SLAC-105
UC-28
(SR)

TWO-MILE ACCELERATOR PROJECT

1 January to 31 March 1969

Quarterly Status Report

STANFORD LINEAR ACCELERATOR CENTER
STANFORD UNIVERSITY
Stanford, California

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

June 1969

ABSTRACT

A status report on the Stanford Linear Accelerator Project covering the period January 1, 1969 to March 31, 1969 is presented. Topics included are accelerator and research area operations, accelerator and research area equipment development, and physics research equipment development.

TABLE OF CONTENTS

LIST OF FIGURES

INTRODUCTION

This is the twenty-seventh Quarterly Status Report of work under AEC Contract AT(04-3)-400 and the twenty-first 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, 1969 to March 31, 1969. Contract AT(04-3)-400 provides for the construction of the Stanford Linear Accelerator Center (SLAC), a laboratory that has as its chief instrument a two-mile-long electron accelerator. Construction of the Center began in July 1962. The principal beam parameters of the accelerator in its initial operating phase are a maximum beam energy of 20 GeV, and an average beam current of 30 microamperes (at 10% beam loading). The electron beam was first activated in May 1966. In September 1968, a beam energy of 21.0 GeV was achieved. Beam currents up to 55 milliamperes peak have been obtained.

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

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

I. ACCELERATOR OPERATIONS

A. Operating Hours

Manned Hours	Jan.	Feb.	March	Quarter
Physics Beam Hours[1]				
Machine Physics	10	31	64	105
Particle Physics	160	370	517	1,047
Total Physics Beam Hours	170	401	518	1,152
Non-Physics Hours				
Scheduled Downtime	6	16	10	32
Unscheduled Downtime Due to Equipment Failure	40	25	19	84
All Other (Machine Tune-Up, etc.)	40	62	38	140
Total Non-Physics Hours	86	103	67	256
TOTAL MANNED HOURS	256	504	648	1,408

B. Experimental Hours[2]

1. Particle Physics

(3) Beam Line	Sched. Hrs. Electronic Experiments (a)	Electronic Experimental Hrs.		%	Actual Bubble Chamber Hours	Actual Test And Check-Out Hours	Total Experimental Hours	
		Actual Hours (b)	(4) Charged Hours	$\left(\frac{b}{a}\right)$			Actual Hours	Charged Hours
A	1,101	901	873	81.8	---	58	959	931
B_N	---	---	---	---	---	---	---	---
B_C	382	274	286	71.7	244	10	528	540
B_S	55	22	20	40.0	---	---	22	20
C	705	579	509	82.1	424	405	1,408	1,338
Total	2,243	1,776	1,688	79.2	668	473	2,917	2,829
2. Machine Physics							124	124
TOTAL EXPERIMENTAL HOURS							3,041	2,953

(1) Number of hours accelerator is run with one or more beams excluding accelerator beam tune-up and other non-physics beam time.
(2) Number of hours an experiment is run including actual beam hours and beam downtime "normal to the experiment."
(3) Refer to Fig. 3 for beam line location.
(4) Total number of experimental hours actually run multiplied by factor (F), where $F = \frac{\text{Average repetition rate}}{180\text{ pps}}$ (F maximum = 1.5 even if calculated amount exceeds this value). This product represents the hours charged to the experiment.

C. Overall Experimental Program Status

1. Electronic Experiments

Approved research hours at beginning of quarter	3,054
Hours charged during the quarter	1,688
New hours approved during the quarter	2,398
Approved hours remaining at end of quarter	3,764

2. Bubble Chamber Experiments

	40" BC	82" BC
Approved pictures at beginning of quarter	630 K	2,050 K
Pictures taken during the quarter	616 K	996 K
New pictures approved during the quarter	906 K	1,111 K
Approved pictures remaining at end of quarter	920 K	2,165 K

D. Beam Intensity

	Jan.	Feb.	March	Quarter
Peak	55 mA	40 mA	38 mA	55 mA
Average	8.5 μA	5.2 μA	3.9 μA	5.9 μA

E. Klystron Experience

	Jan.	Feb.	March	Quarter
Total Klystron Hours	60,445	114,755	153,347	328,547
Number of Klystron Failures	7	6	7	20

F. Data Analysis

	Jan.	Feb.	March	Quarter
Spark Chamber Events Measured	10,499	20,643	24,172	55,314
Bubble Chamber Events Measured	10,187	7,444	8,419	26,050

G. Computer Operations

Manned Hours	Jan.	Feb.	March	Quarter
Computation Hours				
SLAC Facility Group	103	113	102	318
User Group	374	379	410	1,163
Total Computation Hours	477	492	512	1,481
Non-Computation Hours				
Scheduled Maintenance	93	82	60	235
Scheduled Modifications	60	61	81	202
Unscheduled Downtime & Reruns	26	9	54	89
Idle Time	6	4	6	16
Utility Failure	10	---	---	10
Total Non-Computation Hours	195	156	201	552
TOTAL MANNED HOURS	672	648	713	2,033

H. Special Operating Features

1. Positrons

Interlaced positrons and electrons were delivered for 239 hours using the "wand" and for 20 hours using the fixed "wheel." Performance was satisfactory.

2. Beam Knockout

The beam knockout was used for a total of 561 hours during the quarter, including 9 hours of check-out. It was operated at both 10 and 40 MHz.

3. Power Supplies

The 3.4 power supply was run for 318 hours in conjunction with the 82" bubble chamber and for 9 hours of check-out in conjunction with 54" spark chamber in preparation for the Cosmic Ray experiment.

The motor generator facility was run for 305 hours in conjunction with the 40" bubble chamber and for 169 hours in conjunction with the 82" bubble chamber.

In final check-out of the 5.0 MW power supply the primary transformer failed and had to be repaired. It was not operational during the quarter but is expected to be placed in operation in May.

The 5.8 MW power supply was being reworked all quarter and was not used. It is planned to be operational in April.

4. The accelerator was off during the first three weeks of January for a scheduled shut-down.

II. RESEARCH AREA OPERATIONS AND DEVELOPMENTS

A. Operating Schedule

A new accelerator operating schedule was placed into effect during the month of March. The operating schedule is nominally a four-week cycle, consisting of a period of three weeks of accelerator operation followed by a one-week period during which the accelerator is off. This replaces a cycle which consisted of nominally one and one-half weeks of accelerator operation followed by one-half week during which the accelerator was off. The planned long-term operating schedule is shown in Fig. 1. In this schedule, nominally consisting of repetitive four-week cycles, the number of operating shifts per year was adjusted to be essentially the same as was planned for the original schedule consisting of repetitive two-week cycles.

It is anticipated that this new, longer period of accelerator operation with fewer start-ups per year will significantly increase the useful high energy physics beam time. The results in terms of useful beam running time during this month and also during a previous test of this type of operating cycle indicate that the anticipated improvement is being accomplished.

B. General Beam Switchyard (BSY) and Research Area Activities

During this period work proceeded on some major improvements, on the set-up of new experiments, and on the maintenance of equipment. A major extension of the research area utility tunnel system to the east was completed. Preparations were made for the move of the streamer chamber facility. The move is to be made in April. As part of a plan to allow the use of thicker targets in ESA without producing excessive levels of radiation in the yard, a new high power ball-type protection collimator was installed in the beam path between ESA and the beam dump east of End Station A.

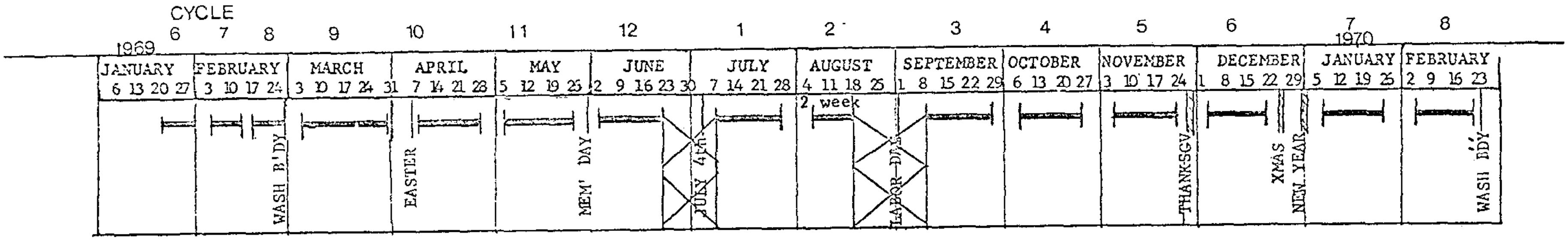
In February equipment was set up in ESA for E-7.* In March this array was replaced by one for E-39.

In February the center beam path in End Station B was prepared for operation as a bremsstrahlung beam for experiment E-4b. In March this was replaced by a set-up of the annihilation beam for use in BC-18. Initial installation and modification of the secondary μ beam for E-38 continued.

---
*See Table 1 for titles of numbered experiments.

DATE: JAN. 28, 1969

ISSUED BY ESO (x2455)



NOTES.

1) Cycles 6, 7, and 8 are standard 2-week cycles. New 4-week cycles begin with cycle 9, March 3, 1969.

2) Operation for standard 2-week cycles begins on Tuesday (refer to Diagram A to the right), and extends through Shift 2 Friday of the second week. Standard 4-week cycles begin on Wednesday (refer to Diagram B) and end on Shift 2 Sunday of the third week. This last shift (Shift 2) is planned for accelerator physics and is followed by a one-week shut down.

3) Perturbations to the above scheme are:

a) Cycle 9 extends for 5 weeks (4 weeks on followed by a one-week shut down).
b) Cycle 2 extends for 2 weeks, immediately followed by 3-week shut down (which includes Labor Day).
c) Operation for cycles 9-12 begins on Tuesday, one full day in advance of the standard 4-week cycle (see Diagram C).

4) Special shut downs are listed below:

a) 2 weeks at end of cycle 12 includes July 4th.
b) 3 weeks at end of cycle 2 includes Labor Day.
c) 2 weeks at end of cycle 6 includes Xmas and New Years.
d) ESA and ESC will be shut down during cycle 11 for installation of polarized target and moving of the streamer chamber. It may be possible to operate ESC the last week of cycle 11, construction permitting.

STARTUP DIAGRAMS

A. Standard 2-week cycle

Tuesday			Wednesday		
1	2	3	1	2	3
Acc. Start up	Oper. Beam Tests	AP	AP	AP R-1	Beam to Exp.

B. STANDARD 4-week Cycle

Wednesday			Thursday		
1	2	3	1	2	3
Acc. Start up	Hot Maint.	AP	AP	AP	R-1

C. "EARLY" 4-week Cycle

Tuesday			Wednesday		
1	2	3	1	2	3
Acc. Start up	Hot Maint	AP	AP	AP	R-1

In the central beam area, installation of equipment and check-out proceeded for E-41. Experiment 37 was completed in March. The set-up was removed to allow preparation of the C-beam site of the Streamer Chamber Building.

Preparations were made for tests of the rapid cycling bubble chamber, using a parasitic beam 10° north of the C-beam. Plans are being made for development of the K_0-beam required in the C-beam for E-48.

The first phase of the major instrumentation and control rearrangement in the Data Assembly Building was completed on schedule. Beam set-up and control is now performed at the west section of the planned dual console. The second or east section will be installed during the next few months and should be in operation this summer. One aspect of the new instrumentation is the improved method of monitoring beam charge and position. Three dual trace oscilloscopes and selector systems allow independent monitoring of beam charge and position for the A, B, and C beam lines. Each monitoring position provides selection and scope display of all of the monitors in the beam line. The scope trace is a time multiplexed display of three pulses: beam intensity, beam intensity times X displacement, and beam intensity times Y displacement.

A new 16 K word memory was received and installed in the BSY-Research Area control computer. This memory is double the size of the previous memory and will relieve limitations in computer control which have resulted from insufficient memory. During recent months hardware and programming has been completed which permit scanning of BSY and End Station interlock and status signals. At present about 100 interlocks are scanned and changes in status are displayed to the operator on a cathode ray tube display. Within a few months most beam interlock and status signals of the BSY and End Stations will be displayed through the computer.

C. Bubble Chamber Operations

The 40" chamber was filled and operated on deuterium for the first time in February. The systems installed for this run performed satisfactorily and 210,044 pictures were taken for BC-18. The rep rate was 1.3 sec per pulse and a program for speeding this up was in progress when a leak developed that prevented further deuterium running at this time. The chamber continued running during March with a broken bellows and took 405,792 pictures in hydrogen for BC-2 before the leak became too large to continue. At the end of the quarter the chamber was open to install a new bellows and make modifications which should improve the chamber dynamics.

The 82" chamber cooled down for operation on January 19th, but because of power supply trouble and then a two-day power failure, no pictures were taken until the last few days of the month. In the few remaining days 206, 067 pictures were taken for BC-11. The chamber completed its scheduled February operations on the 14th. During that month's running, it took 80, 658 pictures for BC-11, 271, 480 pictures for BC-4a, 112, 476 pictures for BC-13 and 8, 000 pictures for tests for other experiments. The installation of a deuterium system was completed. The chamber ran well during March. It was used to obtain 7, 260 pictures for BC-14 and 328, 145 pictures for BC-4a. At the end of the quarter the chamber was full of hydrogen which will be dumped and replaced with deuterium for the BC-17 run scheduled in the middle of April.

D. Power Supply Operations

Activities during January were keyed to the accelerator shutdown. The opportunity was used to complete two major projects: (1) The new 12 kV feeder for the 5.0 MW and the 3.4 MW power supplies was put into service, thus eliminating potential operating interference with the 82" Bubble Chamber cooling system. (2) Vacuum switches were installed for use with the two large spectrometer power supplies, thus making available a circuit breaker in the research area substation where increasing loads demanded an expansion. The shutdown period was also used for an intensive training of the 11-man technician crew that maintains and operates the approximately 150 large magnet power supplies in the Beam Switchyard and Research Area.

On February 28 the 5.0 MW power supply, about 30% through the final acceptance test heat run, had a transformer failure. The transformer was shipped back to the manufacturer for examination and repair; it is expected to be returned in May.

The MG set and the 3.4 MW power supply are at present the only two operating power supplies. The necessary additional transformer protection to permit operation of the 5.8 MW supply is being installed. A prototype for a new reversing switch mounting assembly was installed in one spectrometer power supply. Tests were made on the new 3000 A/1.0 V shunt; heat treatment and a design change will be necessary for temperature stabilization. Modifications for upgrading the BSY B-beam switching power supplies were completed. Modifications were also completed on one of the ten BSY main pulsed switching supplies for an improved stability of 0.05 %; plans are to field test this power supply during the April run.

A growing list of necessary or desirable improvements on existing equipment has been prepared. Principal among the yet-to-be completed projects are: Redesign of the reversing switch installation on the spectrometer supplies; completion of details on the 5.8 MW supply; rework of shunt and switching assembly, and of filter section of the 3.4 supply. Work continued on certain ongoing projects: Construction of a new 3000 A water-cooled precision shunt, design of a 10,000 A precision oil-cooled shunt, determination of the necessary changes to improve the accuracy of the main switching supplies, and redesign of the regulator for the 360 and 400 kW power supplies. Figure 2 is a summary of beam transport power supplies in use at SLAC.

E. Liquid Hydrogen Target Activities

Targets in operation during this period included those for E-7, E-10, E-11b, E-37, E-39, and the annihilation beam target for End Station B. There were five targets in various stages of design and fabrication for use in the following experiments: E-29, E-32, E-39, E-40, and E-41.

The E-29 check-out target for ESA was designed and fabricated during this period. This target consists of refurbished E-4b III target (the forced convection target) mounted in the triangular scattering chamber which was modified to accept both the target and a twelve-position target wheel mounted from the floor of the chamber. This entire assembly will be installed in ESA in April.

The target used in E-32 is being modified for use in E-44 (Coherent Regeneration from Hydrogen). The modifications consist of changing the beam window on the existing target canister to be similar to that used on the E-37 canister. Several windows and a test fixture have been made. Testing and assembly will be carried out in April.

The E-39 target fabrication was completed and installed in March. Two 2" diameter mylar cylinders with dummies make up the target. A carbon block is also included to give a total of six possible target positions. This target uses the motion mechanism for E-7.

DC Power Supply		Below 100 kW	100–350 kW	360–400 kW	567–1600 kW	Over 1600 kW	Total kW	Total Units
Switchyard	Total kW	706	1,150	693			2,549	
	Units	27	4	1				32
Spectrometer	Total kW		360	720	5,600		6,680	
	Units		3	2	8			13
Large Experimental Apparatus	Total kW					17,200	17,200	
	Units					4		4
Other Yard Supplies	Total kW	196	1,620	12,800			14,616	
	Units	15	11	34				60
TOTAL	Total kW	902	3,130	14,213	5,600	17,200	41,045	
	Units	42	18	37	8	4		109

Also:

10 Pulsed switching supplies - 3000 V/330 A, 600 cps, 360 pps
2 Pulsed switching supplies - 4000 V/500 A, 600 cps, 360 pps
10 Pulsed steering supplies - 2000 V/23 A, 600 cps, 360 pps

FIG. 2--SLAC beam transport power supplies
February 1969

The E-40 system design has just begun. The target and target canister will be fabricated early in April so that testing of the concept can be carried out.

Fabrication of the reservoir heat exchanger assembly for the E-41 target is 80% complete. Design effort is currently being placed on the interface between the reservoir and refrigeration system. The Norelco refrigerator is scheduled for delivery in early April.

Testing of the 9" dia. × .006" wall aluminum hydroformed cells was begun during this period. Initial results indicate burst pressures around 90 psi at room temperature for a 1-1/2" high aperture. These cells are proposed for the new larger forced convection target in ESA. The pencil target development was off and on depending on our shop loading during this period. All pieces are now ready to begin final assembly.

F. Spectrometer Operations and Development

The 20 GeV spectrometer was used by E-10 during January. The Magnetic Measurements Group made a survey of the fringe fields of the front end of magnet 201 in this spectrometer. This magnet has its coil ends all on one side and as a result has very asymmetric fringe fields. The measurements were made using harmonic measuring methods. The data is being analyzed and results will soon be available.

The magnet alignment monitoring system for the 20 GeV spectrometer was completed. It is now possible to observe the smallest distortion in the magnet system on a short or long term basis. Almost the only remaining flaw in the system is the fact that the magnet fields pull the alignment wires, but this causes only a small decrease in accuracy.

Group F ran E-7 on the 1.6 GeV spectrometer in February.

During February the Cal Tech Users Group technicians overhauled the hodoscope used on the 8 GeV spectrometer, and by means of better techniques in matching light pipe to photomultiplier, achieved a reported factor of five improvement in efficiency in the momentum counters.

During March the Cal Tech Users Group operated continuously with the 8 GeV spectrometer on E-39.

G. Description and Status of Approved Experiments

Figure 3 is a Research Area plan drawing showing the location of the various experiments. Table 1 is a list of presently approved high-energy physics experiments. The right-hand column of Table 1 gives status and activity of each experiment during the month.

During the 7-8 February 1969 meeting of the Program Advisory Committee (PAC), Experiments E-44, E-47, E-48, and E-49 were approved, and E-37 was granted an extension.

During the 21-22 March 1969 meeting of the PAC, Experiments E-42, E-50a, BC-20, and BC-21 were approved and E-31a, BC-10, and BC-11 were granted extensions. Experiments using accelerator time were: E-7, E-10, E-11b, E-31, E-37, E-38, E-39, E-41, BC-42, BC-11, BC-13, BC-18, and BC-19. Information on the status of certain experiments and descriptions of the newly approved experiments follow:

E-10 — A Proposal to Study Photoproduction at Forward Angles Using the SLAC 20 GeV/c Spectrometer

This experiment was completed during the accelerator running period at the end of January. During this period the experimenter's efforts were devoted to: (1) A study of the A dependence of π^+ photoproduction from nuclei. Targets studied ranged from beryllium to lead. The experiment was run at 8 and 16 GeV, and a range of momentum transfers from $t = 0.04$ to $1.0\ \mathrm{GeV}^2$ was covered. (2) Y* photoproduction at 11 GeV from hydrogen and deuterium over a range of momentum transfers from $t = 0.01$ to 1.0.

E-11b — Proposal to Study ρ^0 Photoproduction from Complex Nuclei at Forward Angles

The gamma beam and experimental equipment were checked out and data taking began in February. The experiment was a prime user of accelerator time during the period.

