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# TWO-MILE ACCELERATOR PROJECT

1 October to 31 December 1968

Quarterly Status Report

STANFORD LINEAR ACCELERATOR CENTER
STANFORD UNIVERSITY
Stanford, California

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

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ABSTRACT

A status report on the Stanford Linear Accelerator Project covering the period October 1, 1968 to December 31, 1968 is presented. Topics included are accelerator and research area operations, accelerator and research area equipment development, and physics research equipment development.

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# INTRODUCTION

This is the twenty-sixth Quarterly Status Report of work under AEC Contract AT(04-3)-400 and the twentieth 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 October 1, 1968 to December 31, 1968. Contract AT(04-3)-400 provides for the construction of the Stanford Linear Accelerator Center (SLAC), a laboratory that has as its chief instrument a two-mile-long electron accelerator. Construction of the Center began in July 1962. The principal beam parameters of the accelerator in its initial operating phase are a maximum beam energy of 20 GeV, and an average beam current of 30 microamperes (at 10% beam loading). The electron beam was first activated in May 1966. In September 1968, a beam energy of 21.0 GeV was achieved. Beam currents up to 50 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 | Oct. | Nov. | Dec. | Quarter |
|---|---|---|---|---|
| Physics Beam Hours[1] | | | | |
| Machine Physics | 53 | 38 | 30 | 121 |
| Particle Physics | 393 | 447 | 277 | 1,117 |
| Total Physics Beam Hours | 446 | 485 | 307 | 1,238 |
| Non-Physics Hours | | | | |
| Scheduled Down Time | 18 | 15 | 16 | 49 |
| Unscheduled Down Time Due to | | | | |
| Equipment Failure | 46 | 31 | 27 | 104 |
| All Other (Machine Tune-Up, etc.) | 50 | 37 | 26 | 113 |
| Total Non-Physics Hours | 114 | 83 | 69 | 266 |
| TOTAL MANNED HOURS | 560 | 568 | 376 | 1,504 |

B. Experimental Hours[2]

1. Particle Physics

| (3) Beam Line | Sched. Hrs. Electronic Experiments (a) | Electronic Experiment Hrs. | | % $\left(\frac{b}{a}\right)$ | Actual Bubble Chamber Hours | Actual Test And Check-Out Hours | Total Experimental Hours | |
|---|---|---|---|---|---|---|---|---|
| | | Actual Hours (b) | (4) Charged Hours | | | | Actual Hours | Charged Hours |
| A | 911 | 719 | 776 | 78.8 | --- | 278 | 997 | 1,054 |
| $B_N$ | 415 | 295 | 385 | 71.1 | --- | 153 | 448 | 538 |
| $B_C$ | --- | --- | --- | | 286 | --- | 286 | 286 |
| $B_S$ | 763 | 674 | 569 | 88.3 | --- | 830 | 1,504 | 1,399 |
| C | --- | --- | --- | | 291 | 540 | 831 | 831 |
| Total | 2,089 | 1,688 | 1,730 | 80.8 | 577 | 1,801 | 4,066 | 4,108 |
| 2. Machine Physics | | | | | | | 106 | 106 |
| TOTAL EXPERIMENTAL HOURS | | | | | | | 4,172 | 4,214 |

(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. 1 for beam line location.

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

## C. Overall Experimental Program Status

### 1. Electronic Experiments

| | |
|---|---|
| Approved research hours at beginning of quarter | 3,876 |
| Hours charged during the quarter | 1,730 |
| New hours approved during the quarter | 908 |
| Approved hours remaining at end of quarter | 3,054 |

### 2. Bubble Chamber Experiments

| | 40" BC | 82" BC |
|---|---|---|
| Approved pictures at beginning of quarter | 884 K | 2,029 K |
| Pictures taken during the quarter | 309 K | 291 K |
| New pictures approved during the quarter | 55 K | 312 K |
| Approved pictures remaining at end of quarter | 630 K | 2,050 K |

| | Oct. | Nov. | Dec. | Quarter |
|---|---|---|---|---|
| **D. Beam Intensity** | | | | |
| Peak | 42 mA | 45 mA | 50 mA | 50 mA |
| Average | 7.5 $\mu$A | 7.0 $\mu$A | 7.3 $\mu$A | 7.3 $\mu$A |
| **E. Klystron Experience** | | | | |
| Total Klystron Hours | 130,375 | 133,347 | 86,108 | 349,830 |
| Number of Klystron Failures | 13 | 7 | 4 | 24 |
| **F. Data Analysis** | | | | |
| Spark Chamber Events Measured | 12,501 | 11,830 | 12,405 | 36,736 |
| Bubble Chamber Events Measured | 5,187 | 9,676 | 11,786 | 26,649 |
| **G. Computer Operations** | | | | |
| Manned Hours | | | | |
| Computation Hours | | | | |
| SLAC Facility Group | 103 | 128 | 100 | 331 |
| User Groups | 204 | 266 | 309 | 779 |
| Total Computation Hours | 307 | 394 | 409 | 1,110 |
| Non-Computation Hours | | | | |
| Scheduled Maintenance | 128 | 85 | 122 | 335 |
| Scheduled Modifications | --- | 64 | 30 | 94 |
| Unscheduled Down Time | 16 | 21 | 75 | 112 |
| Idle Time | 96 | 35 | 15 | 146 |
| Utility Failure | --- | 70 | 3 | 73 |
| Total Non-Computation Hours | 240 | 275 | 245 | 760 |
| TOTAL MANNED HOURS | 547 | 669 | 654 | 1,870 |

H. <u>Special Operating Features</u>

1. Positrons

No positron experiments were scheduled during the quarter. A new wand was installed and tested during December.

2. Beam Knockout

The beam knockout was used for a total of 819 hours during the quarter, including 26 hours of check-out. Of the 793 hours of experimental use, 63 hours was in multiple beam operation. Operation was at 10 and 40 MHz.

3. Power Supplies

The 3.4 MW power supply was run for a total of 661 hours during the quarter, distributed as follows: 40" Bubble Chamber 25 hours, 82" Bubble Chamber 210 hours, 54" Spark Chamber 378 hours and two meter Spark Chamber 48 hours.

The motor generator facility was run for a total of 425 hours during the quarter, distributed as follows: 40" Bubble Chamber 237 hours, 54" Spark Chamber 186 hours and two meter Spark Chamber 2 hours.

The 5.8 MW power supply was being rebuilt during the quarter.

4. The accelerator was off during the last week in December for a scheduled shut-down.

# II. RESEARCH AREA OPERATIONS AND DEVELOPMENTS

## A. General Beam Switchyard (BSY) and Research Area Developments

### 1. Yard Activities

Build-up of the neutral K beam in the center beam in End Station B is complete. This was a major modification of this beam line. Experiment BC-10, which is investigating $K_2^0p$ interactions with the 40-inch bubble chamber, has obtained satisfactory results using this beam. In order to investigate some background problems and to allow for improved beam operations, a new ZnS screen was installed near the pulsed switching magnets in the B-Beam. Plans for moving the streamer chamber facilities from their present location in the A-Beam to a new location in the C-Beam area are complete and initial preparations for the move scheduled during April and May are underway. Plans for the fabrication and installation of the beam line and experimental facilities for E-41 (Rho Production by Pions--A Test of Vector Dominance) are essentially complete and proceeding on schedule. The location of the experiment and its new beam line, consisting of magnets 11D1 to 11D6 and 11Q1 to 11Q5, is shown in Fig. 1. Initial planning is underway for installation of E-28 (Experiment on $\mu^+e^-$ Scattering) in the End Station B $\mu$-Beam (see Fig. 1).

The off period from mid-December to January 20 is being used to proceed with a number of improvement projects, for set-up of new experiments, and for required maintenance. The major activity which will require the entire down period to complete is the installation work on the first phase of the major instrumentation rearrangement in the Data Assembly Building. Monitoring and control equipment in the existing console is being transferred to a new dual console. In addition, many new control panels will be installed. These are improved designs and will provide the operators with better instrumentation for multiple beam operation. The rearrangement is to be done in two phases. The first phase will provide one operating position in the new console, and the second phase will essentially duplicate the first, providing parallel and independent operation for two operators. The first phase will be completed in January and the second in July.

As a continuation of upgrading the beam power transmission through the A-Beam in the beam switchyard, a new water-cooled vacuum chamber was installed in bending magnet B-15. Such a chamber was previously installed in B-14. Both chambers are to prevent thermal damage resulting from high-intensity radiation

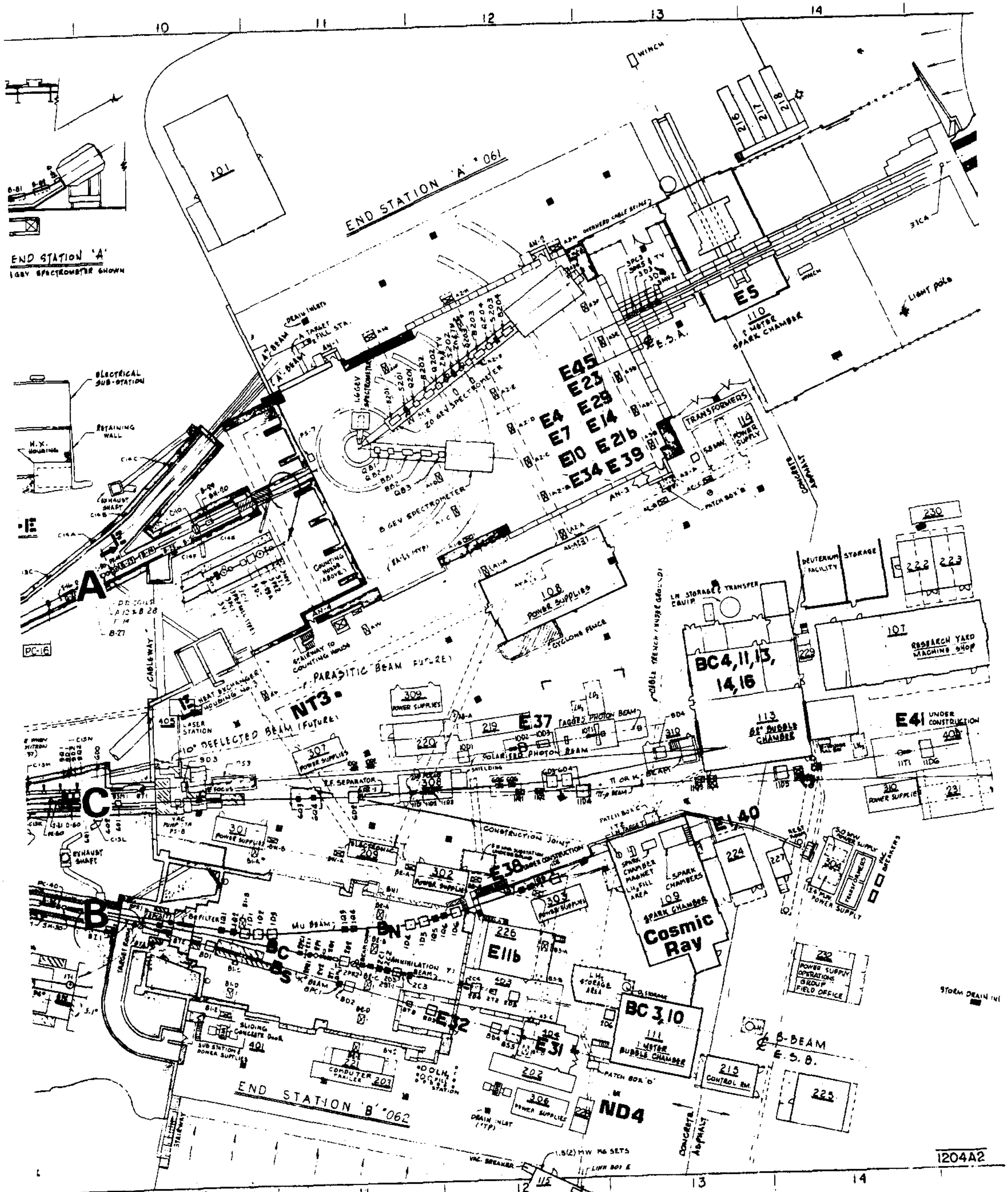


FIG. 1--Experiment locations.

spray coming from the energy defining slits during high power electron beam operation at small slit apertures ($\Delta p/p \leq 0.3\%$). Based on residual radiation measurements it is felt that the vacuum chambers in the bending magnets B-16 and B-17 do not have to be water-cooled at this time.

Fabrication was completed on a new high power protection collimator 3PC3 for the beam transport line between End Station A and Beam Dump East. This unit was installed at the end of the period and efforts are under way to install a 3-foot diameter helium-filled duct between the pivot and 3PC3 for further reduction of the radiation background. The aperture of the new protection collimator is larger than that of the existing one and its power absorption capacity is one order of magnitude higher. This collimator is part of a remodeling program for the beam transport system from the pivot in End Station A to Beam Dump East. The program is designed to obtain a significant increase in the allowable beam power in End Station A for low energies and with thick radiators at the pivot.

Design of a new tune-up dump arrangement for the BSY is essentially complete. This will allow high beam power dissipation during accelerator tune-up and also will protect equipment from damage by a mis-steered high-power beam during operation. Design of a new high-power slit for B-Beam is also underway.

2. Liquid Hydrogen Target Activities

This period started with the target for E-23 (Comparison of $\eta^o$ and $\pi^o$ Photoproduction) in operation in End Station A. On October 14 a new target designed with forced circulation of the liquid hydrogen was installed in End Station A for use in Experiment E-4b, which is studying inelastic electron scattering from protons. The target was designed to give constant density with high power electron beams. Due to a faulty electrical feedthrough the target was removed and reinstalled on October 22. Beam tests on this target indicate that density control is now better than 2%. Two flask failures on the Mu-Beam target resulted in our having to fabricate on a crash basis a new Mu-Beam flask and a spare. With an outstanding effort put forth by the shop this fabrication took place in less than four days. Operations were rescheduled so that little accelerator time was lost.

