more accurately range the tubes.

Another development that occurred during this period was an entirely new, larger tube, the CH1222. It was delivered by Wagner in December 1969. This tube was originally ordered for our 300 kV modulator work; however, depending on its life and cost it could serve to reduce the cost of operating our thyratrons. It has 2000 sq cm cathode area compared with 800 for the CH1191 and a 15 ampere average current rating compared with eight. It has been on life test four months and operates satisfactorily. Indeed, it has the longest time between kickouts or faults of any tube observed on the project (582 hours).

The small trigger thyratrons are running well with an average life of about 8700 hours. We would like to replace them with a semiconductor trigger system which should be less expensive to run. Work toward this end had begun at the end of the period.

7. Semiconductor Switch for Main Modulators

This project was reported on in our status report one year ago. At that time, we had been successful in running at full power briefly using four reverse switching rectifiers (R.S.R.) stacks in parallel but this test was terminated by failure of a large percentage of the devices under test.

We continued to work with Westinghouse, the manufacturer of the stacks of R.S.R.'s, but the work has been on a limited basis. Most of it has been on one stack at the same operating voltage as with four stacks but at 1/4 current (by a modification of the modulator circuit).

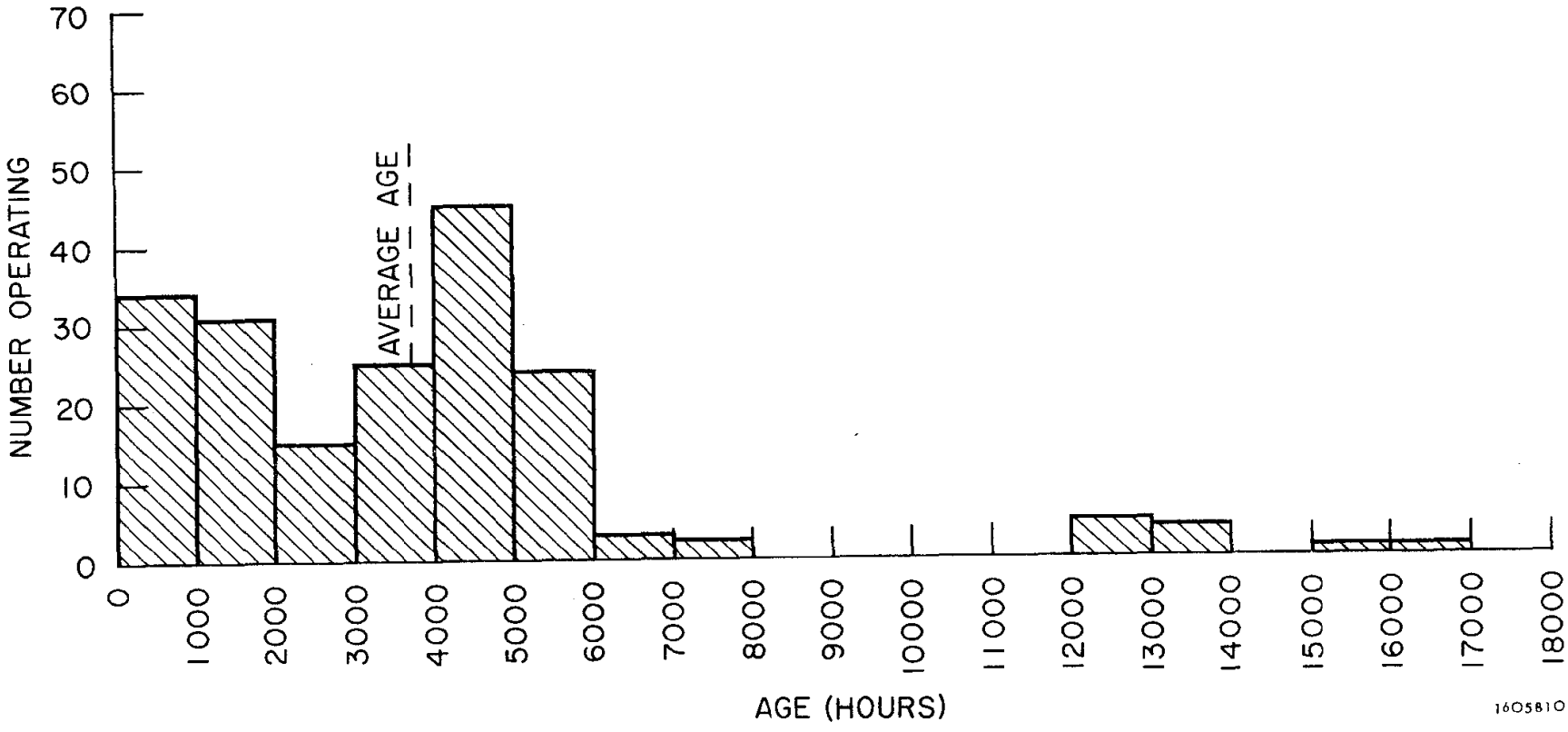


FIG. 14--CH1191 thyratrons: number of tubes operating at various high-voltage hours.