E-37 — Measurement of the Total Photoabsorption Cross Section for Hadron Final States

During February the check-out of E-37 was completed and the first data points were taken. The experimenters were able to test all counters, check the logic and tape unit behavior, and measure some cross sections in the first cycle of 200 pps running. The PAC granted another 200 hours for the A-dependence, making a total of 370 approved hours. The first prime running

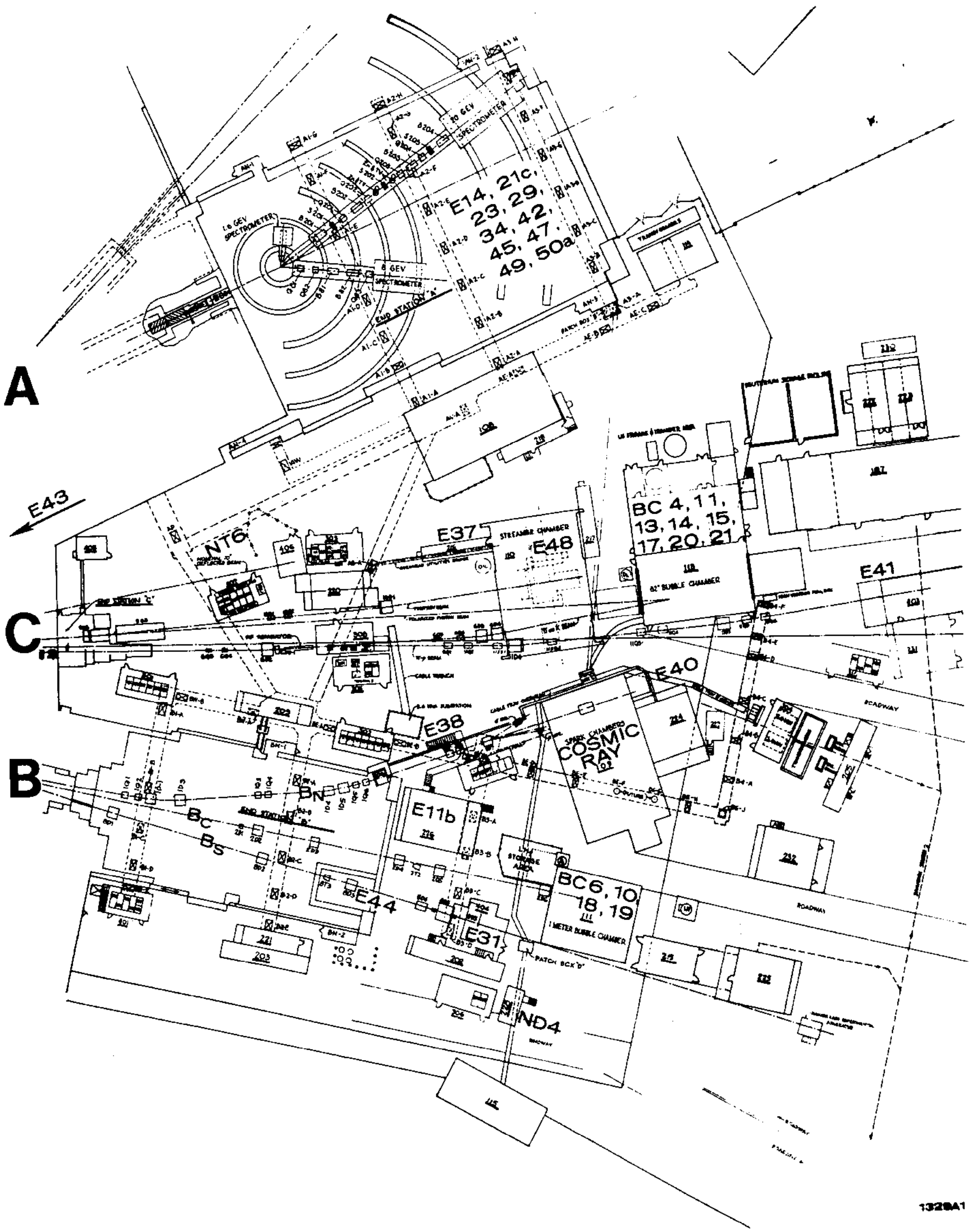


FIG. 3--Experiment locations.

time began with the second cycle in February. The experiment was hampered by a leaking LH_2 target, by some start-up and beam delays, and by e^- beam power limitations, but still ran about 90 hours with good beam. Most of the time was spent at 16.2 GeV e^+ energy. There the experiments carefully investigated the rate dependence and target thickness dependence, and searched for geometrical biases. It was found satisfactory to run at 2 tags/pulse and to use .2 X_0 targets, and it was also found that any geometrical bias was very small. High-statistics points were taken on H_2, D_2, C, Cu, and Pb. The remainder of the time was spent at 4.9 GeV e^+ energy. Some studies of geometrical effects and backgrounds were started. The experimental program was completed during March.

Most of the goals of the experiment were met and several exceeded. The total cross sections on hydrogen and on deuterium have been measured at 28 photon energies from 3.7 to 17.8 GeV, with 3% statistical accuracy. Carbon, copper, and lead were measured at several energies between 3.7 and 17.8 GeV with 5% statistics. The natural lower energy limit, below which the geometrical checks became unsatisfactory and the experiment very difficult, was found to be 3.7 GeV. The highest energy points required almost 70 hours at 20.5 GeV e^- energy, a level of accelerator performance exceeding that requested in the proposal. Analysis while running indicates that the results are internally consistent and agree with other measurements for the most part, but the best numbers and a careful evaluation of systematic effects await analysis of the tapes.

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

This experiment was completed during this operating period. During 480 hours of beam time data were obtained on the photoproduction of neutral bosons in the region of photon energies between 6 GeV and 16 GeV, and for squared momentum transfers to the recoil proton between 1.5 $(GeV/c)^2$ and 4 $(GeV/c)^2$. The experiment used the 8 GeV spectrometer to detect the recoil protons which have a momentum greater than 1.5 GeV and come out at angles between 40^o and 60^o in the laboratory. The proton was identified by its time-of-flight, using the SLAC chopped beam and the 8 GeV spectrometer, with its large flight path. For instance, at the highest momentum transfer $\left[4(GeV/c)^2\right]$ the recoil proton takes 3.7 nanoseconds longer than π mesons and 2.7 nanoseconds longer than K mesons to traverse the spectrometer.

E-42 — Photon-Proton Scattering at Forward Angles

This is a proposal to measure the high energy differential cross section for the reaction $\gamma p \rightarrow \gamma p$ (Compton proton scattering) at forward angles, in the region $0.01<|t|<0.2$ $(\mathrm{GeV/c})^2$. At present there are no data available for this fundamental process. This reaction is closely related by means of the optical theorem to the total γp cross section which is presently under active study. Theoretical models such as that given by vector dominance or Regge theory can be tested by this experiment.

The experimental procedure will use a bremsstrahlung photon beam striking a liquid hydrogen target. A clearing magnet placed after the target sweeps out the charged particles. A pair spectrometer farther downstream measures the energy and angle of scattered photons with energies near the tip of the bremsstrahlung spectrum. The pair spectrometer has a solid angle of 10^{-5} ster and counter hodoscopes provide an energy resolution of $\pm 1\%$. The spectrometer is surrounded by a large concrete shield to reduce unwanted background. The 1.6 GeV spectrometer would be used for detecting the recoil proton, when the proton momentum is greater than 450 MeV/c. A subset of the data would then have events with both the photon and proton measured in coincidence.

E-44 — Coherent Regeneration from Hydrogen

This is a proposal to measure the $\pi^+\pi^-$ kaon decay intensity behind 1 m of hydrogen regenerator to extract $|f_{21}(0)|$ and $(\Phi_\rho - \Phi_{+-})$ in the energy range from 2.5 to 6 GeV. At lower energies one may even be able to predict the regenerator phase Φ_ρ as pointed out by Lusignoli et al.,[1] who used a dispersion theory approach and the total cross sections measured in charged K scattering experiments. If this is the case it may be possible to measure Φ_{+-} accurately to about 0.1 radian. However, this experiment is primarily motivated by the strong interaction physics and places the most emphasis on the measurement of $|f_{21}(0)|$ and the phase Φ_ρ assuming Φ_{+-} to be known.

The experiment will be a continuation of the one just completed (E-32) using the same equipment. A trigger which enhances transmission regenerated events will be used. Wire spark chambers will measure coplanarity to ± 1.5mr, one member of the decay being momentum analyzed in the magnet. Time-of-flight is added as a further constraint. Rates in this proposal have been calculated assuming only decays downstream of the target. Actually, all events

---

[1] Lusignoli, Restignoli, and Violini, Physics Letters 24B, 296 (1967).

coming from the target are taken and the anti-counter is "flagged." If these events can also be analyzed, the net data rate is multiplied by a factor of about four.

20 $\pi^+\pi^-$ events/hour from hydrogen are estimated based on measured trigger rates, and using $|f_{21}(0)|_o$ and Φ_ρ as found from dispersion analyses of K ± n scattering with $\Phi_{+-} = 45^o$. These events will be almost uniformly spread in energy from 2.5 to 6 GeV. 150 hours are requested to measure these events and an additional 100 hours to measure 1000 $K_2^o\ \pi^+\pi^-$ decays.

E-47 — π^+ Photoproduction with a Polarized Target

This experiment proposes to study the asymmetry of π^+ mesons from the reaction $\gamma p \rightarrow \pi^+ n$ where the target proton is polarized normal to the production plane. Such an asymmetry would result from the out-of-phase interference of two t-channel exchange amplitudes belonging to the same spin-parity sequence. The process will be studied at two energies for momentum transfers $0.01 \gtrsim |t| \gtrsim 0.6\ \mathrm{GeV}^2$ using the polarized (alcohol) target which is being brought from Berkeley to study inelastic electron scattering. The π^+ mesons will be produced by a bremsstrahlung beam and analyzed with the SLAC 20 GeV/c spectrometer system.

E-48 — Proposal to Measure the ξ Parameter in the Decay $K_L^o \rightarrow \pi\mu\nu$

This experiment plans to use the SLAC 2-meter streamer chamber in a neutral (chopped) beam and accumulate $\approx 200,000$ $K_L^o \rightarrow \pi\mu\nu$ decays, $\approx 280,000$ $K_L^o \rightarrow \pi e\nu$ decays, and $\approx 90,000$ $K_L^o \rightarrow \pi^+\pi^-\pi^o$ decays. From an analysis of the $\pi\mu\nu$ mode, the ratio of the K_L^o form factors, ξ, will be measured to an accuracy of ± 0.05. In addition, a measurement of the $(K_L^o \rightarrow \pi\mu\nu)/(K_L^o \rightarrow \pi e\nu)$ branching ratio will also yield a value of ξ, serving as a consistency check on the spectrum measurement. λ_+ will also be independently measured from the $\pi e\nu$ spectrum.

E-49 — Inelastic Electron Scattering from D_2

This experiment will extend the inelastic scattering data obtained with protons to D_2 and higher A materials, with a view to obtaining information on the behavior of the neutron in the deep inelastic region. Major questions which should be answered by the experiments are:

1. Is the neutron cross section equal to the proton cross section? This is a requirement of diffraction model explanations of the proton data, could happen in Feynman's model but doesn't have to, and would contradict a simple quark model.

2. If the neutron cross section is different than the proton, does the function F_2 show at least a similar behavior to F_2 for the proton? Is F_2 for the neutron primarily a function of ν/q^2?

3. Does the dependence of the cross sections scale with A or $A^{2/3}$? Data from higher A's will also be useful for checking the procedures for extracting the neutron cross section from D_2.

Another interesting question which will probably not be answered is the extent of the longitudinal contribution to the cross section. Separation of F_1 and F_2 in the proton experiment will be difficult, and unless $\sigma_{Long.}$ is quite large compared to σ_T, the separation will be very marginal in the D_2 experiment which will involve subtractions.

It is proposed to repeat the proton experiments with D_2, at 6^o, 10^o, 18^o, 26^o, and 34^o and to take some triangles on carbon, copper, and lead at large and small angles. The counting rates for the high Z materials will be quite low compared to H_2 since the radiation length (which must be held $\approx$ to the liquid targets) increases much faster than the number of nucleons.

E-50a — Compton Scattering at High Energies from Hydrogen

This experiment complements E-42 by emphasizing a higher range of $|t|$. $\left[0.1 \leq |t| \leq 1.0 \text{ (GeV/c)}^2\right]$.

At small t values, Compton scattering is expected to proceed largely through a diffractive diagram and $d\sigma/dt$ should remain relatively constant with primary energy. At the highest energies this process should become comparable to the cross section for π^o production. In particular from vector dominance it is estimated that $d\sigma/dt \approx .33\ e^{8t}\ \mu b/\text{sterad}$. At high $|t|$ values other exchanges are expected to become important and take over from the diffractive processes. As Compton scattering is the "simplest" process involving a photon it is clear that its investigation is of considerable interest.

Theoretically, photoproduction of π^o-mesons at high energy is assumed to proceed through exchange of natural parity mesons (ρ, ω, ϕ's, etc.) and unnatural parity mesons (B^o, H^o, 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).

In principle the reactions $\gamma + P \rightarrow \gamma + P$ and $\gamma + P \rightarrow \pi^o + P$ 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^o photoproduction can be determined with this technique. Group F has done this successfully with the 1.6 GeV spectrometer for incident photon energies between 6 GeV and 16 GeV and to t values between $-.2\ (\mathrm{GeV/c})^2$ to $-1.4\ (\mathrm{GeV/c})^2$. However, by further observing the scattered photon in a shower counter in coincidence with the recoil proton the two reactions should be easily separated.

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^o-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^o production will be strongly suppressed. Conversely, by increasing the size of the detector and moving it out of the scattering plane the π^o 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.

Summary of C-Beam Experiments. During this period C-beam activities were at a peak with more simultaneous operation of different parts of the system, including e^+, π/k, pulsed π and parasitic e^+ beams. BC-11, BC-4a, BC-13, and CE-37 were run or checked out with beam, as were numerous minor tests.

The first occasion for high-rep-rate, relatively high-power operation in C-beam took place in connection with E-37. It was found that beam power up to 30 kW can be handled without serious difficulty or need for further modification of the system.

BC-20 — A Proposal for an Exposure of the 82" Deuterium Chamber to a Beam of π^+ Mesons at 13.4 GeV/c

This is a proposal to take 300,000 pictures of π^+d interactions in the 82" chamber to study the following reactions.

$$\pi^+ d \longrightarrow pp\pi^+\pi^- \qquad (1)$$

$$\longrightarrow pp\pi^+\pi^-\pi^o \qquad (2)$$

$$\pi^+ d \longrightarrow pp\pi^+\pi^-\pi^+\pi^- \quad (3)$$

$$\longrightarrow pp\pi^+\pi^-\pi^+\pi^-\pi^o \quad (4)$$

$$\longrightarrow np\,\pi^+\pi^+\pi^- \quad (5)$$

$$\longrightarrow d\,\pi^+\pi^o \quad (6)$$

$$\longrightarrow d\pi^+\pi^+\pi^- \quad (7)$$

The object of the exposure is to study both charged and neutral boson systems with both negative and positive G parity. The reaction channels listed should provide good mass resolution (< 20 MeV/c^2). This is particularly true for reactions 1 and 3 which have two low momentum protons in the final state, and are four constraint fits. The boson resonances can be analyzed up to a mass of ~ 4 GeV/c^2 and it should be possible to determine production characteristics and quantum number assignments.

This exposure will provide a continuation of the Purdue group's study of boson resonances already started with π^+p film at the same momentum. Comparison between the two experiments will provide valuable information on I spin assignments of resonant structures.

A study of coherent production of boson systems in reactions 6 and 7 is also intended. This will yield information on exchange mechanisms and properties of I = 1 bosons. Reaction 1 will afford additional information to aid a continuing study of $\pi\pi$ phase shifts.

BC-21 — Study of π^--D Interactions at 12 GeV/c in the 82" Bubble Chamber

This is a proposal for a high energy π^--deuteron experiment at 12 GeV/c incident pion energy. In common with most high energy bubble chamber experiments, which are partly speculative in nature, it is interested in all reactions that may occur with sufficient statistics. However, of especial interest are the following reactions:

$$\pi^- + n(+ p_s) \longrightarrow \pi^- + \pi^- + p(+ p_s) \quad (1)$$

$$\longrightarrow 3\pi^- + \pi^+ + p(+ p_s) \quad (2)$$

$$\pi^- + D \longrightarrow \pi^- + \pi^- + \pi^+ + D \quad (3)$$

Interest in reaction (1) is prompted by results of the counter study of $\pi^\pm + p \longrightarrow \pi^\pm + X^+$ (missing mass) in the incident momentum region 10-26 GeV/c (Foley et al., Phys. Rev. Letters 19, 397). The missing mass spectrum contained two significant enhancements centered at 1400 MeV and 1690 MeV, and the production cross sections $d\sigma/dt$ for these two states was essentially independent of s.

A study of reaction (1) will permit a detailed investigation of the quasi two-body reactions

$$\pi^- + n \longrightarrow \pi^- + N^{*o}(1400) \longrightarrow \pi^- + \pi^- + P$$

and

$$\longrightarrow \pi^- + N^{*o}(1690) \longrightarrow \pi^- + \pi^- + p$$

without the large background from n body ($n > 3$) final states present in counter experiments. Further, the reaction of interest is not obscured by production of boson resonances.

Reaction (1) is preferred to the charge symmetric reaction $\pi^+ p \longrightarrow \pi^+ \pi^+ n$ because the latter is a 1C event whereas the former is 4C. It is known that for incident momenta above 10 GeV/c unambiguous reconstruction of 1C events is very difficult.

In reaction (2) examples of double diffraction dissociation will be sought, e.g., $\pi^- \longrightarrow \rho^o \pi^-$ at one vertex and $n \longrightarrow p\pi^-$ at the other vertex, with small momentum transfer.

At present the nature of the A_1 enhancement is uncertain. A study of coherent production of A_1 in reaction (3) is therefore proposed. In a coherent process, where the recoiling nucleus remains in the ground state, the three outgoing pions have $I = 1$ and $J^P = 0^-, 1^+, 2^-$, etc. The fact that the deuteron has no bound excited states should make it particularly suitable for coherent production processes.

III. ACCELERATOR IMPROVEMENTS

Computer control of klystron replacement in the accelerator was successfully performed on a trial basis in March. Final delivery of associated hardware for the Digital Equipment Company Model PDP 9 computer was made in late January and check-out of the computer and the program was accomplished in February, leading to the trial run in March. Further trial runs are planned for April after which the system will be incorporated into regular accelerator operation.

The planned modification of four sectors of the accelerator to provide pulse-to-pulse steering and focusing continued during the quarter. A prototype pulsed steering power supply was completed in January, installed in February and successfully tested with an existing steering dipole. Three additional power supplies are being fabricated. Late delivery of cores delayed completion of a prototype pulsed focusing quadrupole, but installation is now scheduled for late April, with testing to be conducted in May.

Repair of the main drive line was completed in January. Flanges in Sectors 11 through 30 were straightened and refaced and the drive line insulated. A program for repair of the sub-drive lines is being developed.

Work on an off-axis injector to be located at the west end of the accelerator continued on a limited basis because of spending restraints. Fabrication of the gun modulator continued, but design and fabrication of the pulsed magnet and power supply has been delayed. This injector, when installed, will improve the operation of simultaneous beams with radically different intensities and will improve the reliability of the accelerator by acting as a back-up in case of malfunction of the main injector.

The beam break-up resonance in Sector 2 accelerator pipes was detuned during the January shut-down, utilizing the same dimpling technique as had been previously used in Sector 1. The resonance frequency was increased by an average of 4.3 MHz. New measurements of the beam break-up current threshold were made in late January, the results indicating an improvement due to dimpling Sector 2 in the vicinity of 10%, which is in good agreement with theoretical predictions. The decision has been made to dimple Sectors 3 and 4 during the August shut-down.

IV. RESEARCH DIVISION DEVELOPMENT

A. Physical Electronics

1. Alkali-Halide and Semiconductor Secondary Emitters

Alkali Halide. This area of research has not yet been completely closed because it has been realized that with very little extra effort it would be possible to find out how baked low density films of KCl differ from unbaked films (normally used for our measurements). From the literature it appears that baked films should sustain their state of charge more easily than unbaked films; although that would result in a higher average gain, it is not expected that the statistical distribution of emitted secondaries would be any better from the point of view of detection of high energy particles. Work is now in progress to make comparative measurements between unbaked and baked films to confirm this expectation.

Statistics Measurements on a GaP Dynode. The GaP first dynode of a developmental tube made by RCA will be studied. During this period, two 4 mm^2 silicon lithium drifted radiation detectors have been fabricated and tested for a coincidence measurement at high energies. As soon as the experiments with alkali halides are complete, the electronic setup will be prepared. Much of the equipment is common to both experiments.

Tube for Photo and Secondary Emission From Semiconductors. An old tube has now been modified, preparations have started for assembly of the already available parts, and machining of other necessary parts has continued. The first measurement will be on a single crystal of P-doped GaAs cleaved in vacuum. Photoemission and secondary emission will be studied as a function of surface treatment (Cs monolayers alternating with oxygen layers).

2. RF Superconductivity Materials Research

Room Temperature Field Emission and Breakdown Voltage Measurements. The combined field emission and breakdown voltage measurements for Pb-plated-on-Cu electrodes have been analyzed, and the results are summarized in the following table. In the range 0.25 mm to 2.0 mm the breakdown voltage, V_B, does not correspond to a constant value of the microscopic electric field, E_{mic}. The macroscopic electric field, E_{mac}, for breakdown decreases with increasing gap. The enhancement factor, β, changes due to breakdown.

Electrical Breakdown Experimental Results

Gap cm	V_B, kV	E_{mac}, V/cm	β	$E_{mic} = \beta E_{mac}$, V/cm
.025	15	6.00×10^5	131	7.85×10^7
.050	28	5.60×10^5	158	8.82×10^7
.075	39	5.20×10^5	124	6.45×10^7
.100	45	4.50×10^5	107	4.82×10^7
.125	54	4.33×10^5	136	5.88×10^7
.150	62	4.13×10^5	69	2.85×10^7
.175	66	3.77×10^5	25	9.45×10^6
.200	70	3.50×10^5	114	3.99×10^7

The observed dc breakdown voltage, V_B, can be represented by

$$V_B = \left[45\ \mathrm{kV}/(\mathrm{mm})^{.785}\right] d^{.785}$$

The exponent may decrease from 0.785 to 0.5 as the gap is increased.

Room Temperature Field Emission Measurements. The Pb-plated-on-Cu electrodes were removed from the vacuum system and evaporation-coated with Al_2O_3 to a thickness of 500 Å in hopes of reducing the emission current. The thickness was kept low, despite the fact that for this thickness, ions residing on the dielectric could sufficiently enhance the electric field intensity to significantly increase the emission current. A dielectric film in a cavity would have to be quite thin to minimize the dielectric loss. Upon electric field application, a whisker grew $\sim 7 \times 10^{-2}$ cm long and $\sim 5 \times 10^{-3}$ cm base diameter (upper limit). The enhancement factor, β, of this whisker was found to be ~1000 to ~2000, increasing as it was being measured. The electric field was not applied until the system had reached a pressure of 5×10^{-9} torr, so the change in β was probably due to whisker growth rather than desorption of gases.

Since the Al_2O_3 was applied by an electron beam evaporation process, the Pb substrate may have been heated to above 100°C. The subsequent cooling to room temperature could induce the stress leading to the whisker growth.

Preliminary measurements indicate that the Pb radiation-shielding box is adequate in reducing the X-rays to a safe operating level.

3. Basic Materials and Coating Techniques

Sputtering. Work continues on depositing niobium on copper, the immediate goal being to coat the bottom plate of a C-band cavity (6" diameter). Two test plates were coated with niobium to ~10,000 Å. The first substrate was held at 250 - 310°C during deposition. The second test piece was coated at 350-450°C by modifying the heater. X-ray diffraction examination showed broad 110 niobium peaks for the first and somewhat sharper 110 niobium peaks for the latter. The next attempt will be with a real cavity bottom plate.