Two new targets were being designed during this period, one for E-41--Rho Production by Pions--A Test of Vector Dominance, and the pencil target for the streamer chamber. The E-41 target will utilize a helium refrigeration system to condense the hydrogen and is scheduled for April of 1969.

The target for E-10 (A Proposal to Study Photoproduction at Forward Angles Using the SLAC 20 GeV/c Spectrometer) was completed and installed in November and operated in December. A unique feature of this cell is the piggyback arrangement of deuterium and hydrogen targets enabling the experimenter to shift rapidly from one to the other and thereby avoid the drift problem of previous experiments. The design of the target for E-7 (Proposal for a Survey Experiment on Photo-Meson Production Processes at Backward Center-of-Mass Angles) was completed in this period. This target is a 15-inch long, 3-inch diameter cylinder having 2 mil stainless steel windows. It is required in February 1969. The target for E-37 (Measurement of the Total Photoabsorption Cross Section for Hadron Final States) was completed and installed in November. The new target system was operational early in December. The design of the target for E-41 (Rho Production by Pions--A Test of Vector Dominance) has started. Detail designs are in process on the load heat exchanger and hydrogen reservoirs. The specifications for the helium refrigerator to be used for the target were written and reviewed and bids were requested. The detail design of the target for E-39 (Proposal to Study Photoproduction of Neutral Bosons at Medium Four-Momentum Transfer) was in process during this period. Tests were made on an old scattering chamber which proved its suitability for this experiment.

3. Fire in Liquid Hydrogen Storage Area

On November 15, 1968 a fire occurred at a pipe fracture in a contractor's delivery truck during preparations for transfer of liquid hydrogen to our liquid hydrogen storage tank. The resulting material damage was, fortunately, negligible. However, because of the potential seriousness of the incident a committee has been set up to review the incident and recommend improvements in procedures and facilities for further decreasing the possibility of a future incident, to minimize the exposure to personnel and equipment during future accidents, and also to improve communciations.

4. Power Supply Group

The major effort during the quarter was devoted to repair and installation of the large power supplies and routine maintenance and operation. A transformer which had failed the month before in one of the spectrometer power supplies was repaired. No down time was experienced on this account. Upgrading of the B-Beam pulsed switching supplies was in process and should shortly allow operation at 19 GeV.

The 5.8 MW power supply was finally accepted after completion of the installation and testing in its present rebuilt form. A fifth spare power transformer for this power supply was also delivered after it sucessfully passed all specified tests. During the same two-month period the 5.0 MW power supply installation was completed. Testing of this supply was begun during the week of December 16, but was interrupted when a short caused some internal eqiupment damage. Testing due to resume in January. The motor-generator set, although in operation most of the time when needed, has had some troubles: A failure in a high voltage motor lead insulation caused some down time, and more recently there appeared evidence of heat-damaged insulation in one generator armature.

Contracts were awarded for the purchase of six additional regulated 400 kW power supplies, and four unregulated 150 kW power supplies. A redesign of the regualtor used for the 400 kW power supplies, both for the six new power supplies and to correct problems with the existing power supplies, was also begun.

B. Spectrometer Operations and Developments

Experiment E-4b on the 8 GeV Spectrometer ran continuously in November.

During December the 20 BeV Spectrometer was put into operation for Experiment E-10. Preparations were also started for set-up of the 8 BeV Spectrometer for the Cal Tech user group, Experiment E-39 (Proposal to Study Photoproduction of Neutral Bosons at Medium Four-Momentum Transfer). Special remotely operable slits on the front of the 8 BeV Spectrometer, and a particularly exotic hydrogen target arrangement are required by the experiment.

Plans are being made to add a fourth quadrupole to the 8 BeV Spectrometer. The width of the detector of the present arrangement makes it particularly difficult to build efficient momentum counters. The existing hodoscope is approaching the point at which it should be rebuilt, and it is believed that an additional expenditure on the installation of new quad would be a good investment. Computer runs have been made on the magent optics, using TRANSPORT, but the results are not as promising as originally hoped. After further study the decision to proceed or not will be made during January in order to complete the work in September.

C. Bubble Chamber Operations and Developments

1. 40-Inch Bubble Chamber

The 40-inch bubble chamber was apart during October to complete the Hodoscope installation for BC-10--A Proposal to Investigate $K_2^o p$ Interactions with the

40-inch HBC. After assembly, cool down started on the 29th and was completed on the 4th of November. 308,532 pictures were taken and the first phase of the experiment, using counters and the bubble chamber together, was completed. The chamber then began warm up to prepare it for deuterium operation in February.

2. 82-inch Bubble Chamber

The 82-inch bubble chamber completed the K particle portion of BC-4 in October by taking 88,455 pictures. The laser beam HBC-11 was then checked out with 14,000 pictures and HBC-16 (Johns Hopkins) was given 20,000 test pictures. Four days before the allotted running period was over, the motor generator for the magnet failed and the run was halted to prepare for operation in late November.

The 82-inch bubble chamber pulsed 650,000 times during November and took 183,112 pictures for the Johns Hopkins experiment, BC-16. This completes the pictures allocated to BC-16 ($K^+$-p Interactions Around 7 GeV/c). At this time the chamber is warming up to repair a broken refrigeration line within the chamber and to survey other problems which developed as a result of rather severe pulsing the first day of the run for BC-16. The main vacuum tank bolts were broken the first day of pulsing, allowing the vacuum tank to jump violently with each pulse. This, in turn, caused broken pipes, vacuum leaks, etc. These troubles will be repaired and it is hoped the chamber will be ready for BC-4 in January.

D. Summary of C-Beam Activities

The following is a partial list of C-Beam activities during the period: (a) Tests of secondary $e^+$ beams. (b) Shower counter tests for E-38 (Experiment on $\mu^+e^-$ Scattering). (c) 190,000 pictures taken for E-37 (Measurement of the Total Photoabsorption Cross Section for Hadron Final States). (d) Completion of 12 GeV/c $K^+$ run with 82-inch hydrogen bubble chamber for BC-4 ($K^+$p Interactions near 12 GeV/c). (e) Laser beam engineering run for BC-11 (A Bubble Chamber Experiment with the Polarized Laser Induced Photon Beam). (f) Preliminary run of 6.85 GeV/c $K^+$ run for BC-16 ($K^+$-p Interactions Around 7 GeV/c). There were 20,000 pictures taken. (g) Check out of $\pi$-K beam with new target facility (Beam 6).

Tests of laser beam with the 82-inch HBC confirmed that the yield is adequate and that low energy background in the chamber is negligible. Pair spectra obtained with the BC indicated that the expected energy resolution would be achieved but that improved control instrumentation is required to do so in a practical fashion.

Under conditions where the maximum scattered $\gamma$ energy was 4.9 GeV, the measured pair spectrum extended below the expected lower limit of 4 GeV down to about 3 GeV.

It was established that the secondary positron beam would be satisfactory for use both with the streamer chamber and in Experiment E-37 (Total $\gamma$-Hadron Cross Sections Using Tagged Photon Beam).

Modification of the second stage of the $\pi$-K beam and rearrangements of major equipment in the research yard were commenced in order to accommodate Experiment E-37 and the forthcoming installation of the streamer chamber.

Early in November modifications of the $\pi$-K beam to permit simultaneous operation with the secondary $e^+$ beam were completed. One feature of the modification is a new, movable target assembly where the range of target positions corresponds to positron-to-electron beam energy ratios of 0.2 to 1.0 with an excluded region from 0.4 to 0.7. In addition, the Brookhaven type 8Q48 quadrupole magnets which have replaced the Berkeley 8Q32's in the first stage of the $\pi$-K beam provide about 1.5 times more geometrical acceptance. Tests have indicated a corresponding but smaller increase in $\pi$-K yield ( $\sim$ 1.3) and have shown that rf separation is essentially unimpaired for all possible target positions. As it turns out, the primary electrons for the $\pi$-K beam can be steered on a pulse-to-pulse basis to miss the positron converter which produces the secondary $e^+$ beam. As a result, the $\pi$-K beam yield is not reduced by the presence of the $e^+$ converter and simultaneous operation of the $K^+$ beams for the bubble chamber is possible.

E. Description and Status of Approved Experiments

Figure 1 is a Research Area plan drawing showing the location of the various experiments. Table I is a list of presently approved high-energy physics experiments. The right-hand column of Table I gives the status and activity of each experiment during the month. During the 14 December 1968 meeting of the Program Advisory Committee Experiments E-43 and E-45 were approved, and E-31 and BC-11 were granted extensions. The experimenters using the accelerator beam during the period were: E-10, E-23, E-31, E-32, E-37, E-38, BC-4a, BC-10, BC-11, BC-16, and ND-4. Information on the status of these experiments and descriptions of the newly approved experiments follow:

E-1 — Proposal for a Survey of the $\mu$-p Elastic Interactions at High Energy

This experiment has used the muon beam in End Station B to carry out a detailed study of inelastic and elastic scattering of muons on hydrogen. The beam is produced directly in a water-cooled copper target by the primary electron beam. Pions are removed by a beryllium "filter" just downstream of the target. The muons are then formed into a small phase space, momentum analyzed beam. Muons of either sign can be produced in the momentum range of 2 to 13 GeV/c with a ± 1.5% momentum width and at a rate of up to 1,000,000 muons per second.

The experiment consists of several parts: The study of low $q^2$ inelastic scattering; the study of high $q^2$ inelastic scattering up to $q^2 = 4(\text{GeV/c})^2$; and the study of high $q^2$ elastic scattering up to $2(\text{GeV/c})^2$. Some data have also been taken using carbon and copper as targets. The apparatus consists of large optical spark chambers and a large magnet. The angles and momentum of the scattered muon and the angles of the recoil proton are all determined by the apparatus. The experiment was run for several weeks in March 1968 and June 1968, and was completed by running most of September and October 1968.

E-4b— Inelastic Electron-Proton Scattering

A large amount of data on inelastic electron-proton scattering was taken during the period. The experiment was programmed so that at a given angle setting of the 8 GeV/c Spectrometer, and a given incident machine energy, the yield of inelastic scattered electrons from hydrogen was measured as a fraction of the scattered electron momentum from near the elastic peak to about 1 GeV/c. Data were taken for several different machine energies (4.5 to 18 GeV) at three laboratory scattering angles ($18^o$, $26^o$, $34^o$). The data taken here will be combined with some of the small angle data taken during a similar run using the 20 GeV/c spectrometer in August of this year. Analysis of this combined data will give the two inelastic scattering form factors of the proton in much the same way as has already been done for elastic electron-proton scattering. Hopefully, the ratio of these two form factors will give the contribution to the inelastic electron-proton scattering cross section from longitudinal and transverse virtual photons.

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

The E-10 run was interrupted by the December shut down. A second running period for this experiment is scheduled in January. Data taken during December therefore represents partial information on many reactions. The principal effort was devoted to the study of N*(1238) production from hydrogen and deuterium at an energy of 16 GeV and covering momentum transfers from near zero to about 1.5 GeV. In addition, cross sections for production of Y*(1385) and (1405) were measured at 11 GeV. Since the data taken in the first part of the run is neither complete nor finally analyzed, it is too early to draw any conclusions on the significance of the data obtained.

E-23 — Backward $\pi^0$ Photoproduction

This experiment used 42 shifts of machine time in End Station A to measure the process $\gamma + p \rightarrow \pi^0 + p$ in the kinematic region in which the $\pi^0$ is emitted backwards. The spectrum of forward moving protons was measured using the 20 GeV spectrometer and the curves fitted to yield the cross section for the above reaction. Data were taken at eight to ten different angles for incident electron beam energies of 6, 8, 12, and 18 GeV. This completes the program for measuring this process. The preliminary analysis shows that the data taken together with the measurements of backward $\pi^+$ production (experimental Proposal E-7) will place strong restrictions on theoretical models in this field.

E-31 — Measurement of the Magnitude of $\eta_{00}$

During the month of December three weeks of running were done during which $K^0$ decay data was taken. About 100,000 events (~70 rolls of film) were obtained during this period. Most of this data was free decay, although 2 rolls were taken with a 6-inch copper regenerator. Scanning and measuring is underway, but as yet no data has been processed entirely.

E-32 — A Proposed Study of $K_1^0$ Mesons Regenerated From a $K_2^0$ Beam Incident on Hydrogen

This experiment is designed to measure the forward diffraction scattering and backward scattering of $K_2^0$'s from liquid hydrogen with the use of wire spark chambers and a magnet to analyze the momentum of one of the decay $\pi$'s.

Data were taken on the backscattering of $K^0$'s and the forward regeneration of $K^0$'s from hydrogen during November. The beam conditions were: 16 GeV, 0.6 mA with beam knockout at 40 mc, 160 pps.

A total of 1,500,000 triggers were recorded. The trigger rate was effectively dead-time limited. For forward regeneration, the pair/trigger ratio given by on-line analysis was typically 30-40%. The preliminary and more definitive off-line analysis on previous data has yielded a value of approximately 75% for the pair/trigger ratio.

Data accumulation for this proposal was completed during December. Additional data were accumulated on parasite time during the running of E-31. A combined total of 2,000,000 events for the two reactions has been taken. The programs for the off-line analysis of the data are nearly completed. A minimum of 100 hours of computer time will be needed to analyze the data.

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

During November, the construction of E-37 was nearly finished except for the larger section of the hadron counter and the $LH_2$ target, and check-out was begun. The complete tagging system in the new $e^+$ beam gives a false tagging rate (with no radiator) ~ 0.2% of a 0.002 radiation length radiator; this indicates an extremely clean $e^+$ beam. Backgrounds and $e^+$ yields were checked at 4.8 and 16 GeV/c and found compatible with both $\pi$ and K running of the 82-inch BC. Prior to availability of the $LH_2$ target, a Be target was inserted, and despite the much larger electromagnetic background it was possible to detect the hadronic signal.