Another test was run last October which was not very successful. We got up to 30 kV on the pulse forming network (43 kV is full operating voltage) at which point the string of R.S.R.'s "hung up" (failed to recover between pulses). Twenty-two out of 92 R.S.R.'s were lost, probably because of unequal recovery times in the various units making up a stack.

Their latest plan is to match the recovery times of all devices in a stack. They had done this by the end of the quarter and were about to bring out another stack for further tests.

8. Higher Power Operation of Modulators

This program, designed to increase the energy of the accelerator by operating klystrons at up to 270 kV, continued during the past year.

We started with one modulator operating at 265 kV on July 11, 1968 and gradually increased their number to 32. At the present time we have all modulators in sectors 21, 22, 23, and 24 operating at that voltage. All modulators are operating satisfactorily. The test results indicate that thyratron life will be shorter but by how much is not known. Only five thyratrons have lived their entire life at that elevated voltage (46 kV on the anodes). Their average life is substantially lower than the average for such tubes but there are so few of them that we cannot say at this time what the average life will be. At least 10 of those stations had thyratrons die in them shortly after they were raised to 265 kV so there is a definite tendency toward shorter thyratron life.

Another item that caused us trouble on these stations is the main pulse transformers. Those units have been on the line several years and have slowly deteriorated to the point where they will not operate at 265 kV, but are all right for 250 kV operation. Their cores must be replaced before they will operate at 265 kV.

In connection with higher voltage operation of the modulators and in an effort to increase the reliability of the pulse transformer tanks we modified the klystron socket supports by adding a second insulated mounting plate separated from the first plate and using staggered mounting positions. These changes increased the creepage distances for these components and reduced the possibility of spark-over.

9. Other Modulator Modifications

We redesigned parts of the modulator control and sensing circuits to eliminate a few small but nagging maintenance troubles, such as: "Red Light, No High Voltage",

simultaneous recycling of triggers through the M-K package and modulator end-of-line clipper circuit in the event of klystron overcurrents, shunt trip coil circuits for the main circuit breaker in the modulator to make it independent of variable voltage substation (VVS) output voltage, and modification of the thyratron reservoir and klystron heater undercurrent circuits to make them less sensitive to ac power dips.

These modifications were made on sector 10 and tested sufficiently to prove their worth. At the end of the period we were adding them to additional sectors.

B. Subbooster Modulators

These units continued to give very good service during the past year. The recycles on them were reduced substantially by improvements to the main switch tubes and improvements in the modulator circuits.

By the end of the period one modulator was modified for faster recycles and the fault lights had holding circuits added to them. Previously the recycles took about 30 seconds, but now less than one second, which will help to reduce beam downtime. The fault lights didn't have holding circuits so it was difficult to determine what caused the fault unless one were standing in front of the modulator.

C. Main Boosters

During the past 12 months both main boosters were rebuilt to improve operation and maintenance. The high voltage power supply regulation was improved to 0.01%, holding circuits were installed on the fault lights, a fast recycle vacuum relay circuit was installed, and the series pass tube cooling water drip problem was improved so that it no longer can drip on the high voltage transformer below. Previously, in the event of a load overcurrent or rf reflected power problem the main booster would go off and stay off. Now it will recycle until the fault clears or a predetermined number of recycles is reached.

D. C-Beam RF Separator Modulator

During the past year this unit was finished, installed, and tested. It has been running satisfactorily with little or no trouble for almost a year.

E. Pulsed Quadrupole and Steering Magnet Power Supplies

Several more pulsed steering magnet power supplies were built, tested, and installed on the machine.

A second pulsed quadrupole power supply was designed using an energy recovery scheme in order to reduce the cost of such units. By the end of this report period it had operated satisfactorily on the accelerator and two more were being built.

F. Storage Ring Kicker and Septum Magnet Pulsers

During this report period, two pulsers designs for the two types of magnets were completed. Parts were being gathered and some construction work had begun on prototype units.

G. Trigger System Improvements

1. A new, improved injector trigger generator was designed, built, and installed.

2. A master oscillator pulse synchronizer was built and interconnected with one of the three master trigger generators. When used, it synchronizes the main trigger with the 39 MHz from the master oscillator.

3. The pattern generator subsystem in the Central Control Room (CCR) was modified slightly to supply "Standard" pattern pulses to the pulsed quadrupole power supplies. (However, the latter have since been modified to use the "early" pattern pulses which are used by the pulsed steering power supplies and which were already available, so the modification was temporary and is no longer needed).