Vacuum Thermal Treatments. It was established that X-band niobium cavities would be heated both upright and on their sides in the induction concentrator.

Work continues on building and buying the components necessary for incorporation into an ultra-high vacuum system.

Surface Treatments. It is possible by careful machining to produce < 4 micro-inch finishes on electron beam melted niobium. With care, the grain boundaries are brought out as clearly as with a chemical etch. If one polishes this surface with 000 stainless steel wool an even smoother finish is produced, the grain demarcations are obliterated, and the surface appears shiny. However, examination by X-ray diffraction showed that the polished surfaces are definitely strained when compared to the as-machined surfaced.

Whisker Growth in Lead Films. A separate report will be prepared summarizing our experience with lead whisker growth and Al_2O_3 overlays.

B. Magnet Development

1. Magnetization Measurements

The influence of joints on composite conductors was tested in several samples ranging in dimensions from 15 mils to 0.125" × 0.25". Specifically, joints made by the electron-beam welding method on composite mutli-stranded conductors were evaluated for NbTi. With a non-twisted material, the joint increases the hysteresis losses per unit volume of the conductor by approximately 28 %, compared to a sample without joint. Also the conductor becomes more flux-jump sensitive and susceptible to degradation.

When composite superconductors are charged, magnetization decays due to the presence of copper between superconducting filamentary strands. The effect is pronounced if composite conductor consists of a large number of very fine filaments, not twisted, and running parallel. The decay in magnetization to a final value from the initial number is according to L/R, where L is the inductance between two parallel filaments and R, the resistance of substrate, per unit length. If the conductor is twisted, the decay of magnetization occurs much faster and the decay amplitude is smaller, due to the small value of L, indicating definitely the superiority of twisted conductors for use in ac and dc applications.

It is also observed that a twisted multi-filament composite conductor is less flux-jump sensitive than a non-twisted filament. Up to now, we have been unable to measure flux jumps in a composite conductor having 112 cores with an overall diameter of 30 mils, a ratio of superconductor to copper of 1:3, and the diameter of the individual filaments 0.8 mil. The hysteresis loss curve of the twisted conductor was slightly less (~5 %) than that of the untwisted one, indicating that the ac losses per unit volume of the superconductor are smaller. No flux jumps were indicated when the transport current through the sample was varied at constant external field or when the external field was swept at a constant transport current. This indicates that conductors built in this form are intrinsically stable and operate in magnets to the short-sample performance.

In order to measure magnetization of larger samples, a 2.75" sixth-order coil was designed, giving homogeneities of 10^{-5} over 2 inches of the gap at a peak field of 55 kG. The material for this magnet, a 30-mil insulated multi-filament twisted composite conductor, with a take-off current of 175 A, has been ordered, parts for the magnet are being currently built, and it is hoped that by June 1969 the magnet will be ready for magnetization tests of larger size of conductor up to 0.20-inch diameter conductor.

2. Flux Pump

The flux pump, reported on previously, was disassembled. A lighter and better insulated flux sheet was built and installed, but not tested as yet. The old flux sheet was intended for usage at 2000 Å. The limit for our magnets, however, is 500 Å. It is hoped that the improved sheet, working at designed load, will raise the efficiency from 20 to over 60%.

3. 2-Meter Spark Chamber Magnet Model

Laminations for the core of a model magnet (spark-chamber magnet) were epoxied together. Assembly of the magnet will start with the arrival of coils during the third week of April. For this same magnet, parts of the existing capacitor bank were set up and readied for pulsing the magnet.

4. Superconducting Screens

Tests with various types of home-built NbTi screens are continuing. The ratio of mesh size to conductor diameter has been varied from 10:1 to approximately 3:1. At low fields, up to approximately 8 kG, the screen was able to shield 70 to 80% of the flux. At some critical value, which seems to be 8 kG presently, the field penetrates through the screen, indicating that persistent current loops flowing through the screen do quench and the screen loses its shielding property to about 80%.

5. 40" Bubble Chamber

Detailed field calculations in- and outside the bubble chamber were performed and field maps for axial and radial fields prepared. The field outside the iron (~20 cm) is still 0.6 kG, if the central field is 70 kG. It was felt that the fringing field was too high and required additional multi-layer shielding. Three layers of ~ 0.5 cm iron, interconnected, did reduce the external field to ~200G around the bubble chamber.

6. Storage Ring Magnets

Pole profile shaping for a bending magnet to be used was calculated to produce a field homogeneity of 10^{-3} over a 6" gap width. The pole end shaping allows the reduction of the pole width of a C-type magnet to 10".

C. <u>Conventional Data Analysis Group Activities</u>

1. Maintenance

a) The construction on the SPV-B digitizers is 75% complete.

b) The second SP-6 is installed and working.

c) IMP#4: Mechanical assembly 90% complete, electrical assembly 50% complete.

d) Debugging on MPF #6 is progressing.

f) Updating of NRI system has been started.

2. Programming

Interviewing and selecting of a programmer trainee has been completed. In progress at this time are the following:

a) CDA production program, IBM 360 and NRI system procedures documentation.

b) Production program problem investigation and maintenance.

c) Programming group training.

d) Manual accounting function, e.g., computer run status log.

e) Preparing and scheduling production program runs.

f) EMR 6020 equipment configuration study, i.e., additional core.

3. Scanning and Measuring Operations

The measuring totals for the quarter are as follows:

NRI (5 machines): 4500 hrs. measured; 35,800 events

Vanguard (2 machines): 1400 hrs. measured; 9200 events

SPV-B (2 machines): 790 hrs. measured; 11,300 events.

D. <u>Computation Group Activities</u>

1. Computer-Oriented Logical Inference

Algorithms that draw logically valid inferences from a suitable data base are of central interest in computer systems designed for answering questions about the data base and proving theorems about it (or from it). The problem of constructing suitable inference apparatus for handling the equality symbol, and for curtailing the number of occasions in which the inference apparatus is applied to deduce conclusions irrelevant to the question at hand, has attracted considerable attention in the last few years. The work of C. Green at SRI seems to indicate that the "set-of-support strategy" developed by Wos, Robinson, and Carson of Argonne and SLAC can be of considerable value in curtailing irrelevant inferences in question-answering systems based on ordinary first-order logic. A powerful extension of computer-oriented logical inference techniques to first-order logic with equality has been developed, based on an inference rule called <u>paramodulation</u> (SLAC-PUB-482). The applicability of the set-of-support strategy to the extended system including paramodulation has been proved.

The basic subroutines for implementing the logical apparatus on the computers at SLAC are under development. Some of the computing will be done on the 360/91 and some on the Graphic Interpretation Facility with the two machines acting as an integrated system where practical. A substantial portion (perhaps 75 percent) of the software to be developed will be planned as part of a more general interactive package for the IDIIOM and 360 and will not be limited to the special applications of computerized logical inference.

V. PLANT ENGINEERING

Construction of SLAC's remaining major building project, the Central Laboratory Addition, was virtually completed in February and occupancy was begun immediately. Views of this new facility are shown in Figs. 4 and 5.

Several other projects were completed and the facilities placed in use. Included in this category are: installation of two 12.47 kV vacuum circuit breakers for use on the primary power switchgear of the 1.59 MW power supplies (spectrometer use); a major extension of the utility tunnel east of End Station B; installation of a 5 MVA electrical substation in the Research Yard; and procurement of a shelter for the beam 12 rapid-cycling bubble chamber test program.

Other projects are in various stages of progress. Engineering is underway on: relocation of the SLAC library; enclosing of the Cleaning Shop near the Fabrication Building; enclosing of Room 109 at the Cryogenic Laboratory; scoping of modifications to the B-Target Room radioactive water service; and enclosing of the Klystron Pulse Tank Maintenance Shop. Field work and/or procurement are underway on: modifications to the Crafts Building heating and ventilation system; increases in the LCW cooling and pumping capacity in the Research Area; enclosing the Heavy Assembly Building Welding Shop; relocation of the former Stores and Receiving Building to the Research Area installation of the foundations and utilities for the new location of the Streamer Chamber Building; and installation of a 12.47 kV transformer and low voltage distribution system in the South Staging Yard.

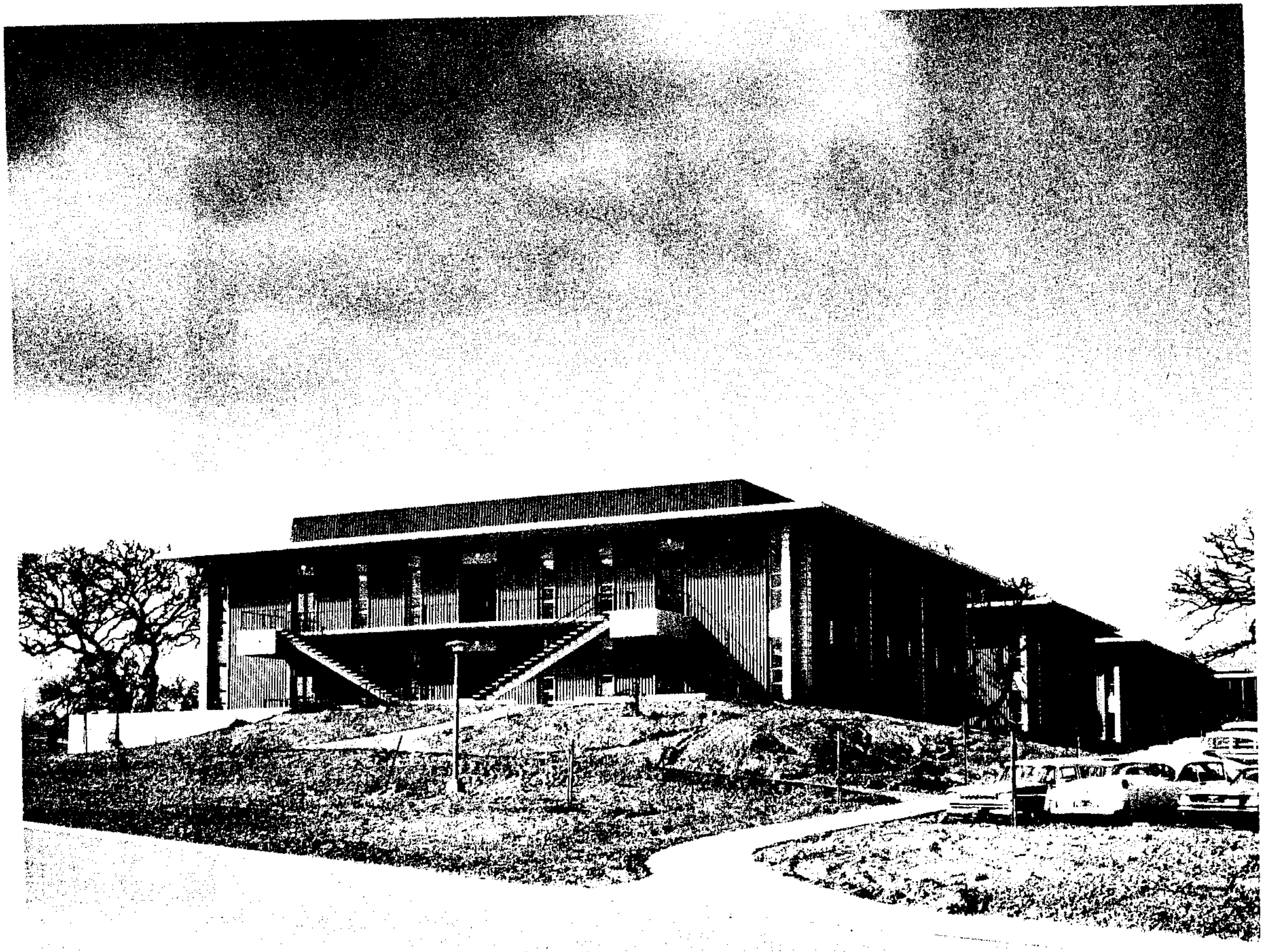
An engineering study for the conversion of the SLAC two-mile machine to a 100 GeV cryogenic accelerator was continued. Scoping and cost estimating are in progress on a proposed storage ring to be sited in the north portion of the Research Yard.

The program of plant utility operation and minor modifications to buildings as a general service to SLAC was continued.

Relocation of the front entryway incident to the widening of Sand Hill Road at the north boundary of SLAC was delayed because of inclement weather. Work has been resumed and the new entryway should be available for use in May 1969.

1329A2

FIG. 4--Central Laboratory addition, viewed from north.



1329A3

FIG. 5--Central Laboratory addition, looking southwest.

TABLE I

TABLE OF PROGRAMMED EXPERIMENTS

Number	Title	Authors	Date Approved	Status
E-7	Proposal for a Survey Experiment on Photo-Meson Production Processes at Backward Center-of-Mass Angles	STANFORD (Group F) D. Ritson, R. Anderson, D. Gustavson, R. Prepost	2/13/66	a,h
E-10	A Proposal to Study Photoproduction at Forward Angles Using the SLAC 20 GeV/c Spectrometer	STANFORD A. Boyarski, F. Bulos, R. Diebold, B. Richter	2/13/66	a,h
E-11b	A Proposal to Study ρ^0 Photoproduction From Complex Nuclei at Forward Angles	STANFORD A. Boyarski, R. Bulos, R. Diebold R.R. Larsen, D.W.G.S. Leith, B. Richter LRL L. Kaufman V. Perez-Mendez, A. Stetz	8/23/66	a,h
E-14	Proposal for Testing of Quantum Electrodynamics by Photoproduction of Asymmetric Muon Pairs	STANFORD (Group A) W. Panofsky, D. H. Coward H. DeStaebler, J. Litt, A. Minten, L. W. Mo R. E. Taylor MIT J. I. Friedman, H. W. Kendall, L. VanSpeybroeck	11/18/66	d
E-21b, E-21c	Proposal for Measurements on the Photoproduction of π^0, η, ρ^0, ω and ϕ Mesons at Small Momentum Transfer t and Photon Energies Up to 18 GeV and a Search for Mesons of Other Masses	STANFORD R. Anderson D. Gustavson, J. Johnson, R. Prepost, D. Ritson N. E. UNIV. R. Weinstein, M. Gettner CAL TECH R. L. Walker, G. Jones, D. Kreinick, A. V. Tollestrup	3/11/67	21b-h 21c-d

Table of Programmed Experiments (cont'd) - 2

Number	Title	Authors	Date Approved	Status
E-29	Search for T-Violation in Inelastic e-p Scattering	U.C. BERKELEY O. Chamberlain, G. Shapiro, H. Steiner, H. Weisberg, C. Morehouse, T. Powell, P. Robrish, S. Rock, S. Shannon STANFORD R. Taylor, L. Mo, E. Bloom, J. Litt MIT H. Kendall, J. Friedman	12/16/67	d
E-31	Measurement of the Magnitude of η_{00} and its Phase Relative to η_{+-}	STANFORD D. Dorfan, M. Schwartz, W. Wojcicki	11/ 6/67	a
E-32	A Proposed Study of K_1^0 Mesons Regenerated from a K_2^0 Beam Incident on Hydrogen	STANFORD E. B. Dally, D. J. Drickey, E. Seppi, R. Zdanis CORNELL L. N. Hand HARVARD P. G. Innocenti	12/16/67	h
E-34	Electron-Deuteron Quasi-Elastic Scattering	STANFORD E. Bloom, D. Coward, H. DeStaebler, J. Dress, J. Litt, R. E. Taylor MIT J. Friedman, G. C. Hartmann H. W. Kendall CAL TECH B. C. Barish	7/ 2/68	d
E-37	Measurement of the Total Photoabsorption	UCSB D. Caldwell, V. Elings, W. Hesse (Student), R. Morrison, F. Murphy STANFORD D. Yount	5/11/68	a
E-38	Proposal to Stanford Linear Accelerator Center for an Experiment on $\mu^+ e^-$ Scattering	UNIV. OF WASHINGTON S. Neddermeyer, N. Scribner, P. Kotzer, G. Eilenberg, T. Koss	8/ 5/68	c,b

Table of Programmed Experiments (cont'd) - 3

Number	Title	Authors	Date Approved	Status
E-39	Proposal to Study Photoproduction of Neutral Bosons at Medium Four-Momentum Transfer	CAL TECH A. Tollestrup, J. Pine, R. Gomez, R. Barish, C. Peck, F. Sciulli, B. Sherwood	8/ 5/68	a,g,h
E-40	High Statistics Study of the Production of Charged $\rho^{\pm}$ Mesons, Neutral ρ^0 Mesons, f^0 Mesons and Nucleon Isobars by Pions	SLAC J. Cox, B. Dieterle, W. Kaune, M. Perl, J. Pratt, J. Tenenbaum, W. Toner, T. Zipf	8/ 5/68	d
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	c,b
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	d
E-43	Velocity of Light Experiment	UCSD G. Masek	12/14/68	c
E-44	Coherent Regeneration from Hydrogen	UCLA D. Drickey, H. Ticho, D. Stork, C. Buchanan, D. Rudnick, P. Shephard SLAC E. Dally, E. Seppi, JOHNS HOPKINS L. Ettlinger, R. Zdanis CERN P. Innocenti	2/ 8/69	d
E-45	Proposal for the Measurement of π^+ Photoproduction with Polarized Photons at SLAC	MIT D. Luckey, L. S. Osborne, R. Schwitters SLAC A. Boyarski, R. Diebold, S. Ecklund, B. Richter	12/14/68	d

Table of Programmed Experiments (cont'd) - 4

Number	Title	Authors	Date Approved	Status
E-47	π^+ Photoproduction with a Polarized Target	LRL O. Chamberlain, C. Morehouse, T. Powell, P. Robrish, S. Rock, S. Shannon, G. Shapiro, H. Weidsberg SLAC A. Boyarski, R. Diebold, S. Ecklund, Y. Murata, B. Richter	2/ 8/69	d
E-48	Proposal to Measure the ξ Parmeter in the Decay $K_L^o \rightarrow \pi\mu\nu$	BNL D. Hill, R. Palmer, M. Sakitt, N. Samios SLAC D. Fries, F. Liu, R. Mozley, A. Odian, J. Park, W. Swanson, F. Villa	2/ 8/69	d
E-49	Inelastic Electron Scattering from D_2	SLAC L. Cottrell, D. Coward, H. DeStaebler, D. Jordan, R. Taylor MIT J. Friedman, H. Kendall	2/ 8/69	d
E-50a	Compton Scattering at High Energies	SLAC R. Anderson, D. Gustavson, J. Johnson, I. Overman, D. Ritson, B. Wiik HARVARD UNIV. J. Walker NORTHEASTERN UNIV. R. Weinstein	3/22/69	d
BC-4a	K^+p, π^+p, and π^- Interactions Near 12 GeV/c (82-Inch HBC)	LRL M. Abolins, O. Dahl, P. Dauber, P. Eberhard, S. Flatté, L. Galtieri, M. Alston-Garjost, J. Kirz, G. Lynch, J. Murray, F. Solmitz, L. Stevenson	12/16/67	a,h

Table of Programmed Experiments (cont'd) - 5

Number	Title	Authors	Date Approved	Status
BC-6	Proposal to SLAC for Study of the One Pion Exchange Contribution to γ-Nucleon Scattering (in 40-Inch Deuterium Bubble Chamber)	OAK RIDGE H. O. Cohn, R. D. McCulloch UNIV. OF TENNESSEE G. T. Condo, W. M. Bugg	9/28/68	c
BC-10	A Proposal to Investigate 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	d
BC-11	A Proposal for a Bubble Chamber Experiment with the Polarized Laser Induced Photon Beam	Spokesman: Günter Wolf	5/11/68	a, h
BC-13	Proposal for a 3,000,000 Picture 7.5 GeV/c π^-p Exposure in the 82-Inch Bubble Chamber	UNIV. OF ILLINOIS G. Abrams, G. Ascoli, B. Crawley, B. Eisenstein, R. Hanft, U. Kruse, D. Mortara, T. O'Halloran, R. D. Sard	8/ 5/68	a, h
BC-14	Proposal for 7.5 and 13 GeV/c, π^+ and π^- Exposures in the SLAC 82-Inch HBC	MIT P. L. Bastien, D. Brick, T. Dao, B. T. Feld, R. I. Hulsizer, L. Kirkpatrick, V. Kistiakowseky, H. Lubatti, D. Miller, A. Nakkasyan, G. Ouannes, I. Pless, A. Sheng, T. Watts, F. Winkelmann, J. Wolfson, R. Yamamoto	8/ 5/68	d
BC-15	Proposal for an Exposure of the 82-Inch Deuterium-Filled Bubble Chamber to a 7 GeV/c π^- Beam at SLAC	UNIV. OF ROCHESTER T. Ferbel, W. Katz, P. Slattery, S. Stone, H. Yuta	9/28/68	d

Table of Programmed Experiments (cont'd) - 6

Number	Title	Authors	Date Approved	Status
BC-16	K^+-p Interactions Around 7 GeV/c	JOHNS HOPKINS UNIV. A. Callahan, B. Cox, L. Ettlinger, A. Pevsner, R. Sekulin, R. Zdanis	8/ 5/68	h
BC-17	A Search for 1^+K^* Mixing Effects by Coherent Production on Deuterium at 12 GeV/c	LRL BERKELEY D. G. Coyne, A. Firestone, G. Goldhaber, J. A. Kadyk, G. H. Trilling	9/28/68	d
BC-18	A Proposal for a 4.25 BeV γ-Deuterium Experiment in the SLAC 40-Inch Bubble Chamber	WEIZMANN INSTITUTE Y. Eisenberg, B. Haber U. Karshon, L. Lyons, E. E. Ronat, A. Shapira G. Yekutieli	9/28/68	a
BC-19	A Proposal for a γ-d Experiment with an Annihilation Beam of 7.5 GeV in the SLAC 40-Inch Bubble Chamber	TEL AVIV UNIV. G. Alexander, I. Bar-Nir, A. Brandstetter S. Dagan, J. Gunhaus, A. Levy, Y. Oren	9/28/68	a
BC-20	Exposure of the 82-Inch Deuterium Chamber to a Beam of π^+ Mesons at 13.4 GeV/c	PURDUE UNIV. D. H. Miller	3/22/69	d
BC-21	Study of π^--D Interactions at 12 GeV/c in the 82-Inch Bubble Chamber	U.C. -RIVERSIDE D. Davison, W. Jackson, W. Mehanti, R. Rice, Y. Williamson, Y. Oh, R. Bacastow, W. Barkas, S. Fung, E. Hart, A. Kernan, R. Poe	3/22/69	d
ND-4	Tests of Sodium Iodide and Other Total Absorption Counters	HEPL E. B. Hughes, R. Hofstadter, I. Sick W. Lakin, L. Madansky	5/ 8/68	g

Table of Programmed Experiments (cont'd) - 7

Number	Title	Authors	Date Approved	Status
NT-6	Fast Cycling Bubble Chamber Development	SLAC H. Barney, R. Blumberg, A. Rogers, S. St.Lorant	12/15/68	c
NFD	A Proposed Study of High Energy Cosmic Ray Muons at Sea Level	U. C. BERKELEY S. M. Flatté, M. L. Stevenson SLAC W. Toner, T. Zipf	8/23/68	c

---

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

VI. KLYSTRON STUDIES

A. Development

1. Summary

RCA and SLAC are continuing a development program to improve tube performance. The basic goal is to increase the operating level to 270 kV instead of the present level of 250 kV maximum, and to achieve reliably a minimum peak power output of 30 MW compared to the present minimum of 21 MW.