Check-out of E-37 continued at 20 pulses/sec during the first three weeks of December. The $LH_2$ target was used for the first time and the hydrogen signal observed at 4 GeV and at 14 GeV was not inconsistent with other measurements. Low-statistics goemetry and rate checks showed the expected behavior. In particular it will be possible to run at two tagged photons/pulse and possibly higher. Two planes of the large hadron counter were installed and checked out. Tests with target materials of higher A, up to Pb, were sufficiently encouraging that a supplement to this experiment is being proposed to study the A-dependence of the total photon cross section.

E-43 — Velocity of Light Experiment

This proposal is for an experiment to compare directly the velocity of light at optical frequencies to the velocity of 2 GeV gammas produced by Bremsstrahlung. The motivation for the experiment is primarily exploratory in that the constancy of the velocity of light has only been verified with high precision over a comparatively narrow frequency range.

Upon reviewing the literature for experiments done on photon velocities above optical frequencies, one finds that the best measurement is a test* made on the velocity of $\gamma$'s from moving sources — 6 GeV $\pi^0$'s. This experiment obtains agreement with e to about 1 part in $10^4$. The experiment proposed here is easily capable of an accuracy of one part in $10^5$ and perhaps to one part in $10^6$, and it makes a direct comparison of the gamma radiation to the optical radiation to this accuracy.

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*T. Alvager, F.J.M. Farley, J. Kjellman and I. Wallin, Phys. Letters 12, (1964) p. 260.

The general method of the proposed experiment is to use the electron beam of the accelerator to produce within the same rf bunch, both visible light from Cerenkov radiation (or synchrotron radiation) and gammas by Bremsstrahlung at a target location about 1/3 of the way down the machine. The remaining 2/3 of the accelerator (3000 M) would be used as a flight path for both radiations, and their relative arrival times at the end of this flight path would be detected by two photomultiplier systems located at the same point and capable of interchange. Thus the initial time of both radiations is fixed to within about 10 picoseconds by the machine bunching, and the difference in the arrival time, $\Delta T$, can be measured by conventional time-of-flight techniques to about 50 picoseconds. This gives a basic limitation in the accuracy of the experiment $\frac{\Delta T}{T} \sim 5 \times 10^{-6}$ where T is the flight time from target to detector. If, in addition, phase sensitive photomultipliers can be used, the basic time difference, $\Delta T$, may be reduced to the machine's bunching limitations of about 10 picoseconds and provide an inherent accuracy of $1 \times 10^{-6}$.

E-45 — Proposal for the Measurement of $\pi^+$ Photoproduction with Polarized Photons at SLAC.

It is proposed that $\pi^+$ photoproduction be measured using the polarized photon beam from a crystal. The $\pi^+$ cross section has possibly 3 regions in -t where differential mechanisms may be operating, suggested mainly by the 3 differential exponential slopes in differential cross section. In addition, since there can be no polarization at $0^o$, a rapid variation in polarization within $-t < m^2$ may be expected. It is presently planned to make measurements at 11 GeV for the following values of -t $\left(\text{in units of } (\text{GeV}/c)^2\right)$: 0.005, 0.02, 0.04, 0.1, 0.2, 0.4, 0.6, 0.8, 1.0, 1.3, and 1.6. An analysis of running times in various t values shows that it will be most feasible to operate between -t = 0.1 and -t = 1.3. However, it still may be possible to operate at the extreme t values. A recent theory by Frøyland and Gordon* predicts a strong polarization dependence for $\pi$ photoproduction between -t = 0.1 and -t = 1.0, so a stringent test of their theory should be provided.

Instead of running at a single photon energy, it may be desirable to investigate the energy dependence at t values where the running times are shortest. This will also provide a good test of the Frøyland and Gordon model. The corresponding running times for lower energies should be comparable to the 11 GeV estimates

*J. Frøyland and D. Gordon, M.I.T., Preprint CTP-38 (1968).

at intermediate values of t. The polarization dependence of $\pi^-$ photoproduction is also an important piece of information and will warrant further study. However, options will be left open until more experience with the experimental problems has been obtained.

The major hardware cost of this proposal is the goniometer and its peripheral apparatus. This facility for producing polarized photons will remain at SLAC and will also be considered for its utility in other experiments -- for example, $\pi^0$ and $K^+$ photoproduction.

BC-10 — <u>A Proposal to Investigate $K_2^0p$ Interactions with the 40-inch HBC</u>

During the period the initially approved pictures for experiment BC-10 were taken: 250,000 photographs at 10 GeV and 16 GeV electron energies, and at $K^0$ production angles of $2^o$, $3^o$, and $4^o$. The photographs were of good quality and contain on the average 5-8 interactions per frame. Scanning and measuring of these pictures has been started. Initial evaluation of the hodoscope counter arrangement shows that the time resolution was somewhat worse than had been hoped, being the order of $\pm .5$ nanosecond.

BC-16 — <u>$K^+$-p Interactions Around 7 GeV/c</u>

This experiment uses the 82-inch bubble chamber and the $K^+$ beam in the Central Beam. The experiment is studying $K^+p$ interaction in several broad categories of interest: (a) Production of new resonances and determination of their properties. (b) Production mechanisms and interactions such as the $K\pi$ interaction. (c) Anti-hyperon production, associated production and infrequently produced reactions. The bubble chamber exposure with 6.85 GeV $K^+$ which ran this quarter completes picture allocation for this experiment.

ND-4 — <u>Test of Large Total Absorption Counter</u>

This experiment uses the $K_0$ beam in End Station B on a parastic basis. The experiment is studying the feasibility of operating large crystals of NaI (T1) both in the vicinity of the $K^0$ neutral beam and directly in the beam. As a test of the latter technique the group is attempting to measure the $K^0$ energy spectrum in the beam by regeneration of $K_S^0$ mesons and detection of all four $\gamma$ rays from the decay $K_S^0 \to 2\pi^0 \to 4\gamma$. Three things have been accomplished.

1. It has proved possible to detect events of the type $K_1^0 \to K_S^0 \to 2\pi^0 \to 4\gamma$ and to totally absorb all 4 $\gamma$'s with the NaI (T$\ell$) detector. This provides a direct method of surveying the $K^0$ components of the neutral beam. A small sample of such data has been collected.

2. Preliminary measurments have been made of the $K^0$ nucleus total cross section in nuclei from carbon to lead for $K^0$ energies larger than 5 GeV.

3. A survey has been made of the total intensity of neutral particles in the $K^0$ beam down to times of flight as long as 15 nanoseconds.

## TABLE I

## TABLE OF PROGRAMMED EXPERIMENTS

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

Table of Programmed Experiments (cont'd) - 2

| Number | Title | Authors | Date Approved | Status |
|---|---|---|---|---|
| E - 14 | Proposal for Testing of Quantum Electrodynamics by Photoproduction of Asymmetric Muon Pairs | STANFORD (Group A) W. Panofsky, D.H. Coward, H. DeStaebler, J. Litt, A. Minten, L.W. Mo, R.E. Taylor MIT J.I. Friedman, H.W. Kendall, L. VanSpeybroeck | 11/18/66 | d |
| E - 21b, E - 21c | Proposal for Measurements on the Photoproduction of $\pi^o$, $\eta$, $\rho^o$, $\omega$ and $\phi$ 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 | d |
| E - 23 | Backward $\pi^o$ Photoproduction | STANFORD B. Gittelman, A. Minten, B. Wiik, R. Anderson, J. Litt, D. Yount | 6/22/67 | a |
| 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 $\eta_{00}$ and its Phase Relative to $\eta_{+-}$ | STANFORD D. Dorfan, M. Schwartz, W. Wojcicki | 11/6/67 | a |

Table of Programmed Experiments (cont'd) - 3

| Number | Title | Authors | Date Approved | Status |
|---|---|---|---|---|
| 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<br>CORNELL L.N.Hand<br>HARVARD P.G.Innocenti | 12/16/67 | a |
| E-34 | Electron-Deuteron Quasi-Elastic Scattering | STANFORD E.Bloom, D.Coward, H.DeStaebler, J.Dress, J.Litt, R.E.Taylor<br>MIT J.Friedman, G.C.Hartman, H.W.Kendall<br>CAL TECH B.C.Barish | 7/2/68 | d |
| E-37 | Measurement of the Total Photoabsorption Cross Section for Hadron Final States | UCSB D.Caldwell, V.Elings, W.Hesse (Student), R.Morrison, F.Murphy<br>STANFORD D.Yount | 5/11/68 | b |
| E-38 | Proposal to Stanford Linear Accelerator Center for an Experiment on $\mu^+ e^-$ Scattering | UNIV. OF WASHINGTON<br>S.Neddermeyer, N.Scribner, P.Kotzer, G.Eilenberg, T.Koss | 8/5/68 | b |
| E-39 | Proposal to Study Photoproduction of Neutral Bosons at Medium Four-Momentum Transfer | CAL TECH A.Tollestrup<br>J.Pine, R.Gomez, R.Barish, C.Peck, F.Sciulli, B.Sherwood | 8/5/68 | d |
| E-40 | High Statistics Study of the Production of Charged $\rho^\pm$ Mesons, Neutral $\rho^0$ 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<br>IBM M.Beniston | 8/5/68 | c |

Table of Programmed Experiments (cont'd) - 4

| Number | Title | Authors | Date Approved | Status |
|---|---|---|---|---|
| E-43 | Velocity of Light Experiment | UCSD G. Masek | 12/14/68 | d |
| E-45 | Proposal for the Measurement of $\pi^+$ Photoproduction with Polarized Photons at SLAC. | MIT D. Luckey, L. S. Osborne, R. Schwitters<br>SLAC A. Boyarski, R. Diebold, S. Ecklund, B. Richter | 12/14/68 | d |
| BC-3 | A Proposal for a Photoproduction Experiment in the SLAC 40-Inch Bubble Chamber Exposed to Monochromatic $\gamma$-Ray Beams (4 GeV Annihilation Photons) | WEIZMANN INSTITUTE<br>Y. Eisenberg, E. Ronat, A. Shapira, G. Yekutieli | 8/12/67 | h |
| BC-4 | $K^+p$, $\pi^+p$, and $\pi^-p$ Interactions Near 12 GeV/c (82-Inch HBC) | LRL M. Abolins, O. Dahl, P. Dauber, P. Eberhard, S. Flatté, L. Galtieri, M. Alston-Garnjost, J. Kirz, G. Lynch, J. Murray, F. Solmitz, L. Stevenson | 12/16/67 | a |
| BC-6 | Proposal to SLAC for Study of the One Pion Exchange Contribution to $\gamma$-Nucleon Scattering (in 40-Inch Deuterium Bubble Chamber) | OAK RIDGE H.O. Cohn, R.D. McCulloch<br>UNIV. OF TENNESSEE<br>G.T. Condo, W.M. Bugg | 9/28/68 | d |
| 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 | a |
| BC-11 | A Proposal for a Bubble Chamber Experiment with the Polarized Laser Induced Photon Beam | Spokesman: Günter Wolf | 5/11/68 | a |
| BC-13 | Proposal for a 3,000,000 Picture 7.5 GeV/c $\pi^-p$ Exposure in the 82" Bubble Chamber | UNIV. OF ILLINOIS<br>G. Abrams, G. Ascoli, B. Crawley, B. Eisenstein, R. Hanft, U. Kruse, D. Mortara, T. O'Halloran, R.D. Sard | 8/5/68 | d |

Table of Programmed Experiments (cont'd) - 5

| Number | Title | Authors | Date Approved | Status |
|---|---|---|---|---|
| BC-14 | Proposal for 7.5 and 13 GeV/c, $\pi^+$ and $\pi^-$ Exposures in the SLAC 82" HBC | MIT P.L. Bastien, D. Brick, T. Dao, B. T. Feld, R. I. Hulsizer, L. Kirkpatrick, V. Kistiakowseky, H. Lubatti, D. Miller, A. Nakkasyan, G. Ouannes, I. Pless, A. Sheng, T. Watts, F. Winkelmann, J. Wolfson, R. Yamamoto | 8/5/68 | d |
| BC-15 | Proposal for an Exposure of the 82-Inch Deuterium-Filled Bubble Chamber to a 7 GeV/c $\pi^-$ Beam at SLAC | UNIV. OF ROCHESTER T. Ferbel, W. Katz, P. Slattery, S. Stone, H. Yuta | 9/28/68 | d |
| BC-16 | $K^+$-p Interactions Around 7 GeV/c | JOHNS HOPKINS UNIV. A. Callahan, B. Cox, L. Ettlinger, A. Pevsner, R. Sekulin, R. Zdanis | 8/5/68 | a, 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 $\gamma$-Deuterium Experiment in the SLAC 40" Bubble Chamber | WEIZMANN INSTITUTE Y. Eisenberg, B. Haber, U. Karshon, L. Lyons, E.E. Ronat, A. Shapira, G. Yekutieli | 9/28/68 | d |
| BC-19 | A Proposal for a $\gamma$-d Experiment with an Annihilation Beam of 7.5 GeV in the SLAC 40" Bubble Chamber | TEL AVIV UNIVERSITY G. Alexander, I. Bar-Nir, A. Brandstetter, S. Dagan, J. Gunhaus, A. Levy, Y. Oren | 9/28/68 | d |
| 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 |
| NT-3 | Fast Cycling Bubble Chamber Development | SLAC H. Barney, R. Blumberg, A. Rogers, S. St. Lorant | 12/15/68 | c |

Table of Programmed Experiments (cont'd) - 6

| Number | Title | Authors | Date Approved | Status |
|---|---|---|---|---|
| NFD-0 | A Proposed Study of High Energy, Cosmic Ray Muons at Sea Level. | U.C. BERKELEY S.M. Flatté, M.L. Stevenson<br>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.

## III. ACCELERATOR IMPROVEMENTS

Fabrication of a new positron "wand" was completed during the quarter. It was installed and checked out in December and is ready for the next scheduled positron experiment.