4. A pulsed beam loading delay unit had been designed and constructed and at the end of the quarter was ready for testing on the accelerator.

H. VVS Overvoltage Interlock

A circuit was designed, installed, and tested on one of the variable voltage substations. Its purpose is to prevent inadvertent overvoltages on the main modulators due to improper operation of the accelerator or a malfunction in the VVS. It is very important for 265 kV operation of modulators because we operate so close to maximum voltage on many components in the system at that power level.

In the past we relied on the limit stop on the VVS rotor to limit output voltage, but that is a crude way to protect for overvoltage because rotor position is not always fixed for a given output voltage. The circuit also contains a meter relay which provides an accurate reading of ac voltage fed to the modulators for setting de-Q'ing.

I. Analog Current Oscilloscope Display

A new system, made necessary because of pulsed quadrupole and steering magnet operation, was designed and installed. It is a sample-and-hold circuit that is interlocked with the pattern generator and provides pulsed magnet current information on the CCR display oscilloscopes.

J. Modification of Battery Chargers on the Accelerator

During this report period we redesigned and began rework of the battery chargers to provide early warning when a charger fails. The old system turned in an alarm only after the batteries had run down to a point where they didn't provide enough voltage to operate accelerator control circuits. These systems are also being improved to provide better and more rapid maintenance.

VIII. PUBLICATIONS

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A COMMENT ON A COMMENT ON A COMPARISON: A REPLY TO LOVELACE AND DONNACHIE. A. D. Brody, D.W.G.S. Leith, B. G. Levi, B. C. Shen (SLAC); D. Herndon, R. Longacre, L. Price, A. H. Rosenfeld, P. Söding (UCRL, Berkeley). Submitted to Phys. Rev.

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SLAC-PUB-712
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SLAC-PUB-716
A STUDY OF THE REACTION $\pi^-p \rightarrow \pi^-\pi^+n$ AT 16 GEV/c. J. Ballam, G. B. Chadwick, Z.G.T. Guiragossián, W. B. Johnson, D.W.G.S. Leith, K. Moriyasu. Submitted to Phys. Lett. B.

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HELICITY CONSERVATION IN DIFFRACTION SCATTERING. F. J. Gilman, J. Pumplin, A. Schwimmer, L. Stodolsky. Submitted to Phys. Lett. B.

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SEARCH FOR T-VIOLATION IN THE INELASTIC SCATTERING OF ELECTRONS FROM A POLARIZED PROTON TARGET. Stephen Rock, Michel Borghini, Owen Chamberlain, Raymond Z. Fuzesy, Charles C. Morehouse, Thomas Powell, Gilbert Shapiro, Howard Weisberg (UCRL, Berkeley); Roger L. A. Cottrell, John Litt, Luke W. Mo, Richard E. Taylor (SLAC). Phys. Rev. Lett. 24: 748-752, 1970.

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MEASUREMENT OF THE POLARIZATION IN ELASTIC ELECTRON-PROTON SCATTERING. Thomas Powell, Michel Borghini, Owen Chamberlain, Raymond Z. Fuzesy, Charles C. Morehouse, Stephen Rock, Gilbert Shapiro, Howard Weisberg (UCRL, Berkeley); Roger L. A. Cottrell, John Litt, Luke W. Mo, Richard E. Taylor (SLAC). Phys. Rev. Lett. 24: 753-755, 1970.

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THE REACTION $\gamma p \rightarrow p\rho^0$ WITH LINEARLY POLARIZED PHOTONS AT 2.8 AND 4.7 GEV: CROSS SECTIONS AND THE ρ^0 MASS SHIFT. H. H. Bingham, W. 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.

SLAC-PUB-728
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MUON PHYSICS. W. T. Toner. Invited paper presented at Int. Conf. on Electron and Photon Interactions at High Energies, Daresbury, England, Sep 1969.

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FILMPLANE RECONSTRUCTION OF TRAJECTORIES IN A NONUNIFORM MAGNETIC FIELD: THE COMPUTER PROGRAM SYBIL. D.E.C. Fries.

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TWO-MILE ACCELERATOR PROJECT; Quarterly Status Report, October 1 to December 31, 1969.

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SEARCH FOR MAGNETIC MONOPOLES IN THE LUNAR SAMPLES OF APOLLO 11. L. W. Alvarez, P. H. Eberhard, R. R. Ross (UCRL, Berkeley); R. D. Watt (SLAC). Science 167: 701-703, 1970.

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CHARGE ASYMMETRY IN THE MUONIC DECAY OF THE K_2^0. M. A. Paciotti (UCRL, Berkeley). Ph.D. thesis.