SLAC has also begun some preliminary design work aimed at the development of a stable and reliable CW amplifier which would be used to supply the rf energy to a proposed superconducting accelerator.

Other work in further window improvements and vacuum system reliability is continuing.

2. High Power Klystrons

Litton Subcontract. During the past quarter the total number of acceptable tubes delivered by Litton has been higher than in the past, although still barely adequate to cover the total number of Litton failures. It must be noted that almost one-half of the accepted tubes were "new" tubes. They were built as nearly as possible to the design and fabrication techniques which Litton had been using in 1965 during the initial production phase of their contract; and the acceptance rate of these "new" tubes is almost the same as that which we observed during the initial deliveries of Litton under this subcontract. This might indicate that the repairability of the tubes which have operated for a large number of hours in the gallery is extremely doubtful and that it might be necessary for the vendors to replace all failures by new tubes.

The above is not to say that there were no problems experienced with the new tubes built by Litton. They had some in-house production problems (leaks and failures in bake) and some tubes showed some instabilities which can be usually resolved by careful mating to specific magnets. In other words, the interchangeability problem still exists, but it appears that some of the major difficulties at Litton (including inability to operate the tubes at full voltage) may have been resolved.

RCA Subcontract. During the past year SLAC has been discussing with RCA the desirability and the possibility of upgrading the existing RCA tubes and making them operable at 270 kV with a minimum power output of 30 MW. Because of the work being done at RCA in this direction, the total number of replacements shipped by RCA has been very minimal. During this last quarter RCA has begun more regular shipments but the acceptance yield has been disappointing. RCA has experienced a number of manufacturing problems, including test equipment failures and quality control of window coating.

We have spent considerable time discussing with RCA the development program which they have outlined to achieve the goals of the improved tubes and we feel that in general their program is now on a firm basis.

On the basis of all evidence available the RCA electron gun is easily capable of operation at 270 kV without exceeding the gradients observed in the SLAC tubes operating at 250 kV. Hence from a cathode design standpoint the RCA tube should be very conservative for the new mode of operation. The problem of obtaining 30 MW output appears then to be mostly one of increasing tube efficiency and decreasing the power density in the klystron collector. The RCA collector has the smallest cooling area of any vendor and it is believed to be unable to operate satisfactorily at 270 kV. (But neither can a bumblebee fly!) Hence, RCA has redesigned the collector to decrease the maximum power density and tested it specifically to be sure that the change in collector size would not introduce unwanted oscillations and instabilities in the tube output. On the question of increasing efficiency RCA has now set up a program of introducing changes in drift distances, of modifying the output cavity Q to optimize the transfer of energy from the beam to the load, and studying the effect of the magnetic field on the power output. It is the goal of this program to achieve the higher efficiency in the same magnetic field used for the present RCA tubes. However, there are a few magnets in existence with a slightly higher maximum field and these will be used on the initial deliveries of the 30 MW tubes. Up to now RCA has built six test vehicles under this program. Unfortunately, they have only been able to ship two of them and one was dropped in shipment by the carrier and has not yet been tested at SLAC. The one tube tested at SLAC gave us a power output close to 29 MW at 270 kV. Unfortunately, the tube would not operate without excessive faulting at 270 kV 360 pps. We believe that the manufacturing problems mentioned above are responsible for the lack of satisfactory operation at full average power at this voltage level. Two of the other test vehicles built and tested at RCA have indicated power output in excess of 30 MW in optimized fields and in excess of 29 MW in the fields available from our permanent magnets. Hence there is good reason to believe that within the next few months RCA will be in a position to deliver tubes which can be operated at 270 kV and at better than 30 MW output. Some of the test tubes will not be shipped because of window problems (multipactoring) or leaks resulting from several bake cycles and rebrazing operations.

SLAC. The majority of the work at SLAC has been as in the last few quarters concentrated in the elimination of gas and arcing problems which had decreased the yield to an unacceptable value. Basically, a gas analysis indicated that the heater coating used during the past year produced considerable gas and resulted in too low a probability of fabrication of acceptable tubes.

A new ceramic mounted heater package has been designed and has been used in the tubes built (or rebuilt) during the quarter. We have also revised the cathode conversion schedule and there appears to be a substantial improvement in overall tube yield.

However, an oscillation which had been observed only upon occasion during the past few years seems to have reappeared on the majority of tubes built this quarter. Although the oscillation can be eliminated by special focusing the right approach seems to be to locate the source of the oscillation and eliminate it. At the present time there are several suspected reasons: a third cavity mode whose frequency is very close to that of the observed oscillation is the most likely suspect. Changes made in the cathode temperature uniformity and in cathode conversion cycle may have resulted in different beam scallops which could now excite the third cavity unwanted mode. Tubes will be built next quarter with the unwanted mode suppressed in the third cavity.

In addition some minor redesign work is being carried on to try to understand the variations in efficiency from tube type to tube type as well as differences within a given tube type. To this effect the special tubes have been built and tested with changes in the diameter of the last two drift tubes. Although these tubes have not given us as high power output as our "standard" XM14B type tube, one potentially significant piece of data was obtained and is given in Fig. 6, which shows the relative output at saturation and the relative output for small signal gain as a function of drive frequency. Tube C is a standard XM14B; A and B are the tubes with reduced drift tube diameters. It appears that if we drove the tubes at a frequency of 10 - 15 MHz lower than at present we could improve the power output by 5 - 10%. Conversely it appears possible then to redesign the tube by changing the cavity frequencies in an appropriate fashion to achieve the same improvement in power at 2856 MHz. Theoretical studies are being carried out on this point and it is expected that some tubes will be built to try to determine the possibility of further efficiency improvements by appropriate tuning of the third cavity.

3. Klystron for Superconducting Accelerator

The paper design of the klystron for the superconducting accelerator has been substantially completed, and the details are given below. Although the same general considerations would be applicable for different frequencies of operation, we are considering at present in any kind of detail only a tube to operate at 2856 MHz.

The klystron is being designed to produce 20 kW of CW power at approximately 50% efficiency. To design a klystron with maximum efficiency a microperveance (μk) ≤ 1.0 and a normalized beam radius (γb) of $0.8 \pm 30\%$ must be obtained. For low beam velocities $\gamma b \cong \beta_e b = \omega b/\mu$. A beam voltage of 20 kV and a beam current of 2 amperes has been chosen which gives a $\mu k = 0.707$. We designed the beam diameter to be 0.394" ($2b \times 1.0$ cm). The above satisfies the power supply, klystron power output and efficiency requirements.

The klystron will be designed to operate in a permanent magnet under immersed focus conditions. The maximum field will be from 3.5 to 4.0 times Brillouin focusing conditions. Brillouin focusing field for this tube is approximately 200 gauss. A modified version of the driver amplifier permanent magnet presently will be used. An electromagnet and a permanent magnet have already been prepared for the application (refer to Fig. 8 for the magnetic fields in the cathode region). Due to phase and amplitude requirements, it may prove essential to use only Alnico 8 magnets. Experience has shown that ferrimag 5 (ceramic) magnets exhibit that some nonuniform field changes when the ambient temperature of the material is changed.

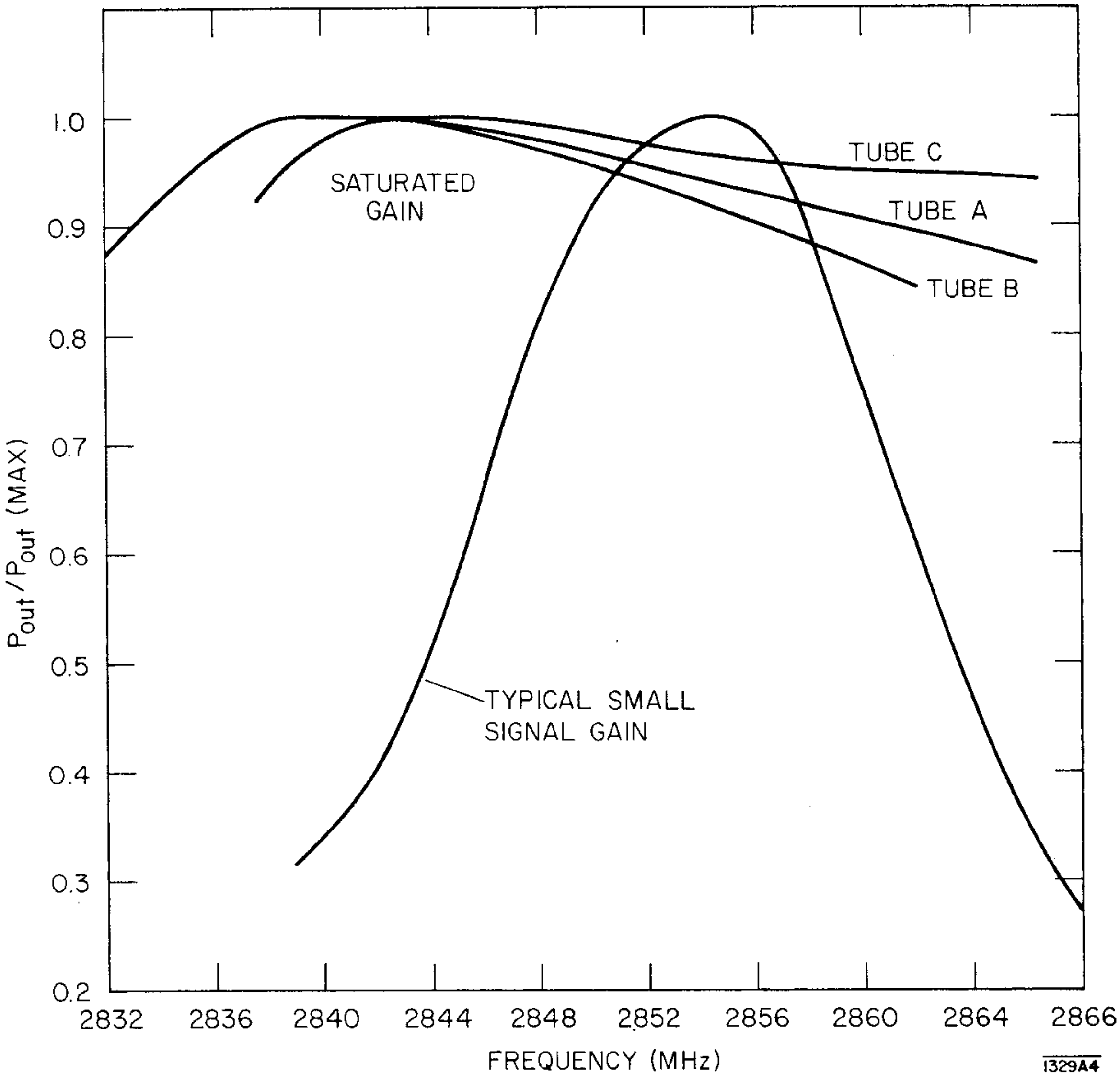


FIG. 6--Frequency response of experimental SLAC klystrons.

A cathode diameter of 1" gives an area convergence ratio of 6.45 to 1 and affords usage of a small magnet such as the present driver amplifier magnet. The first cathodes made will be oxide coated. These will be made to determine the capabilities of oxide cathodes drawing a direct current of 0.400 amperes/cm^2 and to establish the correctness of the gun optics. It is believed that this current density is too high to obtain satisfactory klystron life with an oxide cathode. Hence a dispenser cathode is planned for this application and would hopefully result in a mean life of 10,000 hours from these tubes. The cathode design has been completed making use of the SLAC Gun Program. The computer estimates a $\mu k = 0.70$ and excellent beam handling characteristics (refer to Figs. 7 and 8). The oxide cathode will require a filament wattage of 42 watts and the dispenser cathode will require approximately 100 watts. Extreme caution will be taken in the heater design to prevent stray magnetic fields that might produce unwanted modulations.

The collector should be designed for at least 50 kW CW since the first design models will undoubtably be low in efficiency. The collector presently being used on the 2422 klystron should be usable since this collector is capable of dissipating 80 kW of average power with a water flow of 11 gpm before cavitation problems become severe. Here again we are making use of the SLAC computer program to evaluate this type of collector for impinging power when operating both with and without the output cavity lens effect and the external magnet field which exists when using permanent magnets. The above conditions make the universal beam spreading curve invalid.

The interaction space is designed for maximum efficiency, specified gain with good isolation between cavities and good phase characteristics. The beam radius will be from 0.7 to 0.8 times the drift radius and the normalized beam radius (γb) will range from 0.94 to 1.07. Under these conditions the third and fourth drift lengths should be 0.16 γq and 0.08 γq respectively for optimum efficiency where γq (the reduced plasma wavelength) = 45.8 cm. A plot of normalized rf current is seen in Fig. 9. 40 db gain must be achieved in the first two drift sections. This can be done in approximately 50% shorter drift lengths but it is felt that by detuning the second and third cavities by 45° we can obtain less phase variations per °C change in water temperature and gain better isolation between cavities. The second and third drift lengths are both 0.092 γq.

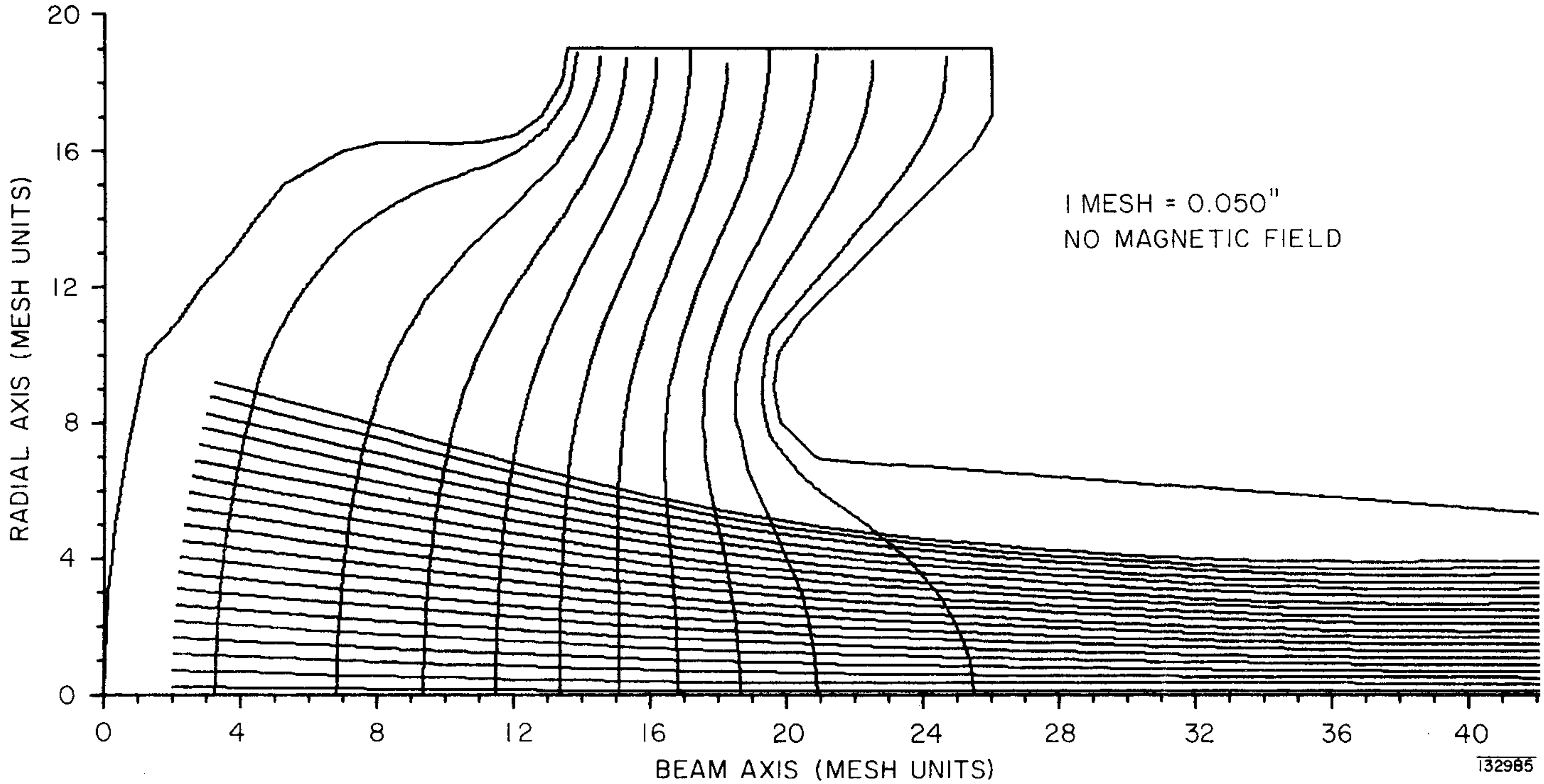


FIG. 7--Computer designed gun design and beam trajectories for superconducting accelerator klystron.

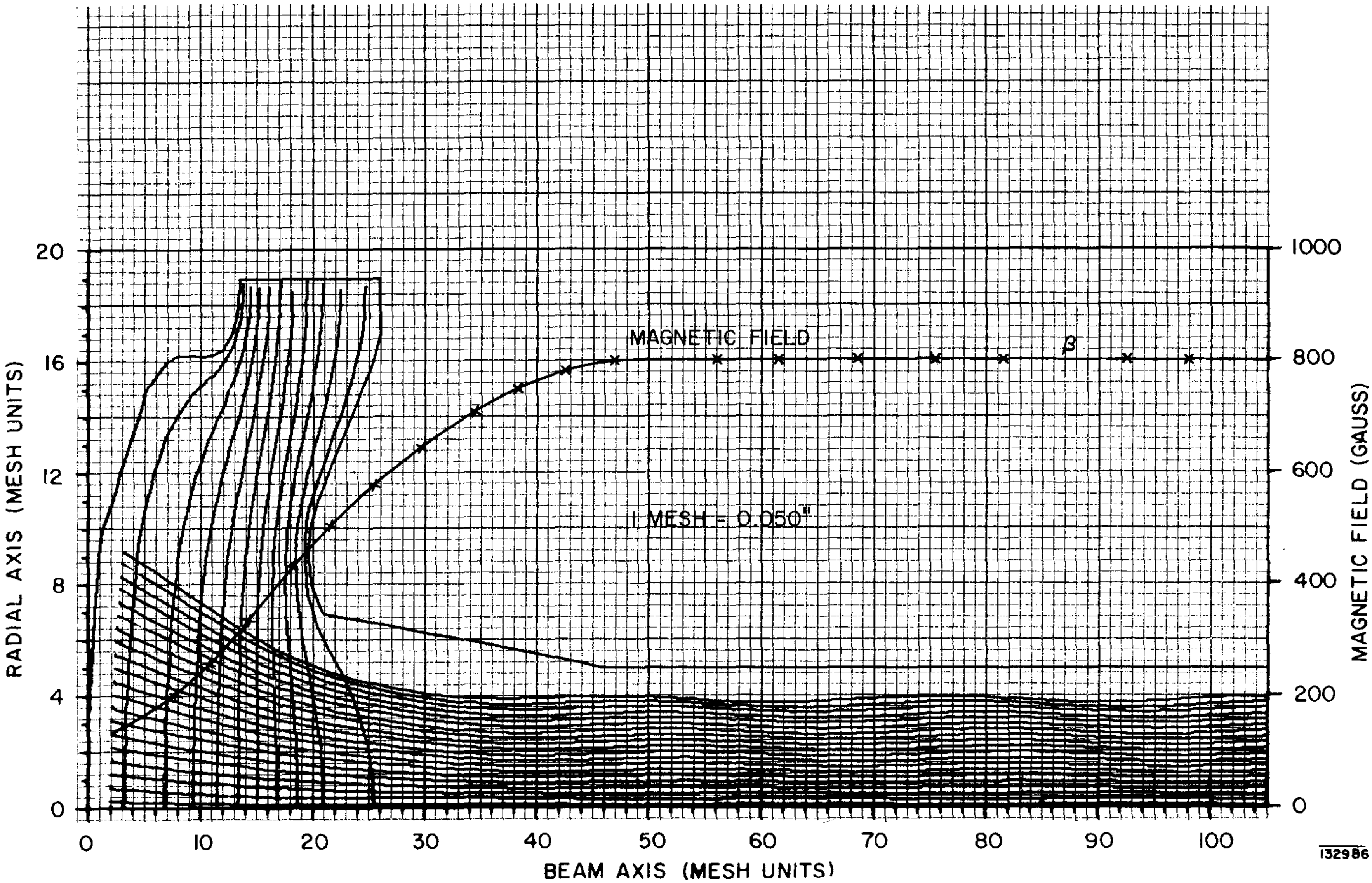


FIG. 8--Computed effect of magnetic fields on beam trajectories for superconducting accelerator klystron.