As a result of a theoretical analysis of the beam break up effects of dimpling of accelerator sections in Sector 1, it was decided to dimple Sector 2 during the December shut-down and make further studies. The dimpling has been completed and studies will be resumed when the accelerator is again in operation.

In a continuation of the drive line maintenance work started during the August shut-down, Sectors 11 through 30 were to be repaired during the December-January shut-down. Insulation was stripped in December and during January the main drive line flanges will be straightened and refaced. Before reinsulating, the sub-drive lines will be checked and any necessary repairs will be started.

The planned modification of four sectors of the accelerator to provide pulse-to-pulse steering and focusing continued during the quarter. Design of a pulsed focusing quadrupole, its associated power supply, and a pulsed steering power supply for use with existing steering dipoles was completed and fabrication of prototypes was begun. Prototypes will be tested in February after which the remaining units will be fabricated.

Design of an off-axis injector to be located at the west end of the accelerator continued during the quarter. This will improve the operation of simultaneous beams with radically different intensities and will improve reliability of the accelerator by acting as a back-up injector in case of malfunction of the main injector.

A Digital Equipment Company Model PDP 9 computer was delivered during October, has been checked out, and is being tied in to the accelerator. Computer control of klystron replacement in the accelerator is scheduled to be operational by February. In case of a klystron failure the computer will automatically select and activate the spare klystron which most nearly matches in values the one that failed, permitting more uniform operation of the machine.

## IV. RESEARCH DIVISION DEVELOPMENT

### A. Physical Electronics

### 1. Alkali-Halide and Semiconductor Secondary Emitters

(a) The ultra-high vacuum chamber for measurements with alkali-halide films and semiconductor crystals is now complete, and with ion pumping alone, pressures in the $10^{-11}$ torr range have been obtained. After conditioning and using the titanium sublimation pump, a base pressure of approximately $5 \times 10^{-12}$ torr remains stable over periods of at least 24 hours.

(b) Complete measurements of secondary emission statistics on bulk density films of CsI, KCl, and LiF have been completed at both low (5 - 10 keV) and moderate energies (≈1 MeV).

(c) Measurements on one film of low density KCl have been completed. In contrast to the results for CsI, it was found the KCl exhibits enhancement in secondary emission yield even at low primary current densities. With approximately 6000 electrons per $cm^2$ per second incident with primary energy near 1 MeV, the probability that one primary generates no secondaries at all, when deflected by shallow angles at the alkali-halide film, is found to be dependent on the voltage applied to the grid located at the exit side of the film. The best result obtained has been $P(0) = .712$ at $V_g = 90$ volts. The average yield under this condition is found to be near 1.0.

DC yield measurements with low energy primaries (9 keV) show that very high yields, of the order of 80, are obtainable at primary currents on the order of 1 to 10 $nA/cm^2$, while with currents 10 times lower, maximum yield is only about 25, indicating that a fairly large current is needed to maintain a high state of surface charge at the exit side of the film. This result is consistent with and complements previous work by E. L. Garwin and J. Edgecumbe at SLAC in which secondary yields as high as 5 were reported for relativistic particles with currents of about 10 $nA/cm^2$, and by Dietz et al. (GE) in which high pulsed yields were observed for KCl at primary currents of 1 $\mu A/cm^2$.

Detailed analysis of the present series of measurements still awaits the resolution of difficulties encountered in the numerical handling of experimental results.

(d) Measurements of secondary emission statistics on low density films of CsI have been carried out on two films of different characteristics: (1) Thickness ≃30 microns, density ≃1.8% of bulk; (2) thickness ≃ 36 microns, density ≃ 2.7%.

The analysis of data is not yet complete but the following tentative results can be indicated:

When the films are freshly made and uncharged, the probability that a 1 MeV electron traverses the film without producing any secondaries is 77.5% for film (1) and 72% for film (2) compared to 83 to 90% found for bulk density films. This probability changes only by 1% in varying the dynode exit-to-grid voltage from 9 to 90 volts for the low density films, while it was insensitive to grid voltage for bulk density. The secondary yield also changes very little as a function of this voltage. The counting rate for this measurement was quite low, approximately 150 primary electrons/sec per $cm^2$.

With low energy primaries (~8 keV) at a count rate of about 2000 primaries per second, changing grid voltage from 9 to 90 V again makes little difference to the yield, which is found to be approximately 12. High yields in the range of 40 or more are only obtained at primary current densities on the order of $10^{-10}$ A/$cm^2$, at which point, the yield changes by factors of 2 to 3 in switching from 9 to 90 V at the grid.

Once a film is charged to a high yield condition, low count rate measurements for both high and low primary energies indicate that the film discharges with a time constant of the order of minutes, and the enhancement of yield obtainable three or four minutes after the high current beam turn-off is negligible.

(e) A furnace for the growth of semiconductor crystals has been obtained. The high-speed diamond saw for cutting semiconductor crystals is now 99% complete, and machining of internal parts for the tube to be used in measurements of alkali-halide and/or semiconductor secondary emitters has started.

2. RF Superconductivity Materials Research

(a) <u>Cavity measurements</u>

A low-temperature test was made with the C-band cavity cleaned and baked at the end of November. Down to $2.5^oK$, Q values were quite similar to those obtained earlier when the cavity was new. At $1.75^oK$, however, Q measurements were lower by 35% ($1.7 \times 10^9$ vs $1.05 \times 10^9$).

The cavity was then exposed to room air for 3 hours, pumped down to $3.3 \times 10^{-7}$, and retested at low temperature without baking. Q spoilage was 15% at $4.2^oK$ and as large as 20% at $1.75^oK$.

Finally, the cavity was baked for approximately 75 hours and retested. Q values appeared slightly improved (+8%) above $3^{o}K$ and further deteriorated below that temperature (-12%). No further tests are planned for this particular cavity; another lead-plated cavity is being prepared.

The sealing problems encountered with the X-band cavity obtained from Varian were solved by modifications in the lead wire seal and the sealing bolts.

The cavity was prepared for a run, but opened while being cooled. It was successfully resealed and will be rebaked.

(b) Room temperature field emission measurements

The $\beta$ electric field enhancement values reported in the last progress report were low, due to the use of an incorrect factor for image force. These corrected values are: $260 \leq \beta \leq 350$ for unbaked copper; $110 \leq \beta \leq 180$ for baked copper; $100 \leq \beta \leq 280$ for lead-plated copper.

Further work has been done on the argon sputtering of cathode whiskers to reduce $\beta$, the field enhancement factor. At moderate emission currents ($\sim 10^{-8}$A) and argon pressures from $4 \times 10^{-6}$ torr to $1 \times 10^{-4}$ torr, the enhancement factor changes quasi-periodically. The length of the period appears to increase with increasing pressure. The enhancement factor both decreases and increases relative to its initial value so that even after a couple of days of sputtering, there is no definite net change. One may stop the sputtering with $\beta$ either in a state of decrease or increase, but at these pressures and current, the decrease is only minor—the emission current decreasing by a factor of three. With an increased emission current of $\sim 10^{-6}$ A, and $P = 1.4 \times 10^{-4}$ torr, a permanent significant decrease in $\beta$ was obtained. Within a few hours, the emission current showed a monotonic decrease which persisted over 24 hours. The emission current was decreased by a factor of 140 (from $1 \times 10^{-6}$A to $0.7 \times 10^{-8}$A), and $\beta$ was permanently reduced from 348 to 167. Efforts were then directed at various means for increasing $\beta$ to its original value. It was difficult to substantially increase $\beta$ by either operating at high field levels for long periods of time, or by electrical breakdown. Finally $\beta$ was increased to 439 by touching and separating the electrodes while a current passed through them.

Selective sputtering of the whiskers was next attempted with He. Results have been inconclusive to date.

(c) Basic materials and coating techniques

Evaporation. Feasibility of electron beam evaporating yttrium borides starting with both hot-pressed, full density pellets and alternately cold-pressed powers was established. $YB_6$ (yttrium hexaboride) was successfully evaporated into glass and quartz substrates in thicknesses of 4000 to 5000 Å. With films 5000 Å thick deposited on glass substrates, X-ray diffraction analysis showed poorly crystallized $YB_6$ as the only phase present. Substrate heating will be tried to promote improved crystal perfection.

Sputtering. A substrate heater was also added to the sputtering apparatus. Adjustments of filament position, magnetic shielding, extraction potentials, and magnetic field strength all failed to reduce plasma quenching pressures below $3 - 4 \times 10^{-4}$.

Future efforts will be concentrated on controlling impurities at the substrate by heating, biasing, pre-sputtering, etc.

Chemical Vapor Deposition. Facilities for chemical vapor deposition of niobium are being set up.

Briefly, the CVD process involves the synthesis of niobium pentachloride, with pyrolysis and niobium deposition at the heated substrate (950 - 1000°C) in the presence of hydrogen.

Surface Treatments. Good, shiny, specularly reflecting surfaces of niobium were prepared by electropolishing a mixture of lactic, sulphuric and hydrofluoric acids at current densities of 200 - 400 mA/cm$^2$. This work is being continued.

Niobium. Some effort was spent in learning to work successfully with niobium. Experience and competence were gained in the following areas: welding, machining, chemical etching, and heating in vacuum to remove $H_2$, $N_2$ and $O_2$ impurities. The polishing technique required for producing high-Q niobium cavities is being developed.

Magnetization measurements by the magnet research group on some rolled niobium wire showed non-linear behavior suggestive of cold work effects. The wire was vacuum annealed and will be re-measured.

Lead. A 500 Å $Al_2O_3$ "protective" film was evaporated onto lead-plated copper samples. Tests for visible corrosion with this coating thickness, will be made.

B. Magnet Development

1. The main activity of the group has been concentrated on preparation for the enthalpy-stabilized porous conductor. The work will be pursued in 3 areas, which will coincide in the final product:

(a) Testing and measuring properties of supercritical helium

(b) Measuring specific heat and thermal conductivity of porous structures

(c) Heat propagation along the conductor having a porous substrate.

In this regard, a number of test gadgets are being built for testing supercritical helium, as well as for determination of minimum propagating current along the conductor, and the balance between thermal and magnetic diffusivity in composite conductor. These tests must be performed at high external fields.

2. Because, up to now, the main source of helium is the 7-WADL helium, we have been concerned about the high helium boil-off rate of the 12-inch SLAC magnet with a working bore of ~10-inches.

After several modifications in the magnet, rearranging supply circuit and the voltage sensing leads, we operated the magnet for a period of ~1-1/2 weeks. The tests had several purposes:

(a) Determination of the maximum boil-off at fields ranging between 50 and 70 kG

(b) Continuous operation of the magnet without close supervision

(c) Charging and discharging of the magnetic field at slow or fast rates, depending on the mode of operation.

At 60-kG field level, connecting two magnet sections in series, we succeeded in limiting the helium boil-off to about 9 liters/hour (a reduction of a factor of 2.2). In addition to our fast-acting switches, which dissipate the field energy within 500 msec into an external shunt, a resistor-and diode configuration was used parallel to the power supply which, after the power supply is disconnected from the magnet, enables a slow energy discharge. Thus the power supply is completely protected and no helium is evaporated.

It was found that the magnet performance is stable and no attention is required if automatic helium filling is provided.

To save helium during cool down, the magnet is precooled to ~$80^{\circ}$K with nitrogen and to $20^{\circ}$K with helium gas from the liquefier operated in close cycle as a refrigerator. To cool down and fill the Dewar with liquid helium, about 500 liters are required, which can be supplied entirely from the SLAC liquefier. The boil-off of 9 liters/hour leaves a balance of ~1-2 liters/hour of helium for experiments with supercritical helium.

In addition, resistors are being calibrated in the temperature range of $0.9^{\circ}$K to $12^{\circ}$K for temperature measurements with an accuracy of ~$1/100^{\circ}$K.

3. Tests with niobium perpendicular to the magnetic field are terminated. Niobium as received, cold-worked, partially and completely annealed, and degassed, has been measured and compared. Tests parallel to the field are being prepared.

4. To find screening effects of superconducting meshes, several model tests with a screen opening of $1 \times 1\ cm^2$ have shown that ~23% of the field could be shielded. Another screen with a mesh of $0.3 \times 0.3\ cm^2$ has been built and tests will soon begin.

5. A new 1-inch, 30-kG magnet was wound and tested. The magnet is capable of being charged within one second to full field and is suitable for magnetization measurements.

6. We have acquired two new current-regulated power supplies (surplus) which, after installation, will enable us to operate up to 10,000 A. The completion of the set up, including regulation, will require several months of work.

7. The test set up to measure thermodynamic properties of hollow conductors is being fabricated by the bubble chamber group.

8. Tests to produce supercritical helium with our own ADL machine have been successfully concluded.

9. A proposal to convert the existing bubble chamber magnet from 26 kG to 70 kG based on superconducting composite conductor, has been completed and handed for further evaluation to the bubble chamber group. This proposal will be part of a general proposal for the conversion of the bubble chamber magnet.

10. The flux-pump, based on a rotating shaft and Nb flux sheets, was tested several times successfully to about 3-W output power. The output voltage of the flux-pump is 6 mV and current was limited to 500 A. We had expected approximately 10-W out of the flux pump; the causes for the small efficiency are now understood and will be remedied, and a 20-W flux-pump will be constructed.

C. Conventional Data Analysis Activities

This quarter, for the first time, newly-hired scanners had a week of general indoctrination and training before being assigned to experiments. The scanning group strength has increased slightly, to 60 people.

The spiral reader has had a successful test.

The fifth measuring machine MPF-5, has been turned over to an experimental group for use. Some final installation work remains, but it is presently measuring as accurately as the other machines.

The program used for sorting the measured data, originally written for a 7090 computer, is being rewritten for the IBM 360/91. A review of the program for the EMR computer is also underway.

## D. Computation Group Activities

### 1. On-Line SUMX

Work is continuing on an interactive SUMX program utilizing the 2250 scopes attached to the 360/91 computer. A package including scope and file management programs, a text editor, and overall monitor has been completed and operates successfully with CERN SUMX on smaller 360 computer systems. Considerable work, however, was involved in making this program compatible with recent releases of IBM systems software for SLAC's model 91. A small on-line compiler was written and plans are to include it to allow physicists to interactively create and modify arbitrary functions of their data.

### 2. Compiler Implementation Language (CIL)

The language has been defined and a report on it is almost finished. CIL is an ALGOL-like language with facilities added for building scanners, syntax analyzers (production language) and for generating code for the IBM 360. This code generation system (CGS) allows one to generate code using high-level constructs; all the details are handled by the system.

The compile time routines for scanning and for interpreting a production language table, most of the basic storage allocation routines, and some simple I/O routines have been written and checked out. About 40 macros have been written to aid in using these routines and to provide subroutine linkage. The actual compiler for production language is debugged and the one for the scanner definition is being checked out.

Work is continuing on programming the main compiler itself and on programming the code generation system.

### 3. Computational Graph Theory

The question of search over large discrete domains is a core problem in computer theory. A formal theory of bi-directional search has been worked out (GSG memo 56) and certain theorems guaranteeing an optimal search procedure have been proved. Recently, an efficient partitioning algorithm has been developed (SLAC-PUB-517) which would further enhance search procedures. Investigations are underway into the question of the usefulness of heuristic information in conducting searches. Some results on this problem are that systematic parallel search is always preferable to random depth-first search in the strong sense that the latter would not normally expect to terminate in a domain as sparse as an infinite rooted binary tree.

4. Interactive Data Analysis

A program called PEG, which utilizes the IBM 2250 display unit for interactive data-fitting by least squares is now essentially completed and ready for general use. A publication describing PEG and detailing its use is also almost completed. Some use of the program is already being made by members of SLAC outside the Computation Group. PEG allows a user to choose (and/or define) a function to be used as the fitting function, enter data on-line, enter parameters on-line, and select from various display modes to examine the results on-line. In addition to PEG, the least squares data-fitting program, another program has been developed for data-fitting by the maximum likelihood method on-line. A third project involves an interactive program for fitting data by a sum of exponential terms. These two programs are also essentially completed. Publications describing their use are being written.

5. Fast Assembler Project

The fast one-pass Assembler (SPASM: an acronym for Single-Pass Assembler) was completed in time for use by students in the Computer Science 139 class in the fall quarter at Stanford. The speed improvement over the use of the IBM-supplied systems is in the range 10:1 to 100:1, with the larger ratios most noticable for short jobs. (The availability of the high-speed batch partition on the Campus Facility's Model 67 accounts for perhaps a factor of 2 on the very short jobs.)

The system currently provides the full OS/360 Assembler Language except for: (a) programmer-defined Macro-instructions (several pre-defined macros are provided for input and output and program debugging); (b) multiple relocatibility attributes are not allowed; (c) conditional assembly is not supported; and (d) two very minor language restrictions which were made to obtain better performance.

6. Graphics

The Graphics Interpretation Facility configuration was installed in December and is currently undergoing acceptance tests. Disk utility routines have been written and the hardware link to the Model 91 has been debugged. A submonitor to reside in the development partition on the 91 and to handle the communciation with the GIF is in the debugging stage.

An instructional program for the IBM 2250's is in preparation. This will enable a user to use a 2250 to learn how the scope itself works and how to use the software package to write display programs.

## V. PLANT ENGINEERING

Construction of SLAC's major building project, the Central Laboratory Addition, was continued. The job is 99% complete and occupancy is scheduled to start early in the next quarter.

Several projects were completed, or essentially so, and the facilities have been placed in use. Included are: rebuilding and rehousing of the 5.8 MW power supplies; construction of a deuterium storage facility in the research yard; erection of a sandblasting facility near the Crafts Building; procurement of approximately 2000 square feet of relocatable building space in the research yard; addition of a 50 ton air conditioning chiller at the Central Control Building; extension of the service yard parking area; improvements in the storm drain system near the Fabrication Building; and excavation of the hilly area north of Sector 12 to preclude lateral movement of the accelerator housing in that vicinity.

Other projects are in various stages of progress. Engineering is underway on: relocation of the Central Laboratory Library; enclosing of the Cleaning Shop near the Fabrication Building; increases in LCW cooling and pumping capacity in the research area; electrical power distribution in the south staging yard area; preliminary scoping of an on-site warehouse; a study for the conversion of the SLAC two-mile machine to a 100 GeV cryogenic accelerator. Bids have been invited on modifications to the Crafts Building heating and ventilating system and on the relocation of the Stores Building (#103) to the research yard. Field work and/or procurement are underway on the following projects located in the research yard: a major extension to the utility tunnel; installation of a 5 MVA electrical substation; foundations for the new location of the streamer chamber building (#110); 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); installation of a 2000 kVA portable electrical substation. In addition, field work is now commencing on enclosing the Heavy Assembly Building welding shop.

Relocation of the front entryway incident to the widening of Sand Hill Road at the north boundary of SLAC is in progress. The new entryway should be available for use in the next quarter.

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

# VI. KLYSTRON STUDIES

## A. Development

### 1. High Power Klystrons

SLAC has continued to investigate the causes of gassing and arcing problems which had reduced the klystron yield to unacceptable levels. During the quarter the yield began to improve. Although all tubes built have not completed tests, so that a final yield figure can not be given, it appears that most of the immediate problems have been solved. However, the yield to obtain 30 MW 270 kV tubes will still not be acceptable because of arcing problems which still show up at high voltages. Hence, additional work is being done to improve the yield of 30 MW tubes.

RCA has not progressed as fast as had been hoped in their program to develop a 30 MW 270 kV tube. However, they appear to have no arcing difficulties in reaching the full beam voltage of 270 kV. Instead they have experienced window problems (probably caused by the transfer of coating process from engineering to manufacturing) which has required the rework of the first few test vehicles.

Litton has not yet fully resolved their technical problems. Although they appear to be able to build tubes which hold full voltage in their own test equipment, we still find many of these tubes faulting excessively when operated on the SLAC modulators. In addition, the Litton tubes have been plagued lately by instabilities caused either by gun oscillations or by returning electrons or body oscillations. Maximum pressure is being brought to speed up their engineering and production programs towards restoring the good yield record experienced by the company during the initial phases of their delivery under this program.

### 2. High Power Window Development

In addition to continuing the studies of the resistance stabilities of the various types of coating, we are also undertaking some studies of gas evolution statistics from the window. Total gas evolution as a function of operating power appears to be different for new windows and used windows coated in presumably the same fashion. The results are very fragmentary and it is probable that a more detailed analysis of the gas evolved will be necessary before a clear understanding of the phenomenon can be obtained.

### 3. Vacuum

Analysis of the gas evolution problems in the SLAC klystron gun package is continuing and we suspect some of the good results reported above in the improved klystron yield is due at least in part to the results of this analysis.

Some preliminary investigation of the viton O-rings used in the vacuum valves in the accelerator has also begun as a result of the discovery of several valves which failed to close satisfactorily. Initial results indicate some hardening of the viton after 3 years of exposure to an ion-pumped, oil-free vacuum system.

4. Driver Amplifier Klystrons

Two SLAC-built driver amplifiers were not acceptable this quarter because of excessive gas problems; however 7 met all specifications and the yield stays satisfactory. No major difficulties are expected in the future.

B. Operation and Maintenance

During the quarter we experienced 23 high power klystron failures for a total operating time of approximately 350,000 hours. The number of spares available for immediate installation remains substantially constant, but the total number of spares available decreased by approximately 15 tubes because of the excess of failures over acceptances. However, we still have a total number of spares on hand exceeding 25% of the number of sockets.

The driver amplifiers operated approximately 47,000 hours in the gallery and 2800 hours in the Test Laboratory. There were a total of 3 driver amplifier failures in the gallery, and 10 spares were available at the end of the quarter.

The main booster klystrons operated approximately 2000 hours without failure.

1. High Power Klystron Operation

Table II gives the summary of tube usage and failure since the beginning of the machine's operation. This table includes all Sperry failures through June 30, 1968. However, since Sperry tubes are no longer in use, the Sperry failures have been deducted from the cumulative numbers beginning on July 1, 1968. In addition, some corrections have been introduced to the tables since the last quarterly report.* Approximately 10 Litton tubes which had originally been "failed" during the previous quarters have been reaccepted without undergoing a complete rework at Litton; for instance tubes which had been failed for "burning" have been reaccepted since a minor magnet modification eliminated the problem.

Operating statistics and klystrons mean time between failure (MTBF) (excluding Sperry tubes from all statistics) are given in Table III. The MTBF has remained substantially constant at 15,000 hours for over 18 months. The tube age distribution at the end of the quarter is given in Fig. 2 showing a mean age for all operating

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*Quarterly Status Report, 1 July to 30 September 1968, SLAC-93.

TABLE II

KLYSTRON USAGE AND FAILURES

Overall

| Dates | Operating Hours | | Failures | | | |
|---|---|---|---|---|---|---|
| | | | Quarter | | Cumulative | |
| | Quarter | Cumulative | Number | Mean Age @ Failure | Number | Mean Age @ Failure |
| To 6/30/66 | 118,000 | 156,000 | 17 | 234 | 39 | 256 |
| To 9/30/66 | 127,000 | 283,000 | 14 | 594 | 53 | 350 |
| To 12/31/66 | 176,000 | 459,000 | 23 | 1070 | 76 | 575 |
| To 3/31/67 | 228,000 | 687,000 | 28 | 1670 | 104 | 860 |
| To 6/30/67 | 303,000 | 990,000 | 25 | 2210 | 129 | 1130 |
| To 9/30/67 | 335,000 | 1,325,000 | 28 | 2881 | 157 | 1433 |
| To 12/31/67 | 265,500 | 1,590,500 | 23 | 3833 | 180 | 1739 |
| To 3/31/68 | 311,000 | 1,901,500 | 17 | 4487 | 197 | 2013 |
| To 6/30/68 | 307,500 | 2,209,000 | 17 | 4620 | 214 | 2225 |
| To 9/30/68 | 314,200 | 2,523,200 | 24 | 5350 | 162* | 3089 |
| To 12/31/68 | 349,800 | 2,873,000 | 23 | 8400 | 185* | 3620 |

* Not including Sperry

TABLE III

KLYSTRON MTBF

(Excluding Sperry)

| Dates | Per Quarter | | | Cumulative | | |
|---|---|---|---|---|---|---|
| | Operating Hours | # of Failures | MTBF | Operating Hours | # of Failures | MTBF |
| To 6/30/66 | | | | 129,400 | 19 | 7,200 |
| To 9/30/66 | 111,000 | 8 | 14,000 | 240,400 | 27 | 9,000 |
| To 12/31/66 | 154,000 | 11 | 14,000 | 394,400 | 38 | 10,300 |
| To 3/31/67 | 207,000 | 13 | 15,900 | 601,400 | 51 | 11,800 |
| To 6/30/67 | 287,000 | 9 | 32,000 | 888,400 | 60 | 14,800 |
| To 9/30/67 | 330,500 | 25 | 13,300 | 1,218,900 | 85 | 14,500 |
| To 12/31/67 | 263,000 | 21 | 12,500 | 1,481,900 | 106 | 14,100 |
| To 3/31/68 | 309,500 | 17 | 18,200 | 1,791,400 | 123 | 14,700 |
| To 6/30/68 | 306,000 | 15 | 20,400 | 2,097,400 | 138 | 15,200 |
| To 9/30/68 | 314,200 | 24 | 13,100 | 2,411,600 | 162 | 14,900 |
| To 12/31/68 | 349,800 | 23 | 15,200 | 2,761,400 | 185 | 14,900 |

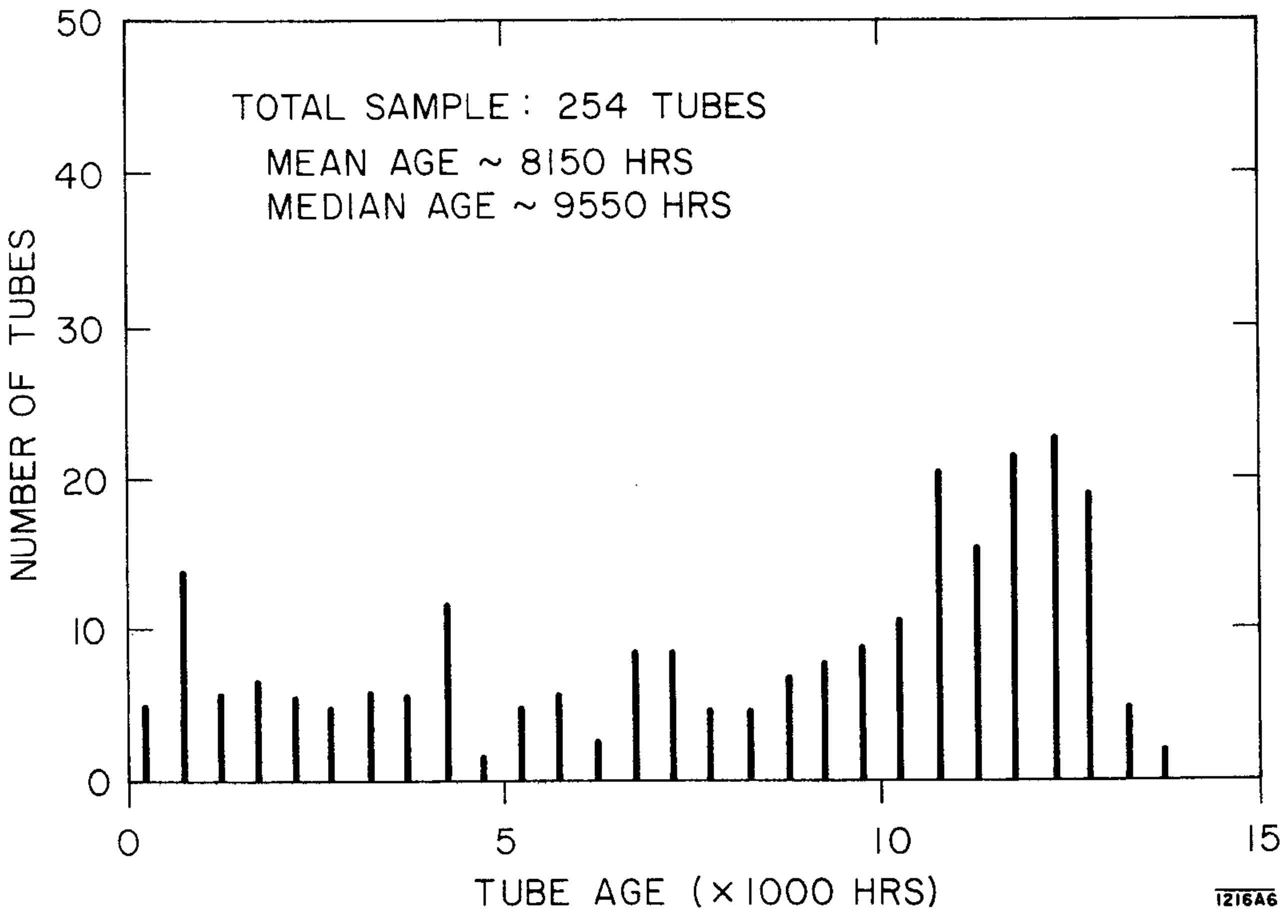


FIG. 2--Klystron age distribution in 500-hour increments, Jan. 1, 1969.

tubes of 8150 and median age of 9550. Comparison with Table II indicates that the mean age of all tubes failed during the quarter exceeds the mean age of all operating tubes at the end of the quarter. In previous quarters the opposite was true. Each vendor at present has at least one tube in operation which has more than 13,000 hours of life.