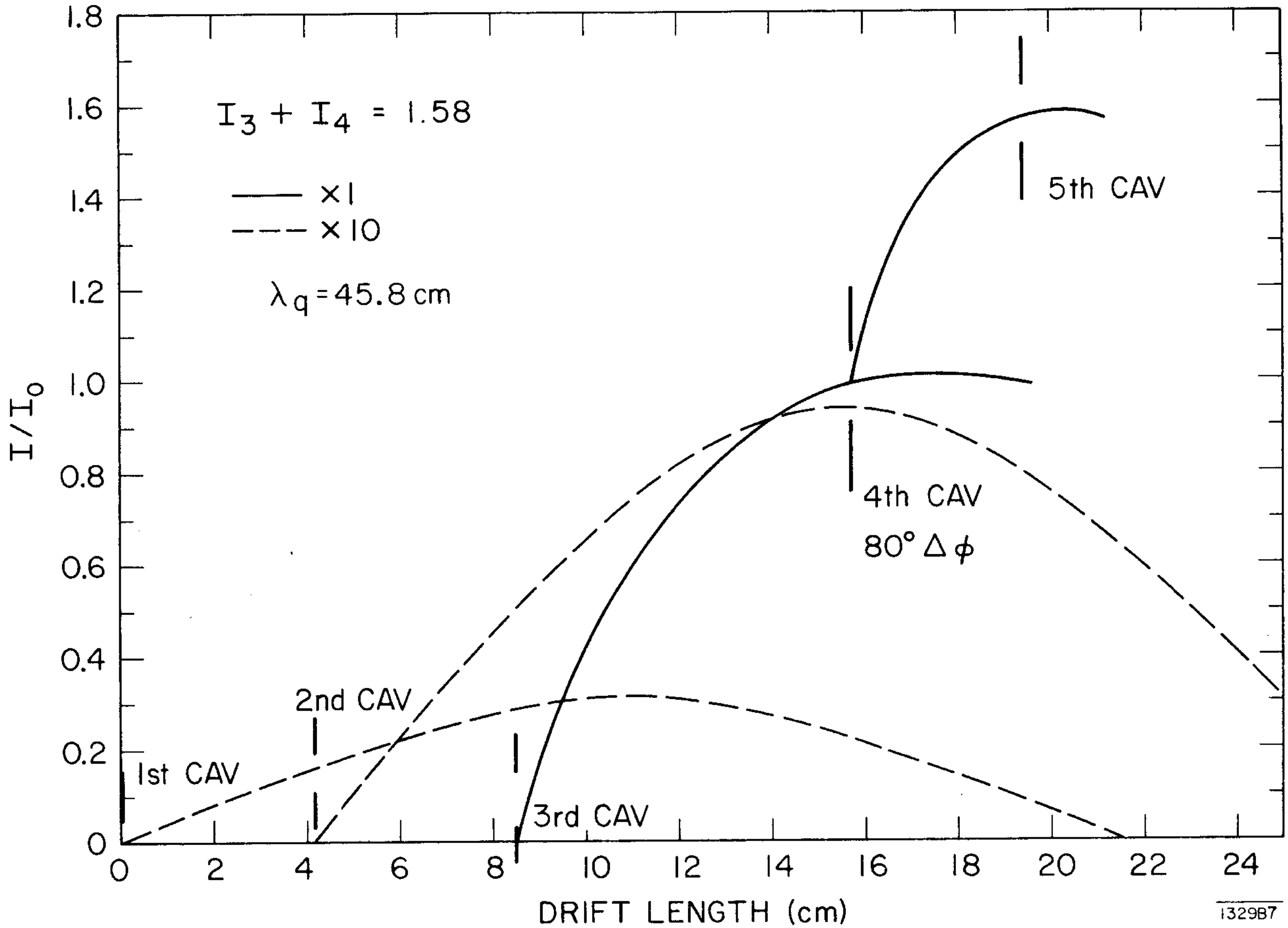


FIG. 9--Normalized rf current, klystron for superconducting accelerator.

A high Q_0 is required in the fourth and fifth cavities because of heating effects during rf drive conditions which cause considerable phase shift as can be seen in the table of parameters (Fig. 10).

Conventional cooling methods will probably be adequate in this application through careful design to minimize phase variations. If conventional cooling schemes fail one might consider use of the heat pipe principle to stabilize temperature gradients and for fast heat transfer. The rf input and output circuits will be temperature stabilized as well as the cavities. It is proposed that a thermal overload be attached to each tube to interrupt operation in case of high body interception. The same window and output flange used at present on the 2422 klystron will be used.

4. High Power Windows

SLAC. During the quarter three SLAC tubes operated at very high window temperature during the initial tests; one of these failed thermally during such tests. Since these windows were coated and tested at approximately the same time, it appears that a new variety of window heating problem may have developed.

Measurements of low resistances on the two hot windows already removed from tubes verify that the excessive heat losses were occurring on the surfaces of these ceramics. The nature and origin of the low resistance layers are yet to be determined. Analysis of the new window heating phenomenon has been complicated by the fact that the three hot windows have shared several conditions that have not been encountered by other windows used recently. All three are new windows on tubes for the first time. All were tested in the resonant ring prior to installation on klystrons, whereas most SLAC windows are no longer tested before tube use. Finally, all three were on klystrons exposed to a new processing and conversion cycle. While other tubes have undergone the new processing routine, only these three have been processed at the $620^{\circ}C$ maximum temperature of the double-vacuum bake station. The processing cycle may or may not be associated with the window heating, but the higher bake temperature certainly aggravates whatever condition is causing the heating.

Apart from the new hot window problem, SLAC windows have been performing quite well recently. Disregarding three failures of windows coated with boron nitride and two windows that failed while operating into partially evacuated loads,

	Units	2856 MHz	1428 MHz*
Beam Voltage	kV	20	20
Beam Current	A	2	2
Microperveance	$(A/V^{3/2})10^{-6}$	0.71	0.71
Relativistic Correction Factor		1.039	1.039
Beam Velocity	cm/sec	8.15×10^9	8.15×10^9
Type Cathode		Dispenser	Oxide Coated
Gun Design		Immersed Flow	Immersed Flow
Max. Magnetic Field	Gauss	800	400
Drift Beam Diameter	cm	1.00	1.5
Drift Tube Diameter	cm	1.27	2.0
Reduced Plasma Frequency[12, 13]	MHz	178	107
Reduced Plasma Wavelength	cm	45.8	74.8
Drift Distances (Plasma Wavelength)	cm		
1 to 2		4.2	6.0
2 to 3		4.2	5.3
3 to 4		7.3	12.0
4 to 5		3.7	6.7
Drift Distances (Plasma Wavelength)	cm		
1 to 2		0.092	0.08
2 to 3		0.092	0.07
3 to 4		0.160	0.16
4 to 5		0.080	0.080
Gaps Transient Angles	Radians		
1		0.5	0.5
2		0.5	0.5
3		0.5	0.5
4		0.75	0.75
Transit Time, Input to Output Gap	Elec. $^\circ$	2450	1950
Phase Shift vs. Beam Voltage	Degrees/%	12.5	10.0
Phase Shift vs. Input Water Temp.	Degrees/$^\circ$C	2.2	
Phase Shift During RF Power	Degrees	0.75-1.5	
Beam Loading Conductance (G_B)[14]			
Cavities 1-3		$0.137 \times G_0$	$0.137 \times G_0$
Cavities 4-5		$0.147 \times G_0$	$0.147 \times G_0$

FIG. 10--Design parameters of klystrons for superconducting accelerator

FIG. 10--Continued

	Units	2856 MHz	1428 MHz*
Beam Coupling Coefficient (M)[14]			
Cavities 1-3		0.76	0.91
Cavities 4-5		0.74	0.89
Correction of G_B and M for Relativity		0.94	0.94
Input Cavity Q_L		420	400
Output Cavity Q_L		135	110
Intermediate Cavities Q_L		575	460
Input Cavity R/Q		100	100
Output Cavity R/Q		100	100
Intermediate Cavities R/Q		120	120
Cavity Tuning	MHz		
1		2856 ± 0.1	1428 ± 0.2
2		2856 ± 0.5	1429 ± 0.5
3		2859 ± 0.5	1429.5 ± 0.5
4 (detuned to $80^\circ \Delta\phi$)		2876 ± 1.0	1438 ± 1.0
5		2856 ± 2.0	1428 ± 2.0
Drift Tube Isolation	dB/cm		
TE_{11} Mode		22	
TM_{01} Mode		33	
Computed Gain (saturated)	dB	54	
Computed Gain (small signal)	dB	71	
Computed Electronic Efficiency	%	57	59

*The data for 1428 MHz is tentative and requires further study.

the window that cracked this quarter was only the second known thermal failure of a SLAC window made or reworked after 1966.

Until recently ceramic leaks have been virtually overlooked as a window problem. During 1965 and 1966 when thermal failure was still the predominant SLAC window trouble, only a few punctures were discovered, along with a few invisible leak paths not then acknowledged to be punctures. Since then ceramics with punctures, usually invisible, have been turning up at a rate of one or two per quarter, mostly on klystrons removed from the accelerator. One of the most puzzling aspects of SLAC window punctures has been the fact that none of the invisible hole failures had been discovered on klystrons made elsewhere. However, it was learned during the past quarter that failures fitting the exact description have become an important problem on windows of high power klystrons made by Thompson-Varian for installation on the injector-linac at DESY at Frankfurt.

Ceramic punctures now comprise a total of 20 of the 65 known failures on SLAC windows coated since September 1964. Six of these punctures are large enough to be visible on one or both surfaces of the ceramic, but the remainder are invisible holes only detectable by means of helium leak detector probing. Approximately 5 % of all windows installed on SLAC klystrons have failed in this way. The rate of punctures per year has decreased in windows manufactured since 1966. A possible explanation for the apparent improvement could be the increased attention to window cleanliness that began in early 1966 when purging the output waveguide with nitrogen became a precautionary routine. Another possible reason could be more effective guarding of the window against over-voltage by reflected energy protection circuitry.

Other Tests. The resonant ring has been used to perform tests on prototypes on the heliarc-welded windows for use with SLAC tubes as well as the comparison of various types of coating; for instance those applied by electron beam evaporation. We are also attempting to establish by use of the ring a technique for measuring the amount of light produced by a window during an operation. The purpose of this technique would be to provide an objective measure of the light intensity and possibly wavelength associated with multipactor activity. It could provide the means of associating window phenomena with other aspects of tube behavior and finally it could be used as a tool to predict the probability of window failures.

The problem of measuring coating resistance changes under vacuum bake cycle conditions has not been resolved yet. It is probable that vapor film deposited from the existing vacuum system impose severe limitations on the measurements made to date. Accordingly an ultra-clean ion pumped vacuum system is being designed to do the work under more controlled conditions.

4. Vacuum

A few Viton-A valves have failed to seal adequately during klystron removals in the past few months. The problem appears to be a hardening of the Viton-A O-rings. Quantitative hardness measurements were made on an assortment of samples taken from the accelerator vacuum system and from spares stored in plastic boxes in cabinets. In general the O-rings taken from the accelerator vacuum system were found to be significantly harder than those stored in plastic boxes. Similarly an O-ring removed from a spare valve stored in atmosphere was found to have a hardness comparable to spare O-rings stored in cabinets.

Experts in the elastomers agree that the hardening effect should not occur in Viton-A at room temperatures as a result of exposure to vacuum. It is, however, possible that vacuum evolution of fillers and curing agents could account for weight reduction and possibly hardening effects. We must still determine whether or not this hardening effect is a continuing process, and we hope to obtain such information by a thorough literature search.

Studies have also been conducted of the possibility of adapting the present vacuum system for superconducting accelerator, and a full report of the probable modifications needed has been submitted.

5. Driver Amplifier Klystrons

No problems.

B. <u>Operation and Maintenance</u>

During the quarter we had 20 high power klystron failures corresponding to an operating time of 329,000 hours. The number of spares available for immediate installation has remained substantially constant and the total spares available are adequate for safe operation of the accelerator.

Driver amplifier klystrons logged 48,000 hours of operation (including 3,000 hours in the test laboratory). There was a total of three failures, 1 Eimac and 2 SLAC during this time.

Main booster klystrons did not present problems. Only one station was in operation during the quarter because the second was being rebuilt.

1. High Power Klystron Operation

Table II gives a summary of usage and failures since the beginning of machine operation, with the exception of removal of all Sperry hours and Sperry failures from the table. Hence there will be substantial differences between this table and those appearing in previous quarterly reports.

The overall life of high power klystrons continues to exceed our expectations as evidenced by the above table and shown in the following figures. Figure 11 shows the tube age distribution for all operating klystrons which indicates mean age of 8, 840 hours and a median age of 10, 600 hours. Figure 12 gives the tube age distribution of all failures since the beginning of operation. The preponderance of failures at less than 500 hours indicates that the high percentage of all failures have been of the infant mortality type.

Analysis based on Figs. 11 and 12 gives the results shown in Fig. 13 indicating the failure probability per 1, 000 hours of operation and survival probability of all tubes used on the machine. There appears to be no significant change in the failure probability from age 1, 000 up to age 14, 000 hours which indicates that the failures are random and should be considered as accidental.

Figure 14 gives a general recapitulation of the cumulative mean time between failures (MTBF), the cumulative operating hours per socket, the mean age of all operating tubes, and mean age at failure per quarter.

2. Effect of Operating Level

With the continuing operation of 96 sockets at 245 kV, the MTBF can be computed for various operating levels, and the results are shown in Table III. The effect of operating level on probably life has also been studied by analyzing the failure rates of tubes installed since July 1, 1967, segregated by operating levels. The results are shown in Fig. 15 which also includes a survival curve for all tubes installed since July 1, 1967 regardless of operating level.

Based on the evidence of Fig. 15 there appears to be indeed a decrease in survival probability as the operating level is raised from 235 to 245 kV. Possibly more interesting is the fact that for all tubes installed since July 1, 1967 the survival probability appears to be somewhat lower (shown in Fig. 13) for all tubes since the beginning of operation. However, in both cases the decrease is small (approximately 10% fewer survivals at 6, 000 hours) and since the total sample used in deriving Fig. 15 is also very small it is not certain that the

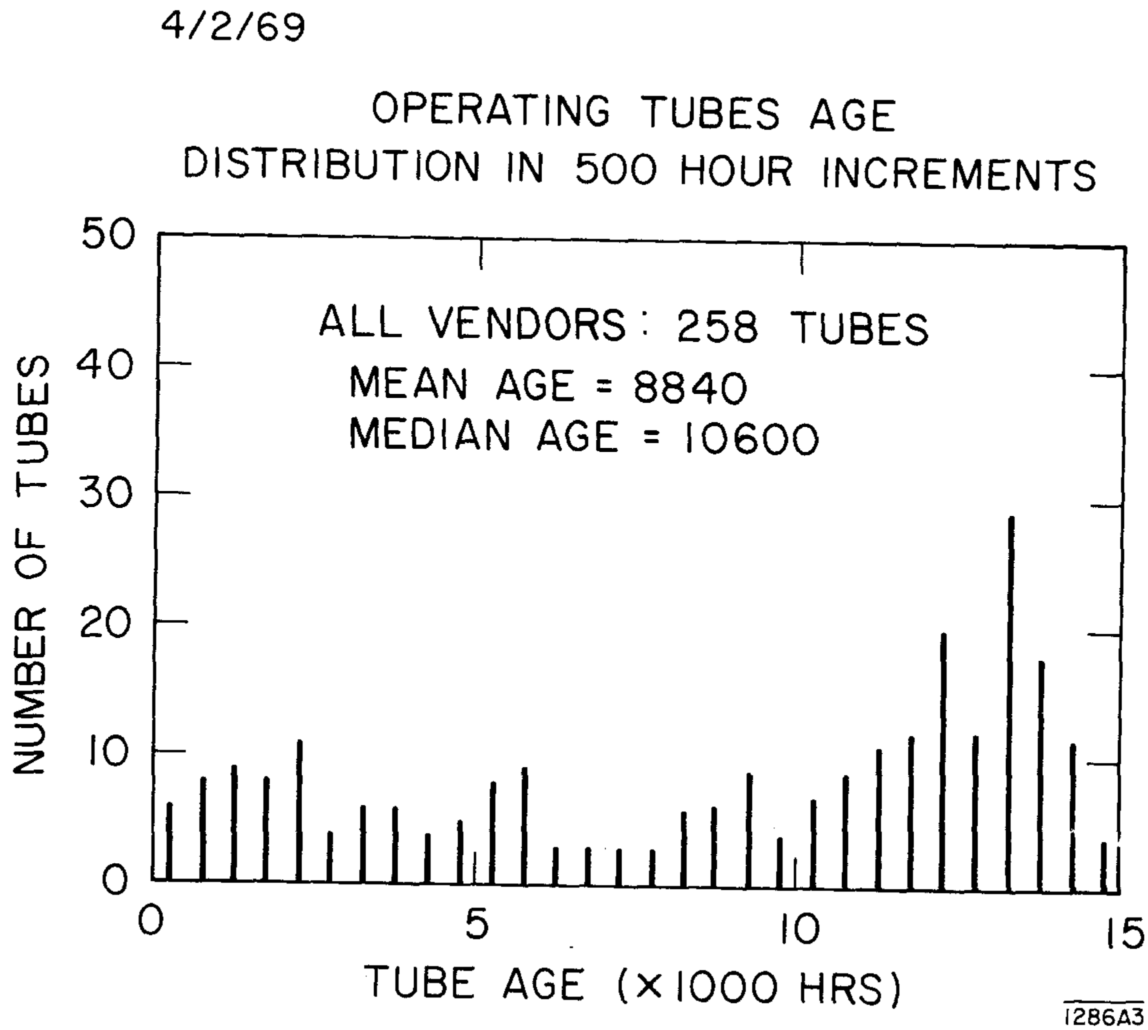


FIG. 11--Age distribution, operating high-power klystrons.

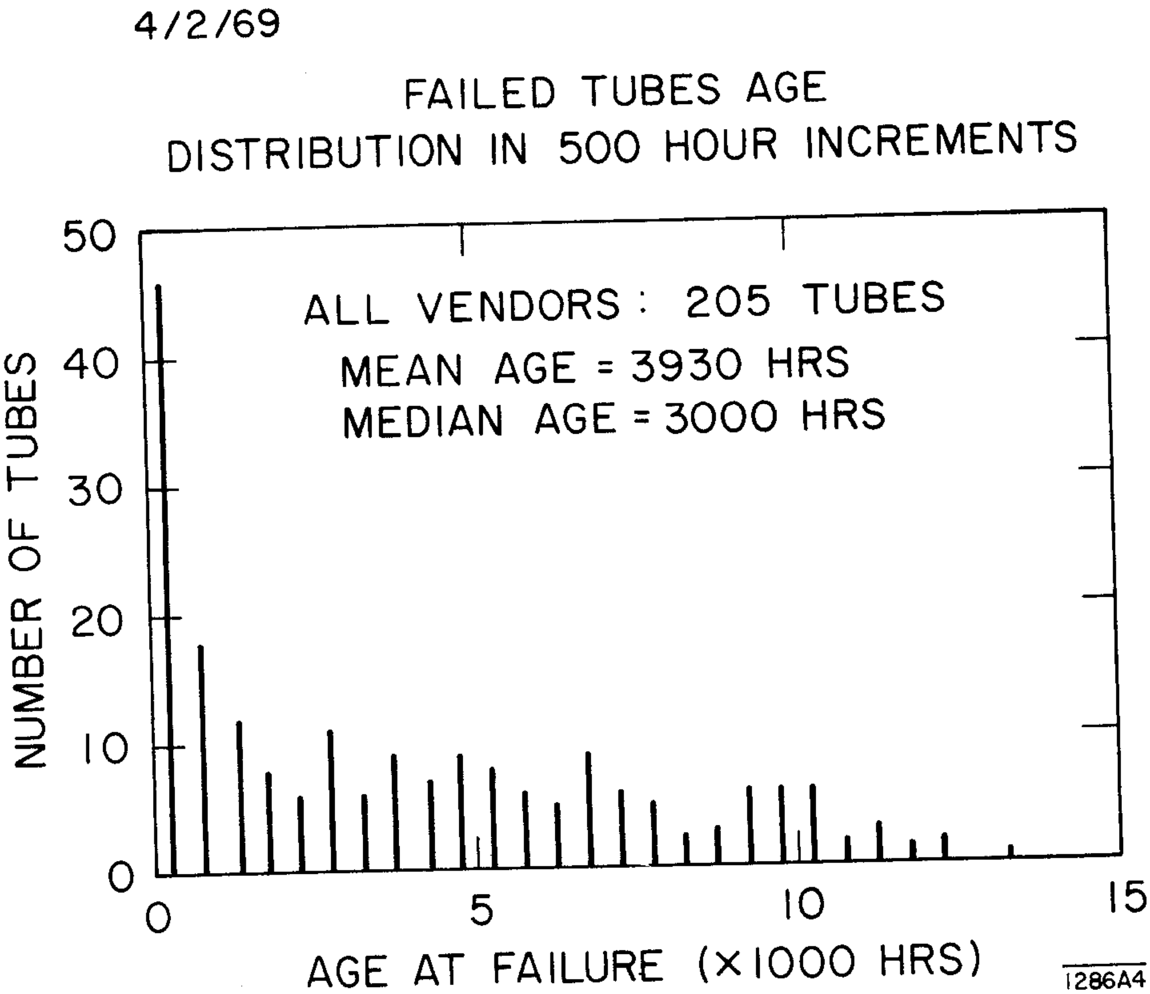


FIG. 12--Age-at-failure distribution, high-power klystrons.