We have computed in the usual fashion the failure probability per 1000 hours of operation and the survival probability for all failures. The results are shown in Fig. 3. There are still no indications of a wear out mechanism since the failure probability per 1000 hours of operation remains substantially constant at 5% per 1000 hours.

Finally Fig. 4 gives a general recapitulation of MTBF (cumulative), average cumulative hours per socket, mean age of all operating tubes, and mean age of failure per quarter since the beginning of operation.

Causes of failure — During this quarter again nearly 50% of the operational failures were window failures, and the ratio was substantially the same for RCA and Litton. The second highest cause of failures was cathode arcing and/or overcurrent, accounting for almost 50% of failures. Also, one failure was caused by low cathode emission.

Effect of operating levels — During this quarter, the number of sectors operating at 245 kV has been 12 instead of 4 previously. Hence we hope to acquire information on the effect of operating levels on klystron life and reliability more rapidly than was possible previously. Table IV gives the overall effect of higher voltage operation on the MTBF. Please note that corrections have been introduced in this table, corresponding to those in Table III to account for the tubes reaccepted from vendors without major vendor rework.

Although the indications to date are that the MTBF is approximately one-half at 245 kV from what it is at 235 kV or less, we feel results are not fully meaningful since very few tubes to date have been operated only at 245 kV. The actual effect of combined operation at several levels has not been determined yet.

2. High Power Klystron Maintenance

The operating experience of high power klystrons used at SLAC is shown in Fig. 5. The mean age at failure is still increasing as already evidenced from Fig. 2. However, the ratio of replacements to failures is still substantially constant. We had 64 replacements for 23 failures this quarter. One-third of all replacements are caused by oil leaks between pulse transformer tanks and magnets;

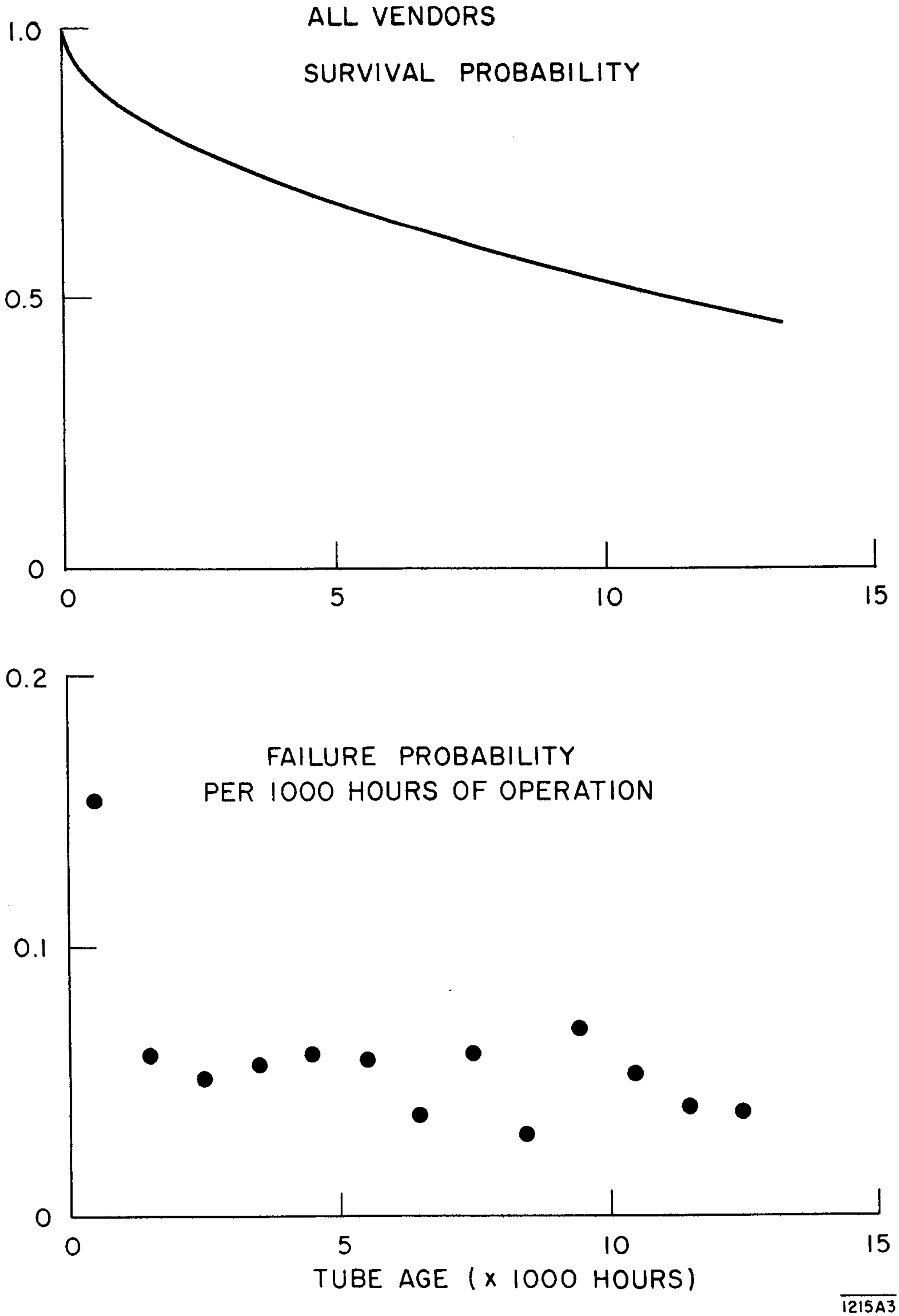


FIG. 3--High power klystron survival and failure, Jan. 1, 1969.

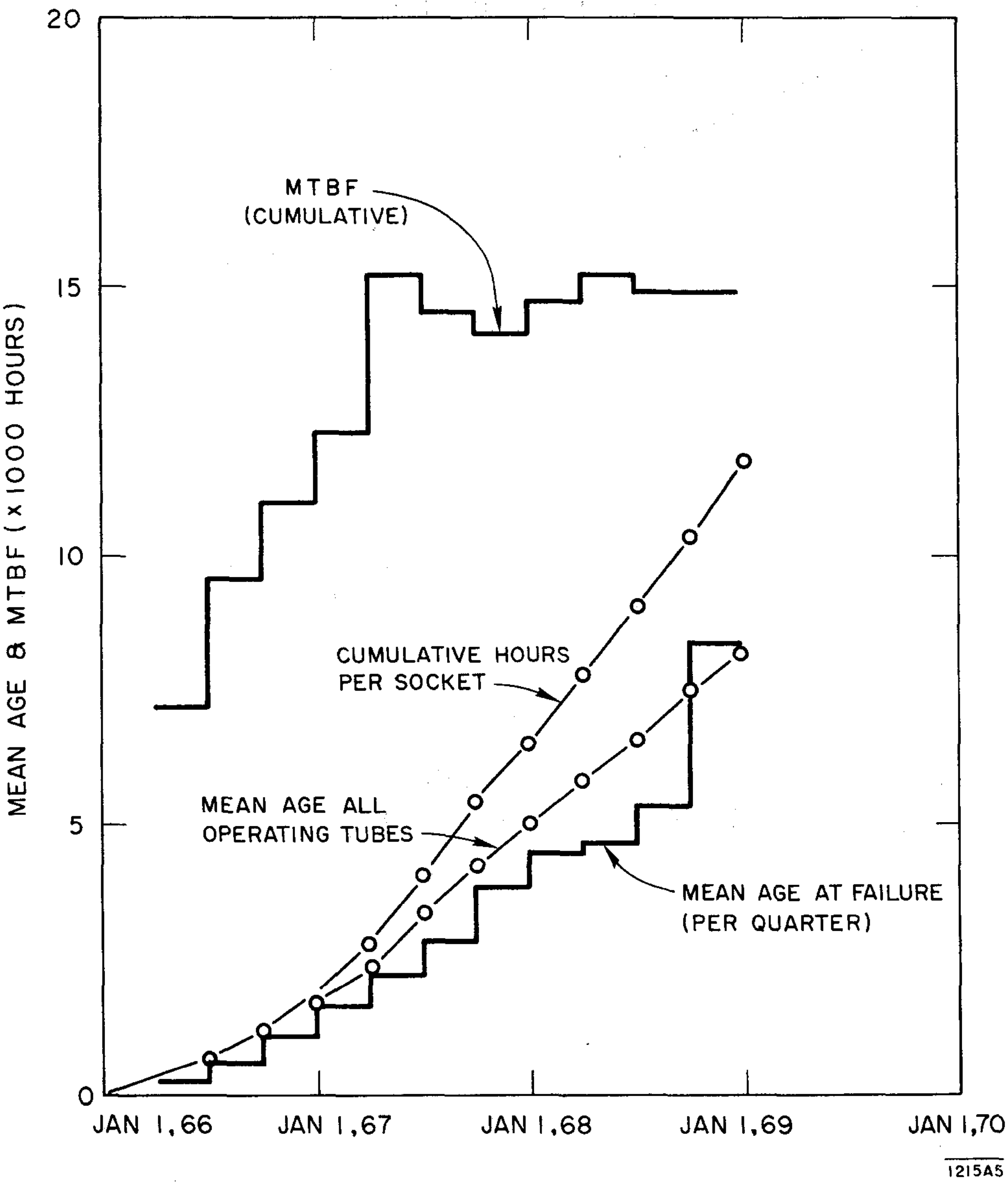


FIG. 4--Operating tube performance.

TABLE IV

| 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 |

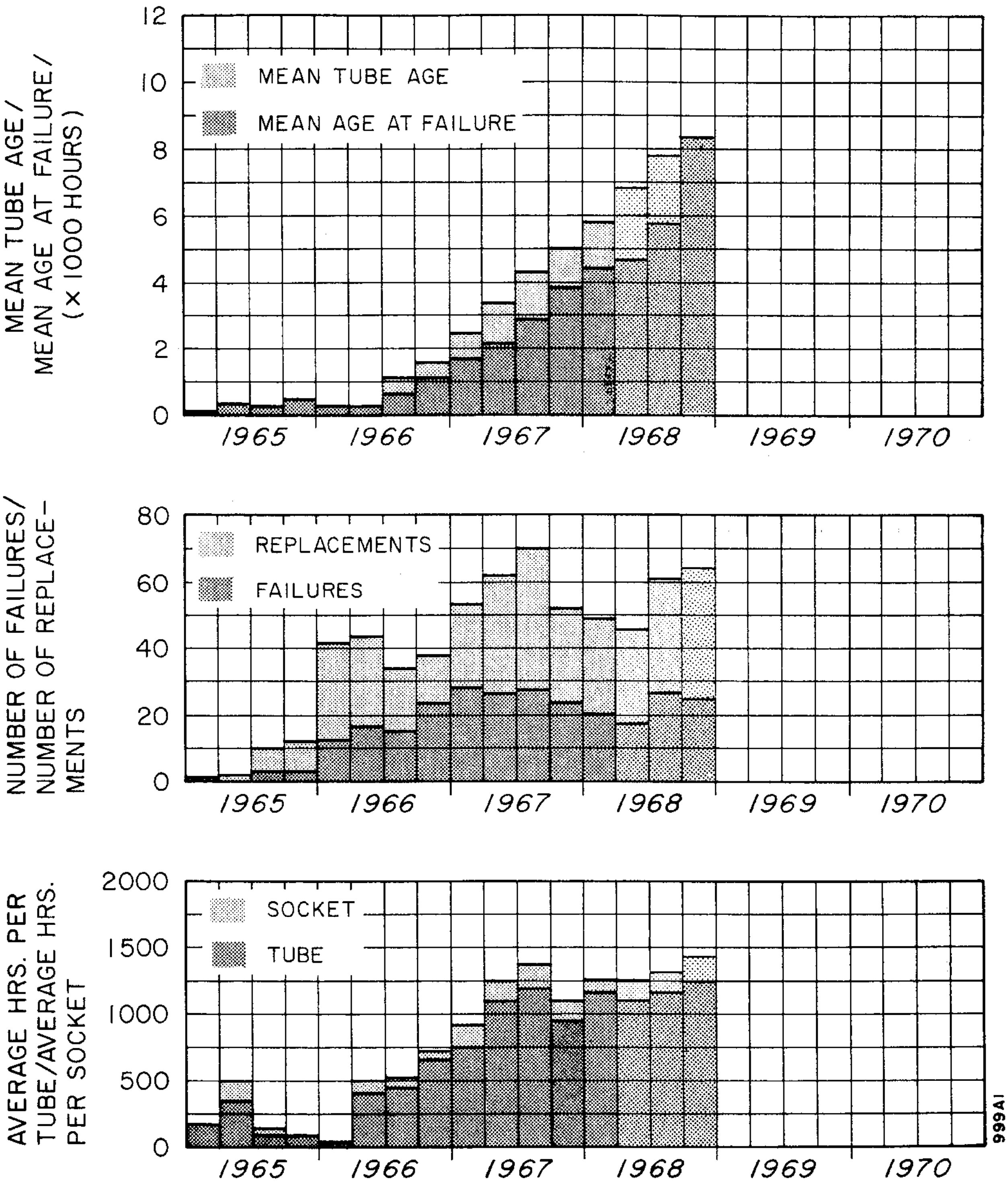


FIG. 5--High power klystron operating experience, Jan. 1, 1969.

one-fourth of the replacements are caused by suspected pulse transformer problems. Obviously all suspected tube problems do not necessarily result in a tube failure. In general operation appears to have been quite satisfactory with probably a small decrease in the rate of replacements and trouble reports per operating hour.

The scheduled maintenance has been further emphasized during the quarter and we have been able to give a thorough operational check to each tube on the average of once every 500 hours. In addition daily data on approximately 50 stations is a great help in pinpointing potential trouble spots such as underdriven stations or cathode problems before real damage can be done to the tube.

A special problem was encountered this quarter with pulse transformer tank oil. We discovered that oil contamination was causing considerable arcing in the tanks. The contamination was traced to a colloidal carbon lubricant used on the valves of the pulse tanks. The valve manufacturer had modified them since our last purchases and added the lubricant. The lubricant particle size was generally 5 microns or larger, and most of the oil can be salvaged by using 1 micron filters. A new type of ball valve has been adopted by Electronics Accelerator Group for use on the pulse tanks and the contamination problem is now under control. By further refinments in overall oil handling and parts cleaning we have been able to achieve test break down voltage greater than 40 kV for a 0.100" gap (standard test electrodes).

3. Driver Amplifier Klystrons

During the quarter we experienced 3 driver amplifier klystron failures, 1 Eimac and 2 SLAC built. The SLAC tubes had approximately 4000 hours of operation each at failure. The tube age distribution of the driver amplifiers is given in Fig. 6. The operating experience for driver amplifiers is given in Fig. 7.

4. Main Booster Klystrons

No problems were encountered with main booster klystrons operation during this quarter. However, the klystron has been removed from main booster station No. 2 to allow modifications to be introduced to the regulation circuitry by the Accelerator Electronics Group.

5. Vacuum System

No major changes occurred in the accelerator vacuum system. The average pressure on the main manifold gauges was less than $1.5 \times 10^{-8}$ torr with klystrons operating, a slight improvement during the quarter.

A few gas bursts were recorded in Sectors 10 and 30. Leak checks were performed in those sectors during the December shut down and small leaks were discovered and repaired. It is expected that the gas bursts will disappear as a result of the elimination of leaks.

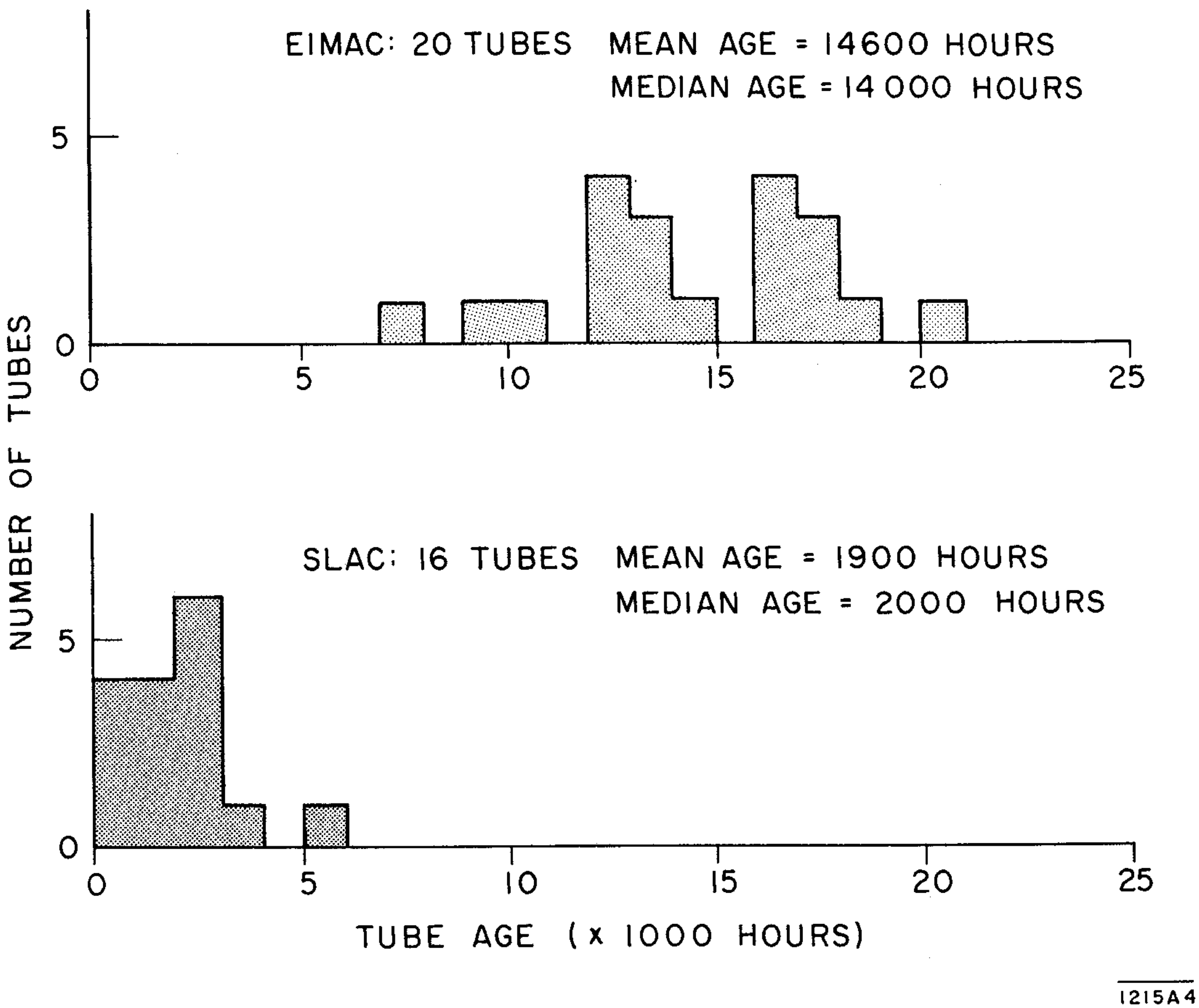


FIG. 6--Driver amplifier klystron age distribution in 1000-hour increments, Jan. 1, 1969.

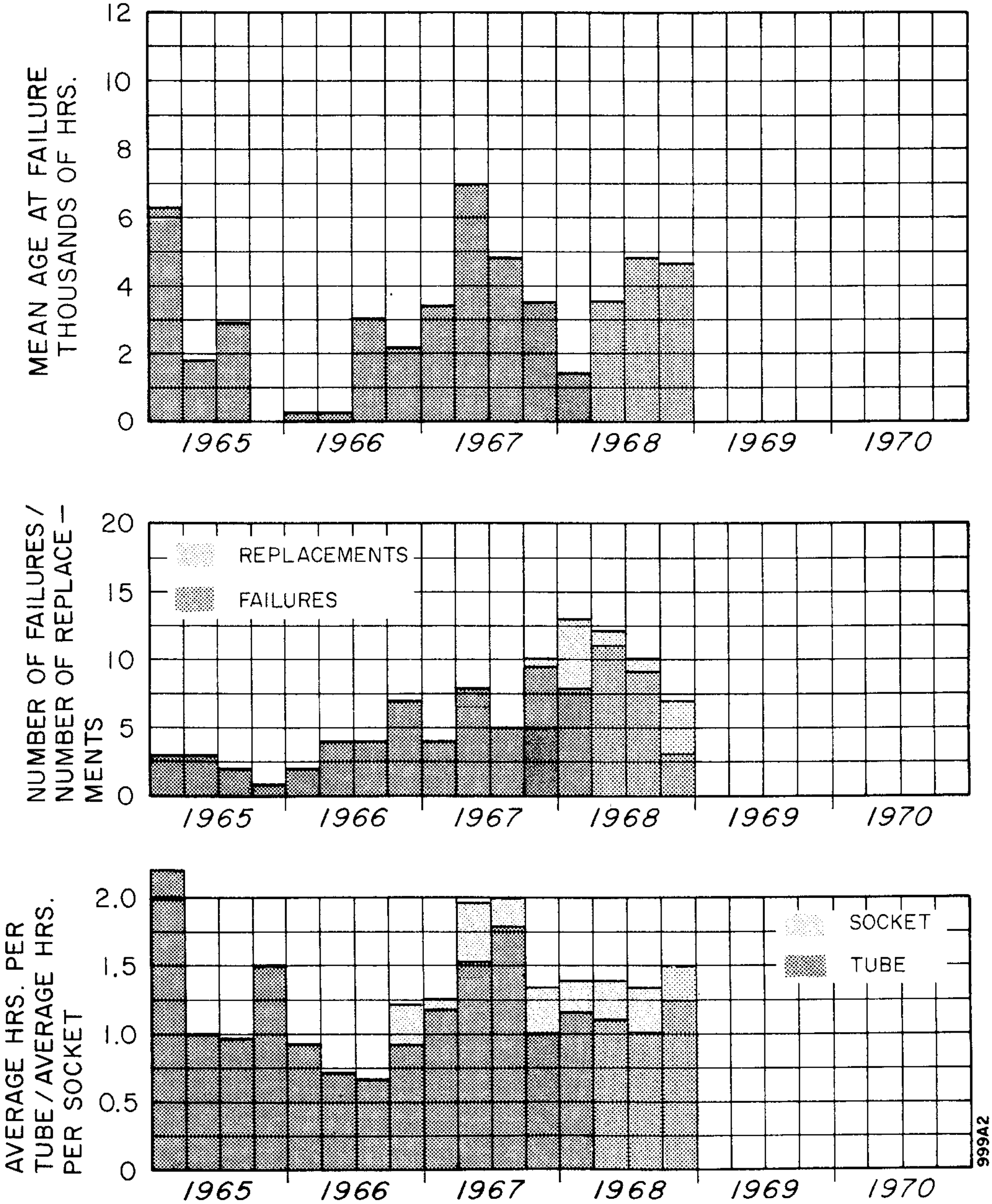


FIG. 7--Driver amplifier klystron operating experience, Jan. 1, 1969.

## VII. COUNTING ELECTRONICS

### A. End Station Charge Monitors

A second End Station A monitor was completed and installed. This unit is monitoring a toroid just inside the End Station A alcove, and about 20 feet upstream of toroid I-30'. Comparison of the two independently calibrated systems shows an agreement of ± 0.1% when using a nominal beam of 1 to 10 mA peak.

End Station B systems continue to operate satisfactorily. Some deterioration of performance of the preamplifiers located in the End Station B Target Room, presumably due to radiation, was discovered recently; so far this has been remedied simply by replacing transistors. Since the electronics is currently very close to the beam pipe, both relocation and addition of lead shielding are being considered. The units operated without difficulty for approximately one year.

End Station A charge monitors have been equipped with a set of buffers in order to relay the analog charge monitor signal to the Data Assembly Building (DAB) and to Central Control Room (CCR). In these two locations, a pair of meters displays the charge measured by each ESA charge monitor. The gain settings and toroid number must be communicated from the Counting House to the DAB and CCR operators. Additional buffer channels are available for future expansion.

Modifications were made in the End Station B units to improve utility for a parasite experimenter. A separate readout control panel and gain-status display were designed to be used remote from the main control panel. Four units were constructed.

### B. Centroid Time-Of-Flight System

No further work was carried out this quarter due to pressure of other tasks. As reported previously, the reasons for poor timing resolution on cosmic ray tests have yet to be explained.

### C. Video Position Monitors For End Stations

The video position monitor response to a chopped beam shows a peculiarity which is being investigated. The chopped beam response is a linear ramp of duration equal to beam pulse width, followed by a slow exponential decay of about 30 $\mu$s time constant. The response to an unchopped beam is a pulse which is a replica of the beam pulse with amplitude proportional to the product of beam intensity and beam displacement from the central axis. The chopped beam signal is independent of beam position and appears to be only a function of beam intensity.

Shielding the X-channel input transformer with $\mu$-metal was attempted, on the assumption that the field from the beam was coupling directly into the secondary of the transformer. This modification resulted in no change in response.

On the assumption that rf signals were by-passing the transformer windings and being rectified to appear as a large common-mode signal, a special input transformer with shielded windings has been constructed and installed in the X-channel. Results of this change will be observed during the next period of chopped-beam operation.

A prototype video position monitor is being built for lab use, primarily to aid in developing a calibration system. This unit will be finished in February 1969. Two extra sets of cards will be built for maintenance purposes.

## D. $K_0$ Experiment Support

Electronics developed for a 12-channel time-of-flight system for Experiment BC-10 was placed into operation. The system consists of time-to-amplitude converters (TAC's) followed by peak-hold circuits which are multiplexed into a 12 bit A/D converter, interfaced to an IBM 1800. Signals multiplexed include 12 channels of timing, 12 of phototube pulse amplitude, and 2 of machine time-reference. Resolution with a test pulse into the EG&G TAC's was 150 picoseconds.