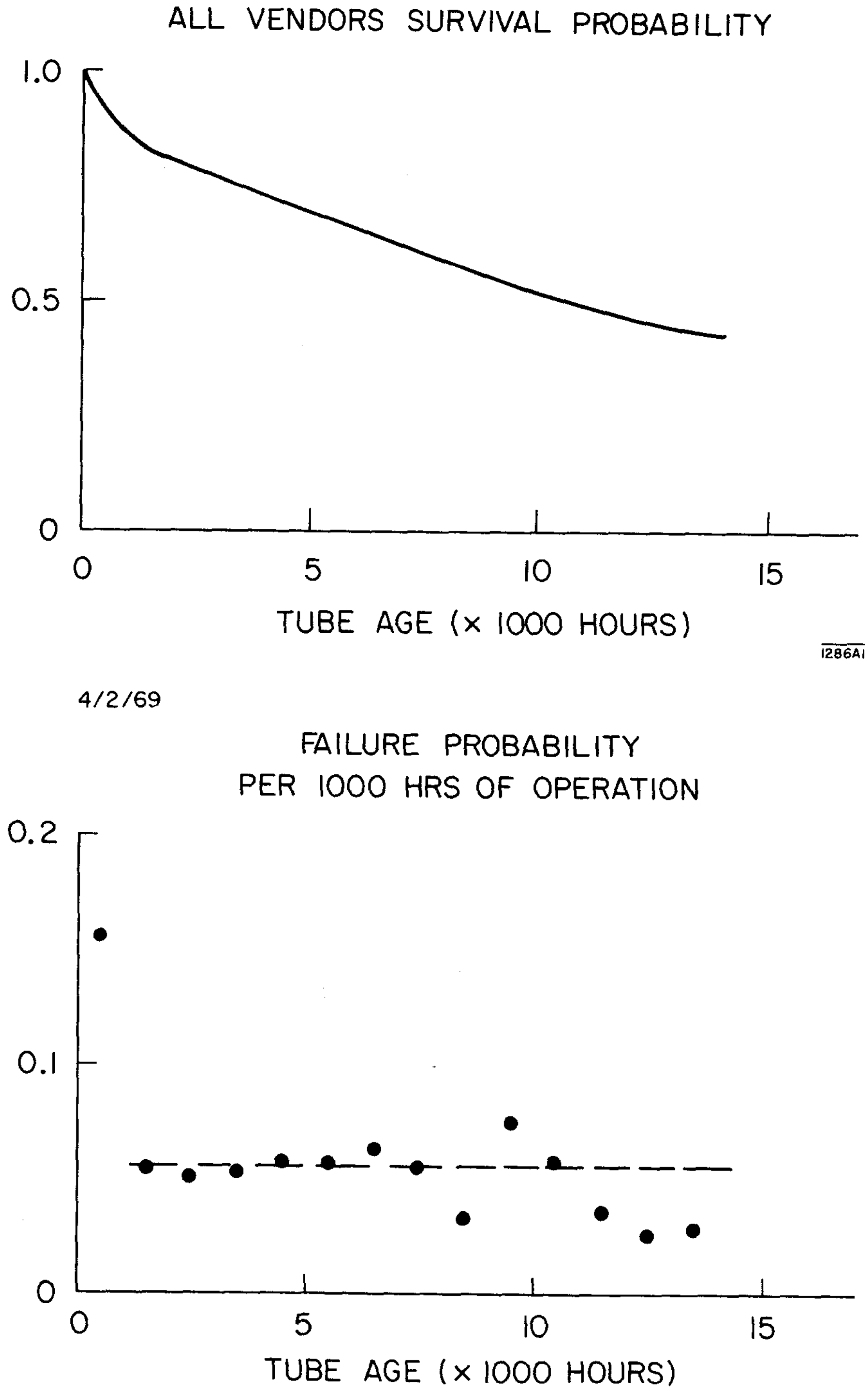


FIG. 13--Survival and failure probabilities, high-power klystrons.

4/2/69

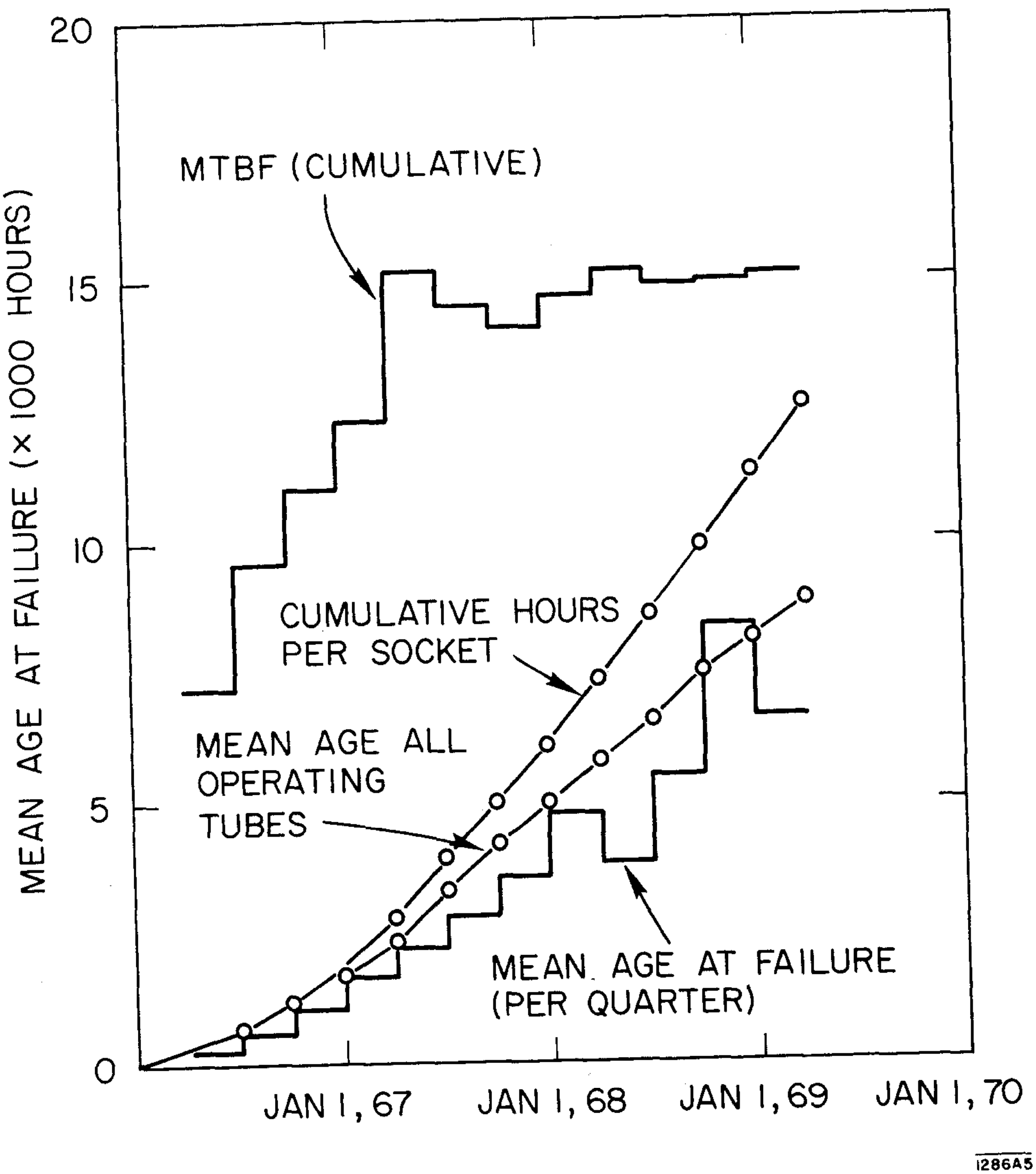


FIG. 14--Operating tube performance, high-power klystrons.

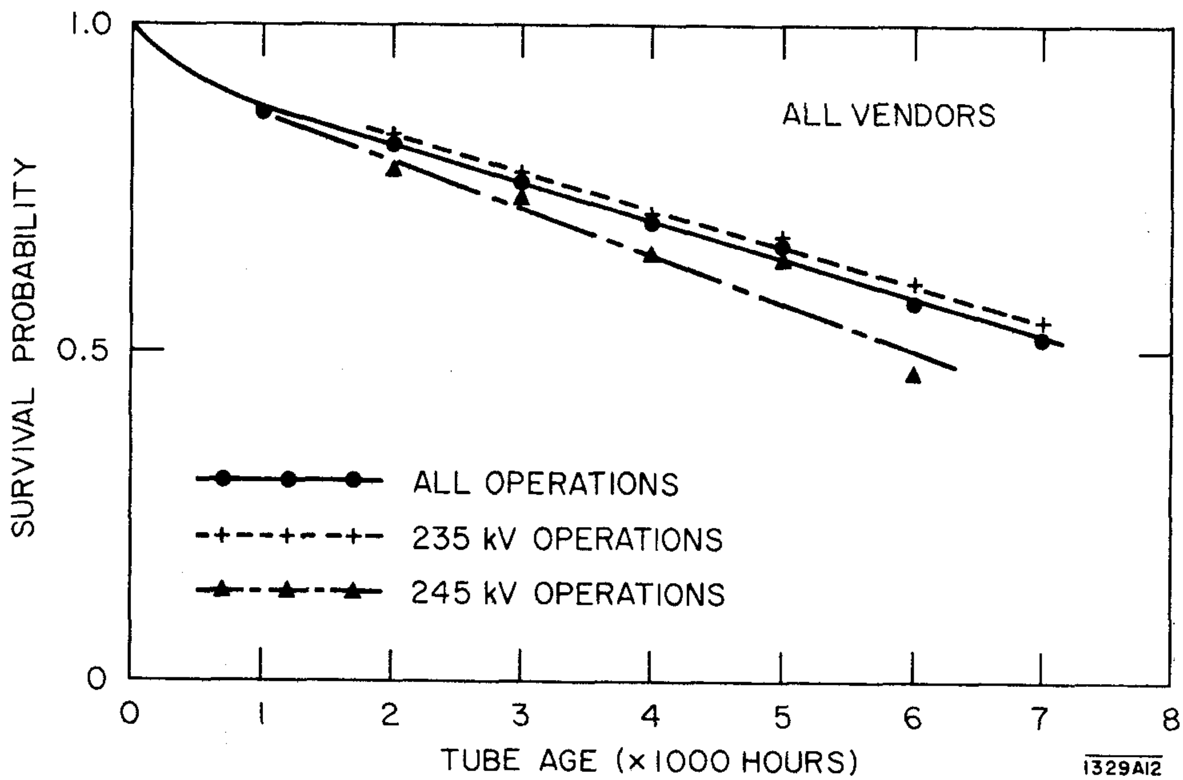


FIG. 15--Survival probability at different operating levels, high-power klystrons.

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

TABLE III

KLYSTRON MTBF FOR VARIOUS OPERATING LEVELS

Quarter	Number Stations 245 kV	Failures		MTBF	
		245 kV	Others	245 kV	Others
7/1 - 9/30/67	32	6	19	7,200	15,200
10/1 - 12/31/67	32	7	14	5,000	16,400
1/1 - 3/31/68	32	2	15	20,500	18,000
4/1 - 6/30/68	32	3	12	13,200	22,200
7/1 - 9/30/68	32	6	18	7,000	15,100
10/1 - 12/31/68	96	14	9	9,800	23,700
1/1 - 3/31/69	96	8	12	16,000	16,700

indicated decrease is significant. Even if they are significant we do not believe that such decrease should give immediate cause for concern should the decision be made to operate the whole machine at 245 kV.

In addition, a small number of sockets equipped with SLAC tubes have been operating at 265 kV. At the end of the quarter four such sockets were in operation; we had experienced one failure at approximately 900 hours, but two of the tubes have accumulated more than 3,000 hours and were still operating satisfactorily. Hence it appears possible that eventually the operating level of the accelerator can be increased to between 260 and 270 kV without resulting in excessive klystron failures but with the possibility of increasing the beam energy to almost 25 GeV.

3. High Power Klystron Performance

Figure 16 gives the measured mean of the beam voltages and beam power outputs per sector pairs during the first quarter of 1969. Note that the readings are taken on the average of once per week for each station but not on the same day for various sectors. Each point on the curve then represents the average of the readings of the 16 stations for each sector pair. Looking at the values of beam voltage first it appears in general the klystron beam voltage is maintained very constant within a sector pair with a few exceptions (2 high readings in Sectors 11 and 12, 1 high reading in Sectors 1 and 2, 1 low reading each in Sectors 19, 20, 21, 22, 25, and 26).

Note also that Sectors 21 and 22 do not represent the same averaging as those for other sectors. The first 4 stations in Sector 21 are operating in general at a beam voltage of approximately 265 kV, the other 12 stations of the sector pair at 235 kV.

Whereas in general there is very little change in beam voltage measurements from week to week there appears to be substantial differences in power output measurements. For instance Sectors 9 and 10 show one (1) point which is almost 10% below the average readings of the other measurements in those sectors. Similarly Sectors 17 and 18 show several very low points. Finally Sectors 5 and 6 show a drop in power output without corresponding change in beam voltage some time about the middle of the quarter. It is not clear at this time whether these changes in power output are caused by accidental change in drive affecting one of the two sectors or whether they are caused by the inherent differences in measured power output compared to measured beam voltage. In

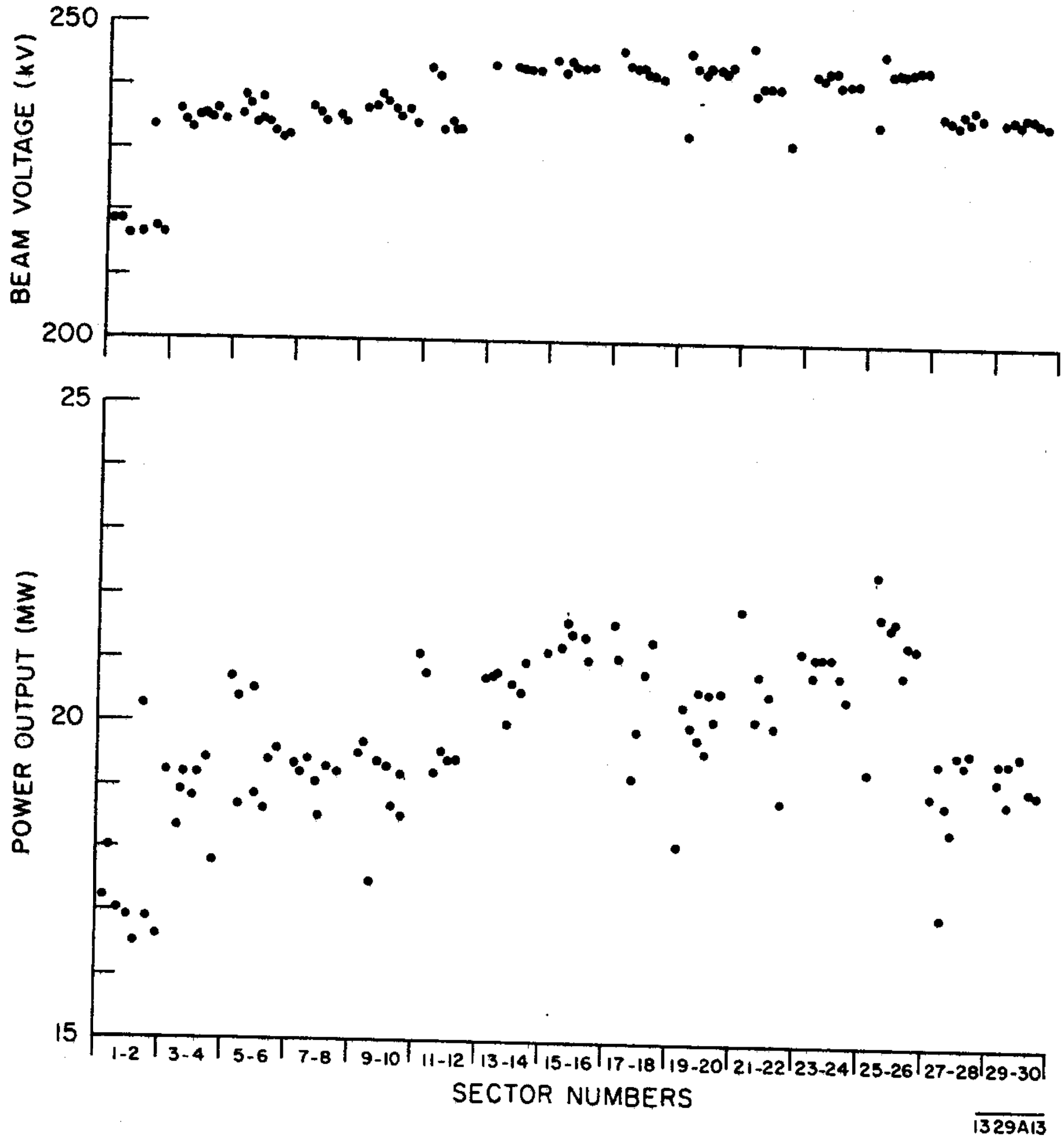


FIG. 16--Mean beam voltages and beam power per sector pairs.

any case it appears that the sectors running at between 240 and 245 kV exhibit a peak power of 21 MW, whereas those running at 235 kV have a peak power of approximately 19 MW.

4. Causes of Failures

Of the 20 operational failures experienced this quarter seven were caused by window failure, five by klystron over-current, five by tube vacuum, two by high voltage seal failure and one by low emission. As in the past, RCA has a higher proportion of window failures than SLAC or Litton, whereas tube vacuum and over-current problems account for the majority of Litton and SLAC failures.

Looking at the overall failures since the beginning of operation roughly 40% of failures have been window failures, 20% tube vacuum, 20% over-current (arcing, cathode-anode arcing), 5% high voltage seals, 5% low emission, the remainder miscellaneous.

The fact that cathode attrition resulting in low emission is such a small percentage of total failures again confirms the findings of statistical analysis that the failures to date have not been due to old age but rather either infant mortality or accidental.

5. High Power Klystron Maintenance

Operating experience of high power klystrons through the end of this quarter is shown in Fig. 17. It can be seen the ratio of tube replacements to tube failures stays substantially constant at about 2.7 to 1. Accordingly the replacement rate stays at approximately 1 replacement per 6,000 hours. It is interesting to note that during the month of March, which set a record for continuous running, the number of failures per operating hour and replacement rate per operating hour was the lowest observed for a long time with a replacement rate of less than 1 tube per 11,000 hours of operation.

Figure 18 gives a plot of fault counts as reported by CCR during the quarter. As in the case of replacement rates it can be seen that the fault counts have been lower during the long uninterrupted operation in March than at other times during the quarter.

As in the past oil leaks and pulse transformer tank problems account for more than one-half of the total replacements.

Scheduled maintenance is continuing at a reasonable rate although the reduction of down periods and the longer operating schedule have resulted

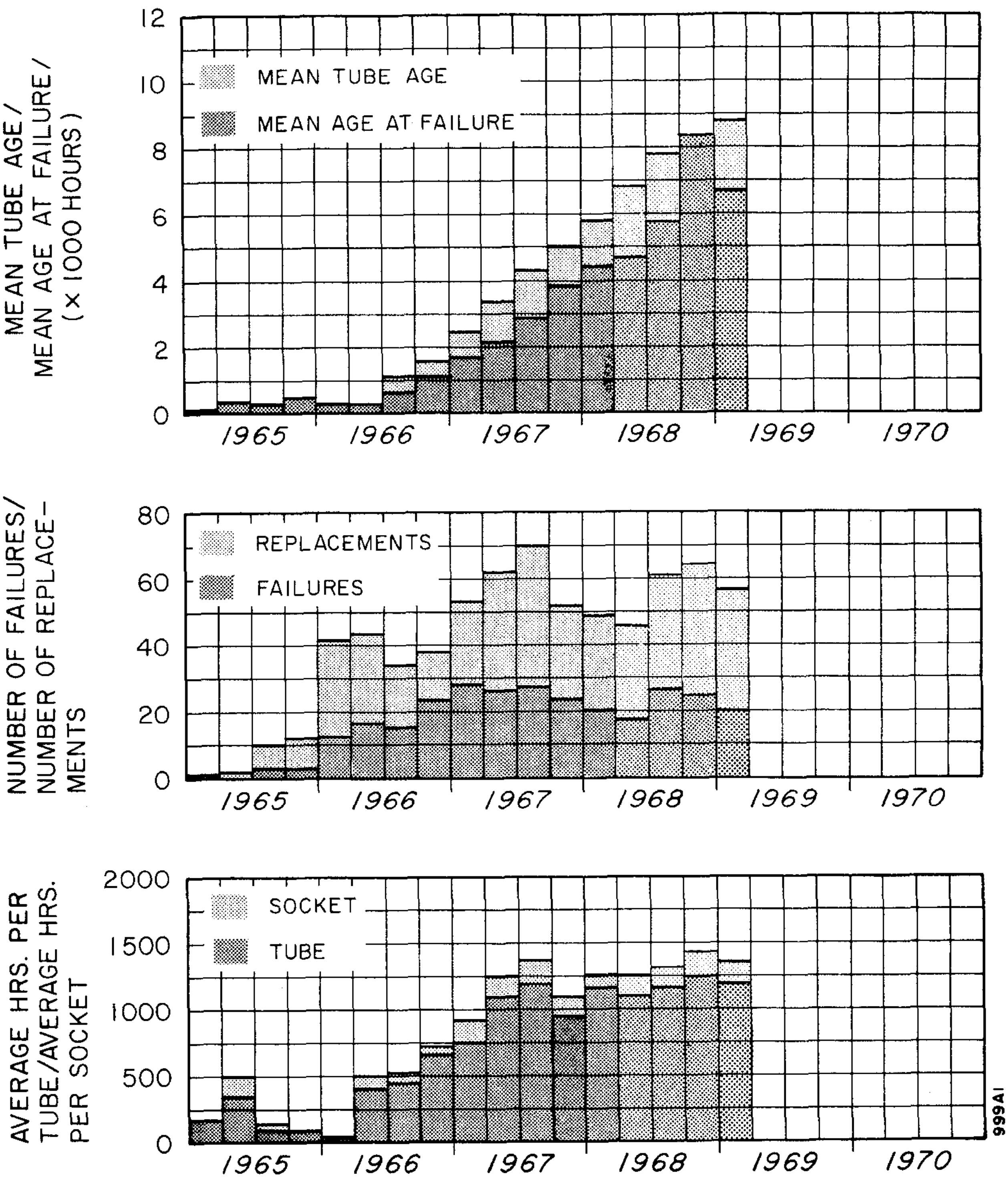


FIG. 17--Quarterly operating experience, high-power klystrons.

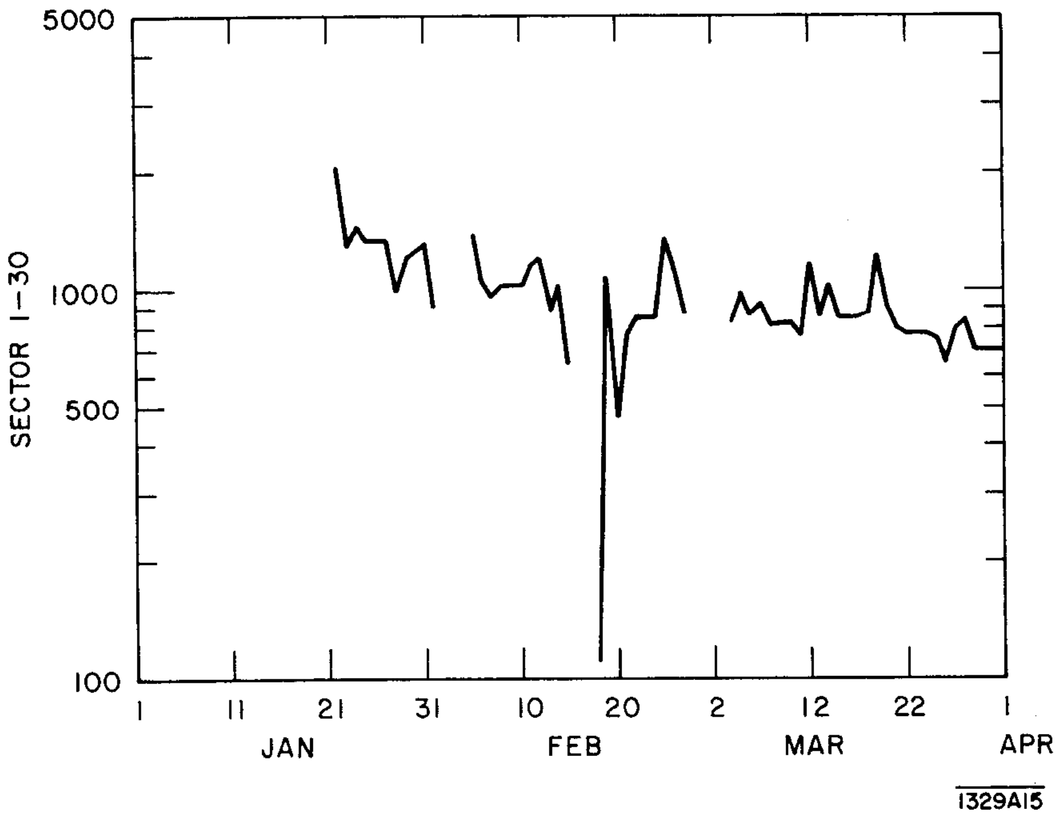


FIG. 18--Fault counts, first quarter 1969.

in an increase in the average time between klystron preventive maintenance checks. The klystrons were checked on the average of once every 660 hours.

6. Driver Amplifier Klystrons

The maintenance criteria remained essentially the same for the driver amplifier klystrons this past quarter as for the previous. General aging effects - drops in perveance, power output, phase droop - continue to be observed but no indication of catastrophic failure.

Instabilities originally attributed to the klystrons have in several instances been traced to sub-drive lines where corrosion at couplers had led to breakdown. A maintenance program for all the sub-drive lines has been undertaken by the accelerator electronics maintenance department using a temporary sub-drive line in the sector being worked on. While necessary, the substitute drive line may introduce instabilities since it is not temperature stabilized and uses flexible coax lines connecting to the stations.

The operating experience on the driver amplifiers continues extremely good with a total of 3 failures. Figure 19 shows the tube age distribution for driver amplifiers, segregated between Eimac and SLAC tubes. Figure 20 gives the operating experience for all driver amplifiers.

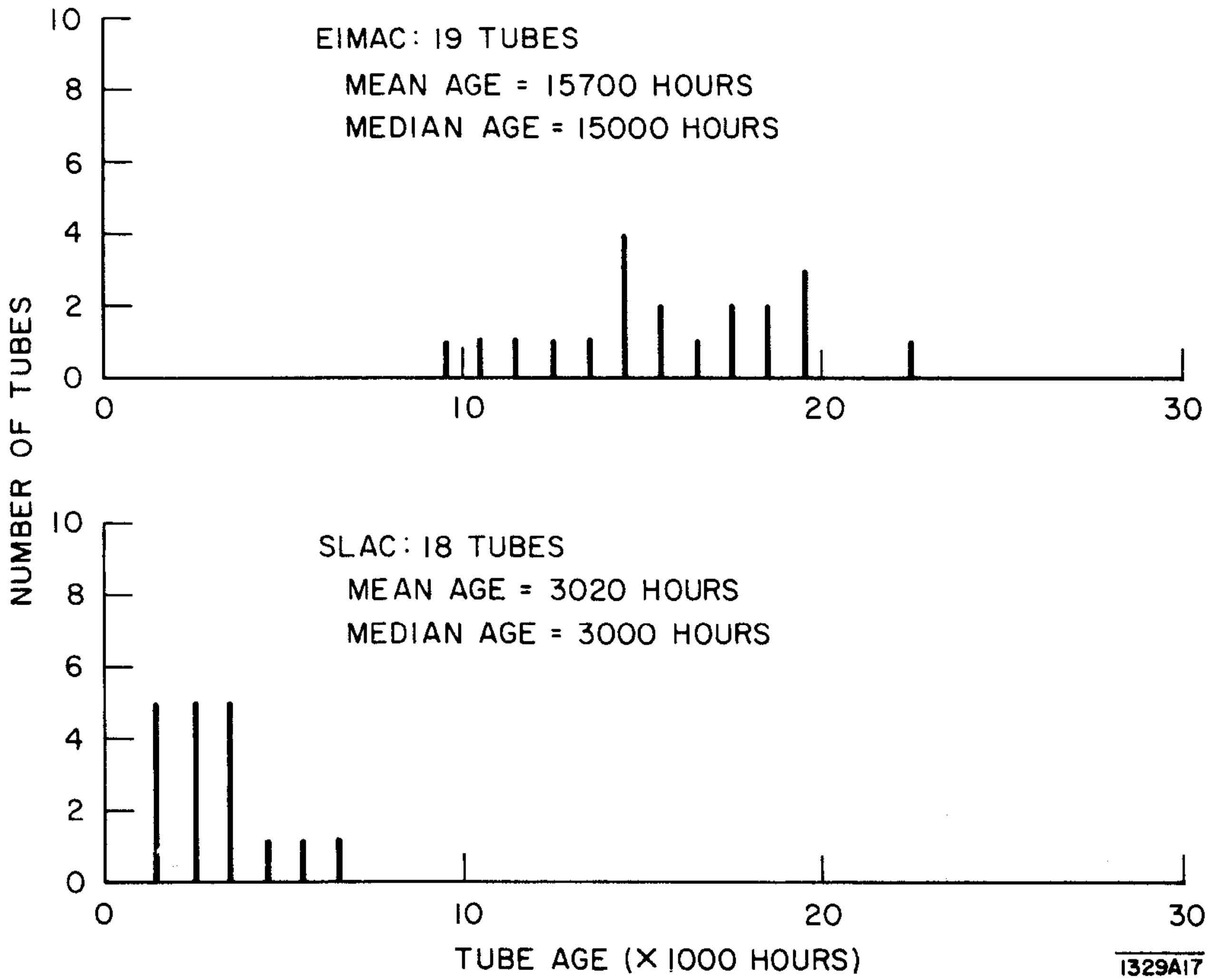


FIG. 19--Age distribution, driver amplifier klystrons.

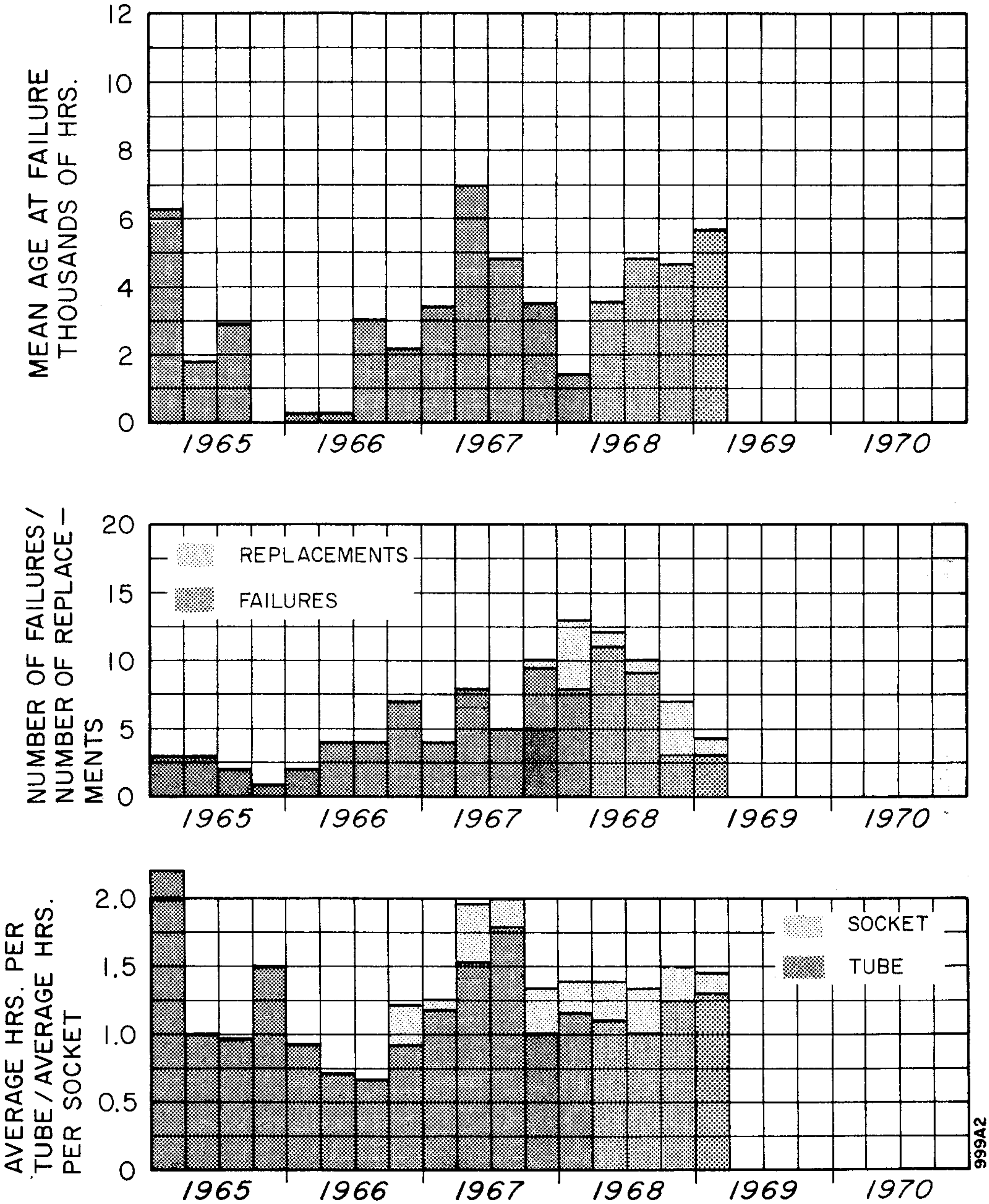


FIG. 20--Quarterly operating experience, driver amplifier klystrons.

VII. ACCELERATOR ELECTRONICS GROUP

(April 1, 1968 to March 31, 1969)

Accelerator and Research Area Operations

1. Main Modulators

These units continued to operate satisfactorily during the past year in spite of poor quality pulse capacitors, and failures in other components. The average operating time for all modulators is now 13, 077 hours. We have watched all problem areas and instituted modifications where the design needed improvement and started backup sources where components were failing rapidly. In general, when all the modulators are started up on the line 93% will start, 5% will have various electronic problems and 2% will have klystron problems. After 24 hours, only three (about 1%) will still have problems. For the rest of the run generally two or three will be off at any given time, as shown on the chart in Fig. 21. This is very good performance for such high power modulators. The problem areas were as follows.

Pulse Capacitors. The failures among the pulse capacitors continued to be our most troublesome area in the modulators. During the past year, we had 644 failures (13% of the total number of pulse capacitors in the modulators) or about 54 per month. Figure 22 shows the distribution of failures during the past 12 months. For the nine month period prior to April 1, 1968, we had 418 failures, or an average of 46 per month, so it appears the failure rate is increasing somewhat.

About a year ago we began looking for better quality capacitors. We obtained capacitors from several sources. All units were installed for life testing shortly after receipt. We are continuing to build up life experience in these units.

During this quarter two contracts were let for additional capacitors. At the end of the quarter both companies were about to start deliveries.

Rectifier Transformers and Charging Chokes. We continued to experience oil leaks around the high and low voltage bushings. In most cases they were repaired by this group and restored to service. A total of 60 rectifier transformers and 10 charging chokes were repaired during the past year.

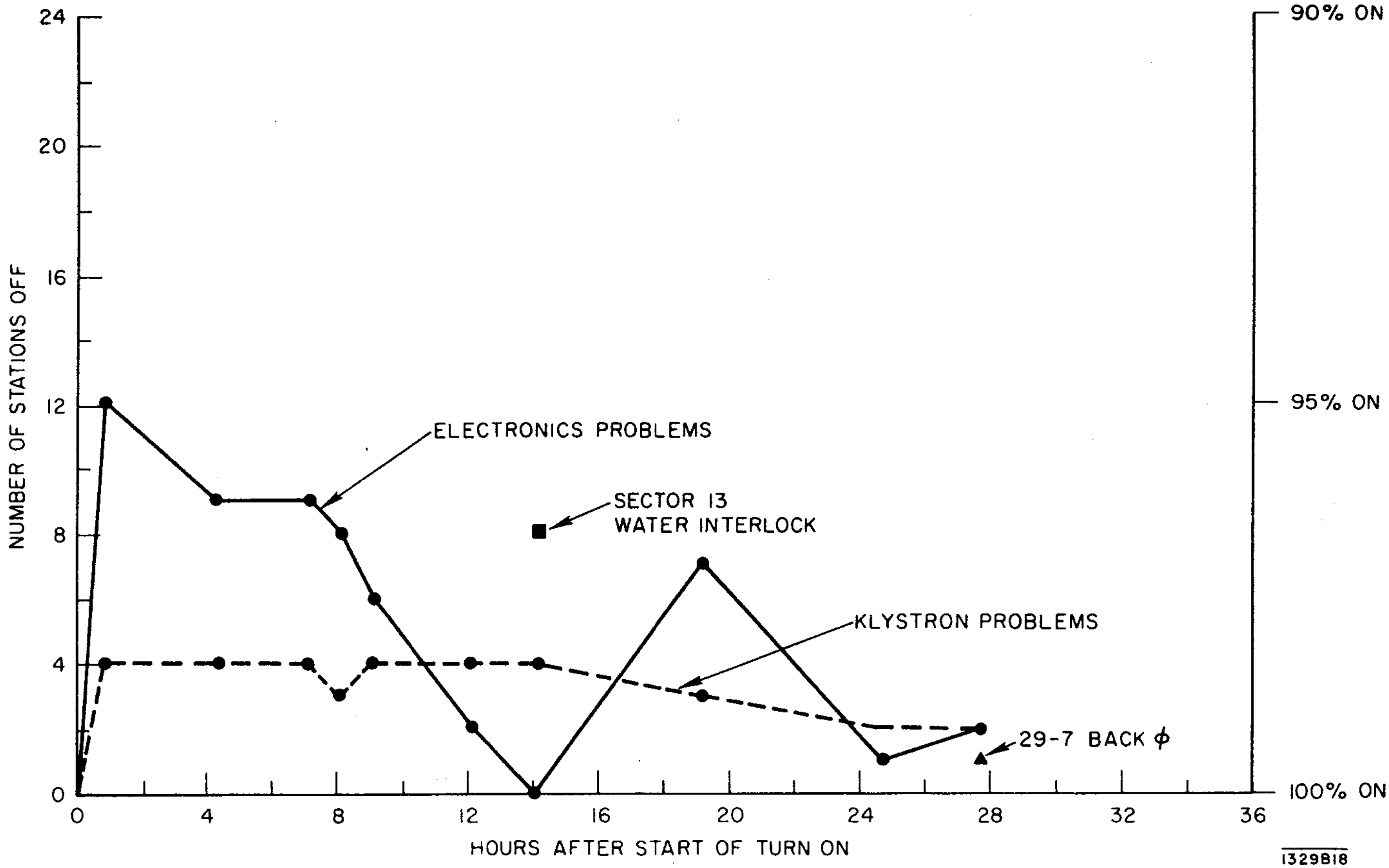


FIG. 21--Stations off during accelerator turn-on, July 23-24, 1968.

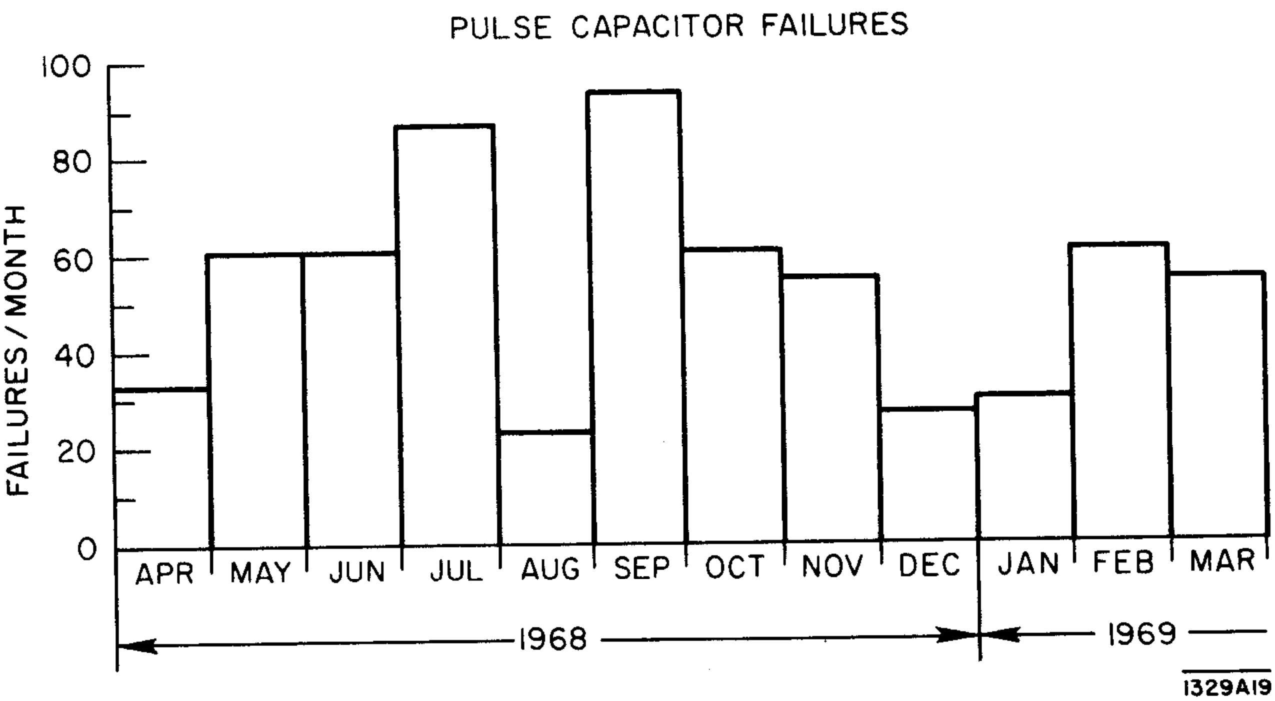


FIG. 22--Pulse capacitor failures.

Two rectifier transformers failed internally due to shorting at the lugs inside the transformer because the studs were inadvertently turned while jumper links were being changed. This was remedied by changing to a plug-in jumper system, which was installed on all transformers on the line last summer.

To make it easier to get into the transformer for certain recurring repairs, the welded top is changed to a removable top when units require internal work. During the past year ten transformers have been modified in this manner.

During the past year the charging chokes have become more troublesome than ever before. It appears we are approaching end of life on many of them. Evidently there is a small amount of corona in the windings which breaks down the dielectrics and generates gas. The gas pressure builds up over the years causing swelling of the cases and leaking at the bushings. Twelve of them were damaged badly enough to require rewinding. By the end of this quarter three units had been repaired. They will be put into operation immediately for life testing and nine more will be sent out for repair.

Main Rectifiers. Twenty-four main rectifiers failed during the past twelve months. In each case only two or three cards were involved out of a total of sixty. After the defective cards were replaced the rectifier was placed back in service. The fire alarm circuit which has heat sensitive wires placed strategically around the interior of the modulators operated in each case of a rectifier fire. Three such wires are mounted over the rectifier stacks. In each case of a failure a small fire always results; the heat sensitive wire closes a circuit which turns off high voltage, stops the cooling fans, and turns in an alarm to CCR. In every case the fire went out by itself and firemen were not needed. This system has saved much damage and downtime on these modulators.

Twenty-nine backup source rectifiers have been in service for over a year and have operated satisfactorily with no trouble whatsoever. Each one has about 8000 hours running time.

De-Q'ing SCR Assemblies. We continued to experience SCR failures, and lately in increasing numbers mainly due to charging chokes failing. The chokes develop shorted turns, sometimes intermittently, and probably arc to ground inside them occasionally as they deteriorate. These faults often ruin the SCR's in the De-Q'ing switch assembly. Sometimes we lose several sets of them before the charging choke is proven to be bad. Figure 23 shows the distribution of failures with time.

During the last quarter we designed and tested a circuit using a SCR and diode combination which will replace the matched pairs of SCR of units as they fail. It utilizes a transient suppression circuit that is superior to the old ones. In this way we can reduce the cost of replacements. We also feel that a single SCR and diode combination will work with the present SCR's but we haven't had a chance to try them.

Pulse Cable Assemblies. As can be seen in Fig. 24, these units had a rising failure rate during the past twelve months. We experienced problems with erosion of the finger stock on the connectors, and corona in air pockets between the layers of polyethylene which makes up the major dielectric. The corona gradually decomposes the dielectric until it finally shorts out completely.

During the past twelve months we obtained 150 new assemblies and installed 95 of them in place of old ones which were about to fail. At the end of the quarter we had 120 assemblies as spares.

For years we have been searching for a solid dielectric cable to replace the layered-insulation type that we have been using. The solid dielectric cable would be presumed to have no air pockets and hence no corona. Silicone rubber cable looked promising in previous tests so we asked for bids on 10 full size assemblies for life testing. Delivery of the first assembly is expected shortly.

Hydrogen Thyratrons. The average life of our large thyratrons, which for both companies started at 2400 hours in May 1967, gradually climbed to a peak of 3700 hours for ITT and is leveling out near 7000 hours for Wagner tubes, as shown in Fig. 25. The average life of the ITT tubes actually began dropping during the last quarter because their latest tubes, KU275B's, were shorter lived than the previous KU275A. They have since stopped production on that tube and are planning to bring out an improved cathode in a KU275C version.

The average failure rate was 16.1 tubes per month for 15 months prior to August 1968; then for the next six months it was 23 tubes per month and during February and March 1969, it was 31 tubes per month. This is shown in Fig. 26. This increasing rate is probably due to two factors; one is the short life of the KU275B and the other is the higher failure rate for the old, first generation, tubes on the machine.

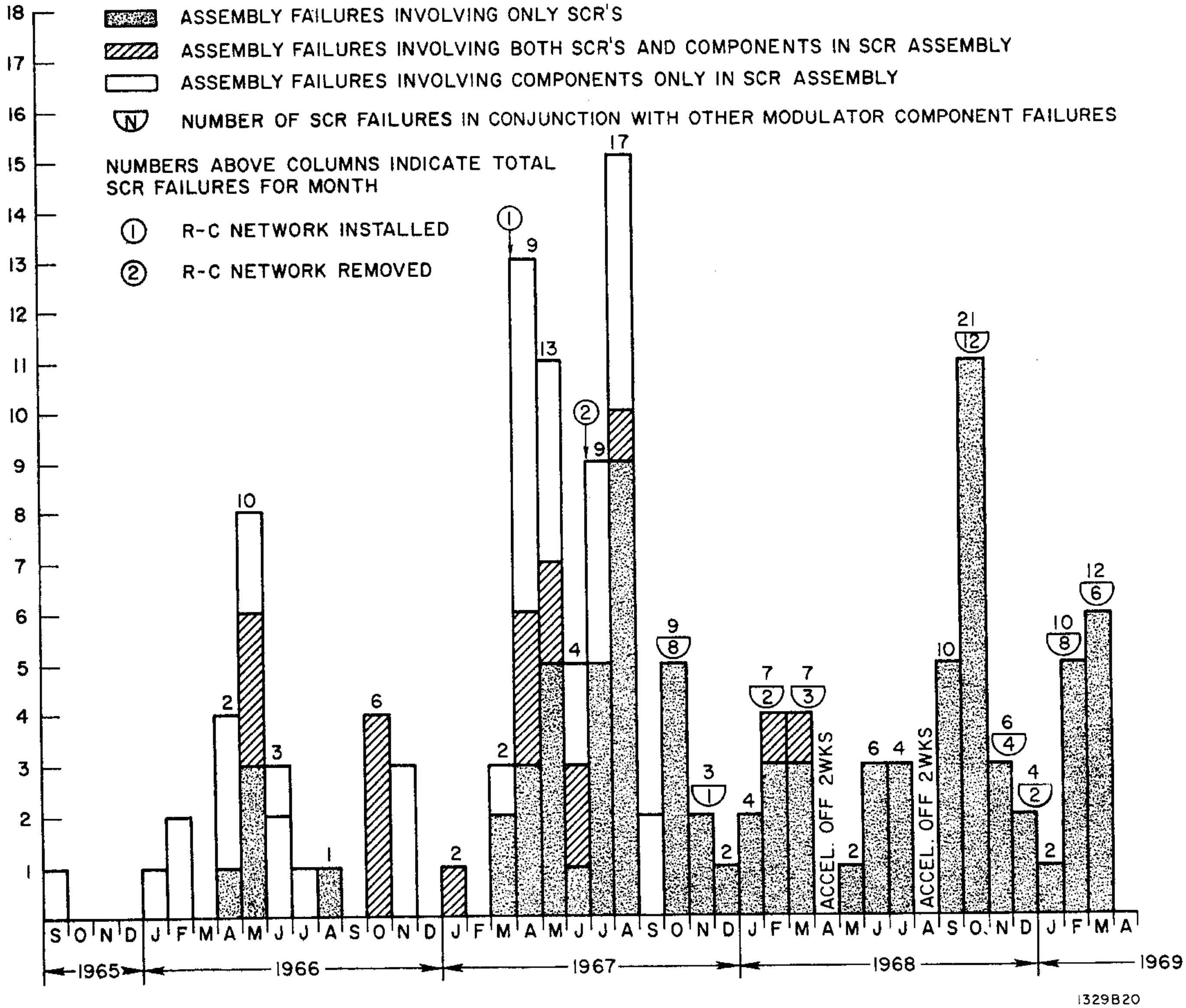


FIG. 23--SCR assembly failures.

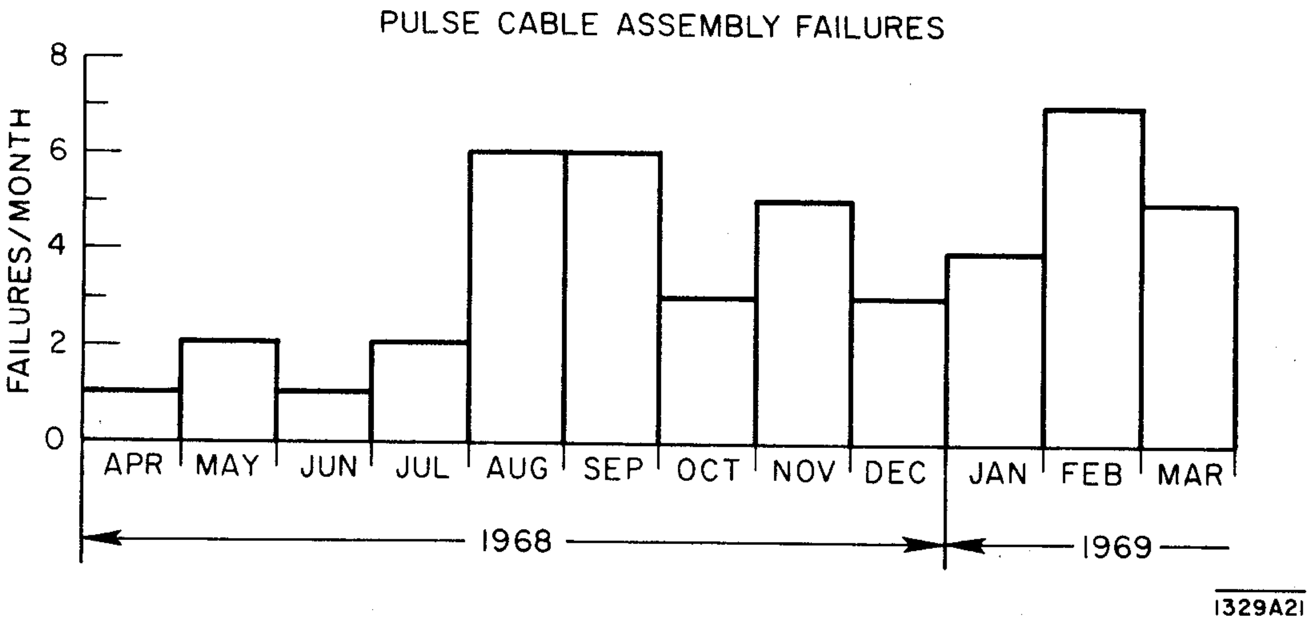


FIG. 24--Pulse cable assembly failures.

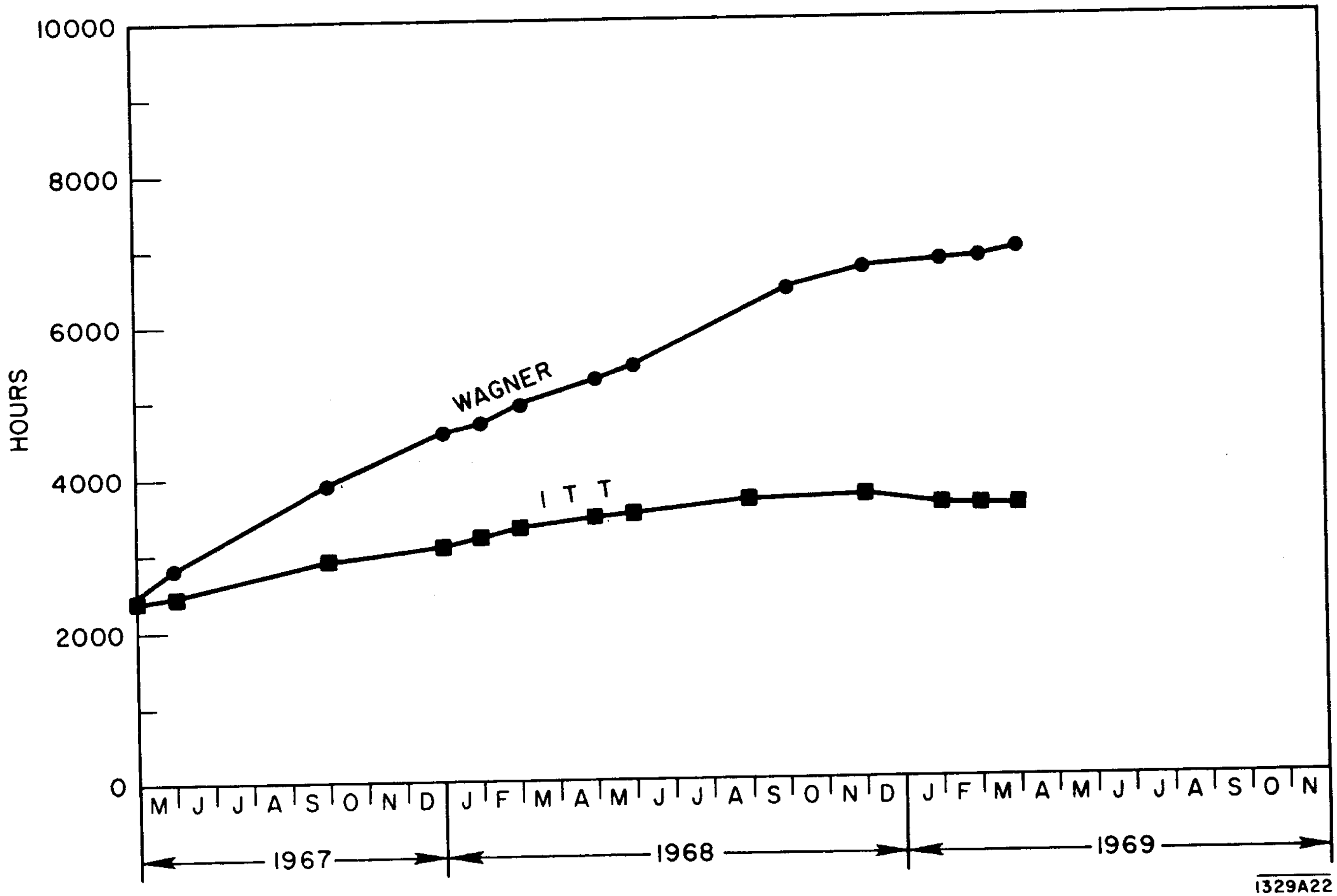


FIG. 25--Average life of failed thyratrons.

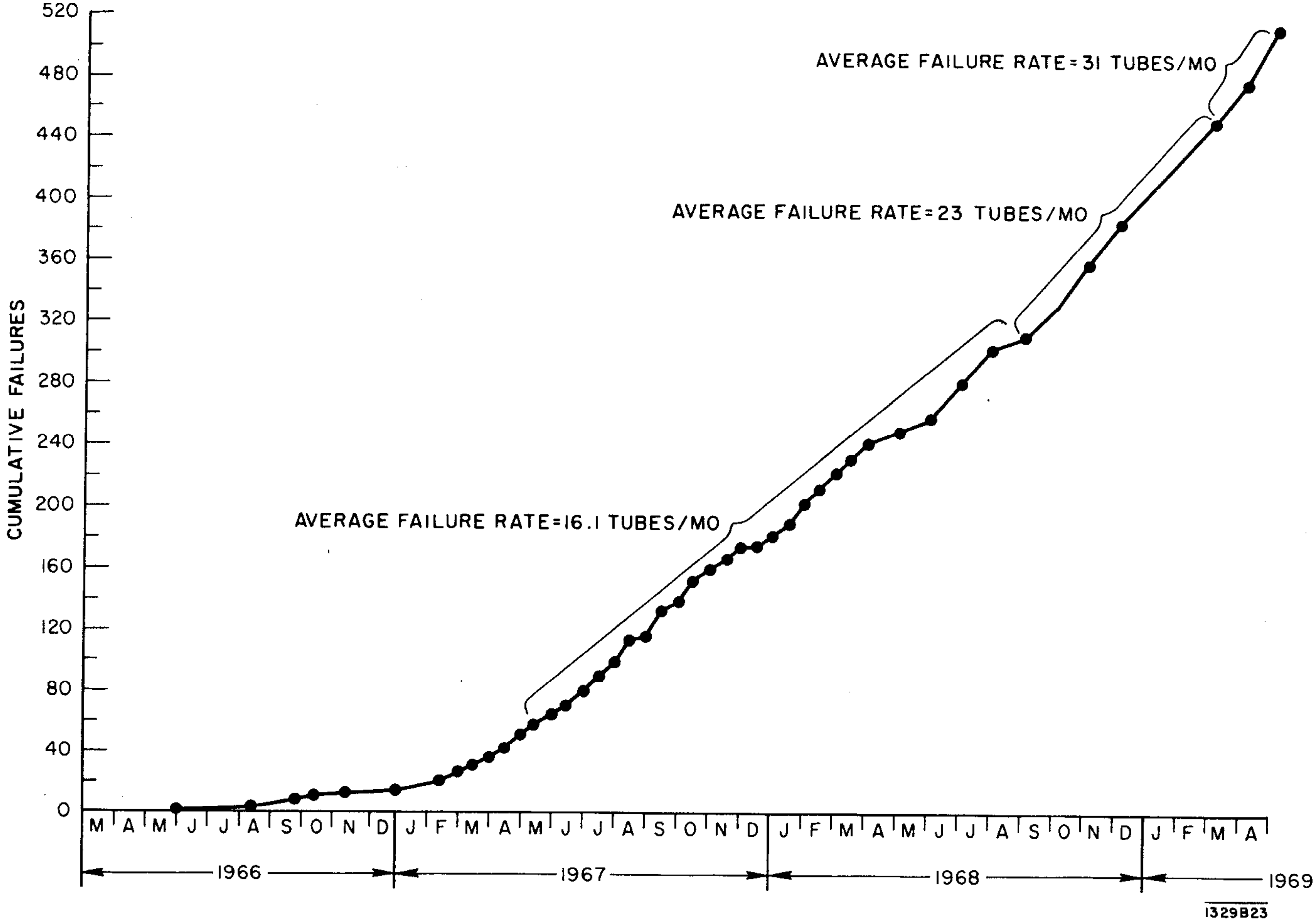


FIG. 26--Cumulative hydrogen thyratron failures.

Semiconductor Switch For Main Modulators. Since the beginning of the design of the main modulators we have been looking for a semiconductor switch which would replace the costly thyratrons and, hopefully, live many times longer than thyratrons and have much reduced operating costs. Semiconductors, if properly applied, have lived extremely long lives.

About a year ago Westinghouse showed us a new product called Reverse Switching Rectifier which in the forward direction acts like an ordinary diode and in the reverse direction will hold off up to 1000 volts. If that voltage is exceeded the device breaks down rapidly and can conduct 2000 amperes peak with a rate of change as high as 10,000 amperes per microsecond. Schematically, the device looks like Fig. 27.

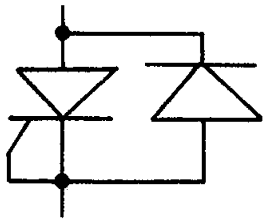


Fig. 27

Its electrical characteristics would be shown as in Fig. 28.

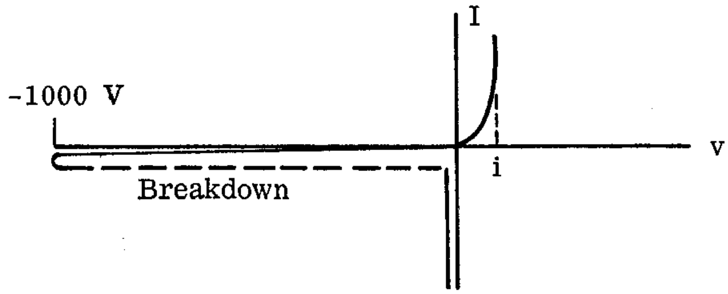


Fig. 28

It is triggered by overvoltaging, much the same as a spark gap. However, a very fast trigger must be used so that current is not drawn too long, resulting in too much power being dissipated in the junction.

Westinghouse made up four complete stacks for testing in our modulators at full power. We installed two in parallel on one pulse forming network and two in parallel on the other. Initially, we had a great deal of difficulty getting up to operating voltage. We found that it was necessary to add stacks of R.S.R.'s in series on top of the other stacks. This aided recovery of the R.S.R.'s because it enabled them to hold off voltage in both directions. The real break-through occurred when we added a backswing diode across the pulse transformer primary. We were able to get to very nearly full power and operated into a diode load (which is equivalent to a klystron as far as the modulator is concerned). We operated several hours during which the load arched a few times and the R.S.R switch lived through this type of operation so it is encouraging. Subsequent testing resulted in the loss of many R.S.R. units. Some were lost due to a sparkover from the end-of-line clipper assembly to the center of one of the R.S.R. stacks. Others were lost due to other component failures.

Another problem is that the time delay through the stacks, or switching time, is variable with voltage and power and can amount to as much as one microsecond, which is serious compared with our modulator output pulse width of 2.5 microseconds. This of course would be no problem if we always operated at a fixed voltage and average power level as is the case most of the time. The thyratrons are stable to 0.02 microseconds. Another difficulty with the R.S.R.'s is that they seem very delicate electrically and if not handled carefully they could be ruined in normal modulator troubleshooting. However, we are not finished testing them, and they may yet turn out to be a satisfactory substitute for our thyratrons.

Higher Voltage Operation of Modulators. In an effort to increase the energy of the accelerator, we explored the possibility of increasing the operating voltage of the modulators to accommodate 30 megawatt klystrons that operate at about 270 kV.

We ran the ac input voltage to a test modulator up about 10% and ran successfully over a period of a month. The pulse width naturally decreased a little because the klystron load impedance is smaller at 270 kV than at 250 kV. Our pulse width for a high perveance klystron which is normally 2.5 microseconds in the 99.5 - 100% amplitude band at 250 kV shortened to 2.4 microseconds at 270 kV. We added two pulse capacitors to the pulse forming network and regained our lost pulse width, but this increased the average power in the modulator so much that we went out of specifications on temperature rise in our large magnet components.

It was decided to live with the shorter pulse and try the scheme on the accelerator so we obtained and installed booster autoformers on four modulators in Sector 21 as klystrons became available about a year ago. They have been operating satisfactorily roughly 600 hours to 4000 hours. Their kickout rate is a little higher than lower voltage modulators but otherwise there is little difference.

2. 0.1^{o} Pulsed Magnet Regulation Improvement

At the request of the Research Area Department, we reviewed the design of these units with an eye toward an improvement in output pulse regulation to better than 0.05%. This was accomplished by speeding up the response of an amplifier feeding the driver tube, installing a Powerstat which automatically tracks reference voltage so that the voltage across the series pass tube is always optimum, and changing the voltage divider to a lower impedance one. It was also modified so that it had automatic rundown to simplify start-up circuitry by eliminating an auxilliary contactor, and start-up resistors.

At the end of the quarter one supply was modified and ready for beam tests.

3. One Kilowatt Amplifier for Superconducting Cavity Experiments

During the past year, another job that was completed was the design and construction of a power supply and housing for a 1 kW Eimac klystron.

4. Trigger System Improvements

a) The master trigger generators were modified to provide a -1025 microsecond pretrigger. Also, certain circuit improvements were made in the MTG delay line driver circuit, decreasing the pretrigger-to-main-trigger time jitter from a microsecond or more to about 40 nanoseconds.

b) A PLIC/pattern generator interlock cirucit was provided by which a PLIC fault on any beam blocks only the corresponding beam pattern until the operator corrects the condition and resets the interlock circuit, meanwhile permitting any and all other beams to continue uninterruptedly.

c) The pattern generator power supply was expanded to comprise three independent sources, any two of which can carry the full load, thus facilitating repairs or adjustments on any source without excessive downtime. A special power distribution panel was added to enable rapid (although manual) reconnecting each pattern generator unit from one source to another. Provision was made for adding automatic reconnection if and when it becomes desirable.

d) A special purpose driver was provided for lines to the two pulsed power supplies in Sector 11 and to the six RAD lines. Special threshold gates interlock the lines in each group on a pulse-to-pulse basis to prevent operators from applying pattern pulses simultaneously to both power supplies or more than one RAD line, and at the same time to prevent a switching error on one beam line from affecting any other existing beam.

e) To overcome certain beam loading problems at the injector, the formerly fixed accelerate trigger pulse delay for injector klystrons 01 and 02 and modulators 01A, 01B, and 01C was replaced by the adjustable beam loading delay in the sector trigger generator in Sector 1.

f) To enable the CCR beam monitor oscilloscopes to be triggered from any "time slot" instead of only "time slot 1" as before, all six pattern generator beam lines were connected to the CCR local trigger generator.

g) The existing injector trigger generator was modified in several respects to accommodate the new gun modulator.

h) Now that the new gun modulator has been thoroughly checked out, design of a new and simpler injector trigger generator was begun.

i) Pattern generator controls in CCR were relocated on the operation console, partly for greater operator convenience and partly to provide for computer sensing of the switch positions.

5. C Beam RF Separator Modulator

A hard tube modulator much like the Sub-Booster Modulators on the machine was requested for use with the C beam rf separator.

The unit was designed and nearly completed by the end of the quarter.

6. Six-Level Pulsed Steering Magnet Power Supply

A power supply providing six amplitude levels in its output to steer up to six beams in the machine was designed, constructed, and installed.

7. Six-Level Pulsed Quadrupole Power Supply

A pulsed power supply to power two quadrupole magnets in series was designed and construction started this quarter. It will provide two output pulse amplitudes and by varying timing of its sine wave output pulse with respect to the beam pulse will provide an infinite number of output settings.