A study was made of some ten 16 to 18 bit computers of the PDP-9 class, and a specification written for a unit to replace the IBM 1800 in this experiment.

## E. Rho Experiment Support

The previously reported spark counters for the LRL Magnetostrictive Read-out System were completed. In addition, spare cards for the system were constructed and tested.

Work was begun on new instrumentation intended for use in an enlarged experiment working with a smaller IBM 1800. Since the new IBM 1800 must accept more data on fewer input channels, a decision was made to place all data on a single input channel using time-division multiplexing. Design of a prototype scan control unit and a scanner was completed and the new units were installed in the $K_0$ experiment. Based on experience gained with this unit, a new design for a sophisticated scan control unit was begun.

In addition, design of a 64 channel strobed latch unit with a built-in scanner (multiplexer) was begun. The new unit uses Motorola MECL II integrated circuits; the prototype shows a coincidence overlap, using standard -700 mV logic pulse inputs, of $< 4$ nsec.

Design of the Counting Room layout for the expanded experiment was accomplished, and equipment ordered to allow preliminary beam checkout in February 1969.

## F. High-Speed Integrated Circuit Development

Emitter-coupled integrated circuits are being utilized in the development of a basic discriminator, a remote controlled digital delay box, and an 8-channel strobed latch. Prototypes of these devices have been constructed. The discriminator operates at a maximum rate of $> 90$ MHz. The delay box (20 to 52 nsec in 1 nsec steps) was tested to 90 MHz also. The strobed latch, referred to in Section E, operates with an input pulse overlap of $< 4$ nsec.

Separate measurements of coincidence curves of MECL II circuits show that a minimum input overlap of about 5 nsec is required for a full logic output.

## G. Laser Beam Position Monitor

Electronics was developed to control the flash and camera advance of the 82" Hydrogen Bubble Chamber as a function of the position of the incident laser beam.

The position of the laser beam is monitored by four shower counters; the total charge of each counter during each beam pulse is digitized by seven-bit analog-to-digital converters described in SLAC Report No. 90. The flash and the camera advance of the bubble chamber can be inhibited by upper and lower limits set on each of the four charges, on the sum of the four charges, on the difference of the charges of the left and right counters, and on the difference of the charges of the up and down counters. The differences can be also monitored on two meters.

## H. Group G Support

A peripheral device is under development for control of experimental apparatus. It incorporates a randomly addressed multiplexer of 256 states, PDP-9 interface circuitry, and a Digital Voltmeter suitably modified to enable communications between the DVM and the computer.

128 Multiplexer states are used for remote setting and reading of photomultiplier voltages. These can be set with a resolution of six bits, the total range being 795 volts, nominal. The system is capable of providing control with a 12-bit resolution when two addresses are dedicated for one controlled point.

## I. Conventional Data Analysis (CDA) Support

The fifth NRI film measuring table was put on the NRI system in the first week of December.

The computer interface to the ASI 6020 computer was redesigned and installed in the NRI System in the last week of December. The new design, using Signetics DCL logic, eliminated the transmission noise problems which existed in the previous interface. At the same time, Interrupt Protection Circuits were added to the interface which stop any false interrupts from being generated when the power to an individual table is turned off.

Approximately two-thirds of the logic for the sixth NRI table has been redesigned using integrated circuits. The total cost of this logic including materials and labor is approximately $2000. The cost of the old logic package was more than $6000. The new design uses the new NSC 4 bit up-down counter chip for its scalers which achieves a considerable savings in packaging costs and wiring labor.

Design work on two new SPV-B Digitizers was started. These units will use 9-track incremental tape units to store measuring information for the two SPV-B tables now in use.

## J. Group A Support

A 250 channel low level analog scanner was built and installed in the ESA Counting House, to replace the Dana scanner.

A 144 position magnetic beam stepper with analog-to-digital converter for magnet currents has been built and installed for use with a frozen alcohol target.

A raster scan CRT data display system with multiple remote readout is being designed to replace the present display system.

A Slit-Collimator Readout System, which became operable in the ESA Counting House in mid-October, permits selection and display of SL10, SL11, C-0, C-1, and C-10 jaw and tank shaft encoders by means of a Display Selector in the Counting House. The system consists of a logic level converter chassis, and a multiplexer in the DAB, with a Display Selector in the Counting House.

A Computer Interrupt Preset Scaler, which was designed and placed in operation in November, counts pulses from a Hewlett-Packard DVM and sends an interrupt pulse to the computer when a preset count, selected by thumbwheel switches, is reached.

### K. $LH_2$ Target Instrumentation

Continuing electronic support for the $LH_2$ target group has been provided during this period. One new target control system was installed in End Station B.

The End Station A target control system has undergone considerable change. Provisions were made for automatic filling using the diode probe. A more sophisticated vacuum control system was installed and the primary drive system for the vertical position was changed from a pneumatic system to an electric motor drive.

Work was initiated on the following systems for the End Station A target:

1. Continuous filling of the target utilizing a feedback control system.
2. Continuous vertical adjustment of the target.
3. Vertical position readout utilizing shaft encoders.

### L. Count Rate Meter

A rate meter was developed at the request of Group C to monitor counter rates when setting up experiments.

The instrument displays on four channels the rate of counts observed at the output of four different discriminators. This rate is evaluated by feeding the discriminator signal into a scaler, during a preset number of beam pulses. The operator can select 10, 100, or 1000 beam pulses, depending on the accuracy required, and the average number of counts per beam pulse is flashed and held for inspection for about 0.5 second.

Each channel scaler accepts logic pulses at a maximum frequency of 40 MHz. Gating of these signals can be performed externally, or internally, in synchronism with the beam trigger waveform.

One unit has been completed and installed in Counting Room A. Two additional units have been ordered.

## M. Video Intensity Monitor and Calibrator

A calibration and control panel is being developed to monitor the video outputs of toroids in ESA. The components of this instrument have been developed and a prototype of the complete system is now under construction.

The instrument will monitor any of four toroids and produce an output pulse proportional to beam intensity. A preamp is located near each toroid for good signal-to-noise performance. A built-in pulsed current source with six discrete current levels, 0.1 mA, 0.5 mA, 1 mA, 5 mA, 10 mA, and 50 mA will provide calibration for any of the toroids. The calibrator will be accurate to within 0.5%.

The useful range of the instrument will be from less than 5$\mu$A to 50 mA beam current. A risetime of 10 to 20 nsec will ensure adequate pulse detail.

## N. General Projects

### 1. Magnet Mapper Electronics

A dual channel pulse counter using integrated circuits was designed and constructed to replace the TSI Pulse Counter. This counter is used to count the x and y positions of the measurement cart, and supplements the shaft encoders.

### 2. Scaler Test Unit

A Scaler Test Unit was built and installed during this period in ESA. The device generates a known number of pulses to test scaler counting and readout. The device is under computer control. Automatic switchover equipment was built by Electronics personnel attached to Group A.

### 3. Spark Gap Trigger Units

A prototype unit is being studied. Several units have been requested pending completion of a satisfactory prototype.

4. Evaluation of the XP1210 High-Speed Photomultiplier Tube[1]

High-speed light-pulser measurements were conducted on the Amperex XP1210 photomultiplier tube. At a gain of $\sim 10^7$, an anode signal risetime of 0.8 nsec and a width at half height of 1.4 nsec were measured. Light pulses spaced at 3 nsec result in two clearly separated anode pulses.

5. Tunnel Diode Analysis[2]

An analysis was performed of the transient response of tunnel-diodes modeled by an equivalent circuit of two capacitances, an inductor, and the dc i-v characteristic of the diode. The nonlinear differential equations of the transition were solved numerically, and waveforms were computed for a wide range of circuit parameters.

6. Integrated Circuits for General Stores

A number of individuals and groups cooperated in determining a suitable stock of integrated circuits and associated hardware for general stores.

7. Engineering Seminars

A series of seminars on circuit analysis, with emphasis on high speed electronics, was held during this quarter.

8. Equipment Pool

An equipment inventory computer program has recently been completed. The program is primarily designed to locate and monitor Pool loan equipment, as well as modular equipment owned by various Research groups. Various subroutines allow equipment to be listed by manufacturer type, by group, or by function.

A survey was carried out among the various Research groups planning experiments in FY69. As a result of this, approximately $60K of new modular equipment was approved and is being procured.

Usage of Pool equipment continues to run near 100%. Additional quantities of HV distributions, scalers, modular scalers, discriminators, and 7-bit ADC's have been requested and will be procured in the next quarter.

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[1] A. Barna and E. L. Cisneros, "Light-Pulser Measurements on the XP1210 High-Speed Photomultiplier Tube," Rev. Sci. Instr. (In Print), SLAC-PUB-509.

[2] A. Barna, "An Analysis of Transients in Tunnel-Diode Circuits," Report SLAC-88, Stanford Linear Accelerator Center, Stanford University, Stanford, California (August 1968).

## VIII. INSTRUMENTATION AND CONTROL

### A. Central Control

#### 1. Control Room Consolidation

The perennial proposal to operate the switchyard and accelerator from one location was reopened this year: This time the specific proposal to combine control rooms at the Data Assembly Building (DAB) was examined in detail, evaluated, and again tabled.

A dominant question was that of the desirability of consolidating the two existing control rooms within a singular Main Control Center (in DAB) for overall improved efficiency at SLAC. A second and perhaps even more important question was that of deciding what further instrumentation and control would improve the capability and efficiency of the machine independent of consolidation.

There are two sources of operational problems related to the control system: interactions of multiple beams and division of responsibility between two groups of operators.

(a) Multiple beams: With unfavorable combinations of beams or, perhaps, while setting up new beams, finding the optimum compromise adjustments is a demanding task, so that some established beams may appear not to receive adequate attention from the operator. A number of adjustments (steering, focusing, beam loading, phase closure) are not yet independent in contrast to energy, current, and destination which are.

(b) When the experimenters' beam disappears or is degraded, it is not always clear which operator, Central Control Room (CCR)or DAB, must make a correction to restore the beam. Sometimes, indeed, each can make an adequate correction. Sometimes neither operator has sufficient information to determine correctly where the fault lies.

Problems relating to (a) above require extensive improvements to the control system, first, to improve independent control of beams, and second, to simplify the work the operator must do. The problems of (b) might be reduced by combining control rooms; they would be eliminated if the controls could be redesigned so that one operator can operate the entire machine.

It would remove the communications bottleneck between the two control rooms. The experimenter would communicate with a single center. Separate communication, however, would still be required between the Main Control Center and the accelerator gallery, the injector, and CCR for maintenance purposes.

The main argument against consolidation is that it is costly, both in money and in manpower. It was recommended that no consolidation plan that may be adopted should be allowed to divert funds from other accelerator and beam switchyard I and C improvements presently contemplated. These improvements will by themselves create greater relative increases in overall efficiency than consolidation.

It is futile to attempt partial control of the accelerator from the Main Control Center in DAB; the only reasonable consolidation of control rooms requires complete operational control - beam set up, monitoring, maintenance, and troubleshooting.

There are many instrumentation and control improvements desirable whether or not consolidation takes place. Some of these could cause greater improvement in overall efficiency and beam quality than consolidation. The principal areas of present inefficiency are centered about multiple beam set up and maintenance and in the detection of faulty operation of equipment.

Several long-range plans for consolidation of control rooms were examined. They may be lumped roughly into three categories:

(a) Physically move all equipment from the Central Control Building to DAB.

(b) Build parallel instrumentation or move selected panels to DAB according to a progressive plan, until all control has been functionally transferred to DAB.

(c) Defer any physical consolidation until control of most accelerator functions can be accomplished through computer links.

The third plan was recommended by the study. The following points can be made with respect to this plan. (a) The plan postpones start of implementation of hardware for consolidation by at least one year. (b) The feasibility of the use of the CCR computer for accelerator control to the extent necessary to allow consolidation as discussed above needs to be proven. (c) The plan minimizes the cost of consolidation both economically and in terms of accelerator down time. Little, if any, accelerator down time is required. (d) Even on the most optimistic schedule, complete operational consolidation will not be accomplished for at least three years. (e) The plan will require relocation of some DAB control panel instrument. However, the cost and effect involved is minor compared to the entire program involved. (f) The plan allows for a future review.

2. Console

A number of changes have been made in central control, reflecting the individual projects described later in this report. The most significant circuit changes have been installed in the last three months in connection with the new control computer, but these changes are largely invisible to the operators. Among the most significant operational changes have been the relocation of console panels with no change of function. During the same period that the DAB control room has been expanded to provide a threefold increase of operational console space, the CCR console has been rearranged to vacate nearly half of the console area originally provided. Space originally reserved for equipment to monitor beam quality as delivered to BSY and the experimenter has been released to start development of two parallel operating positions for the accelerator. Specific additions to the console made primarily for operating convenience were: moving the continuous klystron status indicators from the "maintenance" console; a new set of pattern generator control switches; new intercom and relocated paging and radio controls. The operations control console in CCR was rearranged so that two operators could work better in parallel, each having primary responsibility for the beam going to some experiment or set of experiments. At present, the splitting of controls applies only for certain functions which affect the beam energy. Many other functions, e.g. steering and pattern controls, continue to be shared.

3. CCR Computer

Summary — A PDP9 system was selected for the control computer in CCR. The computer was delivered in the Fall and installation of the system is well under way. The hardware interface and I/O routines to read accelerator status into the computer and transmit control comments from the computer to equipment are complete and checked out. Operator interface routines and the first automatic control response ("slow" klystron replacement) are now being written and are expected to be operational early in 1969.

General — The justification for the computer and the philosophy to be applied in the development of the system were described as follows:

Klystron replacement — The first project selected for implementation was a portion of the task of replacing recycling klystrons in order to maintain beam energy.

"Fast" klystron replacement would require the computer to make tentative corrections to the number of klystrons accelerating each beam, on a pulse-to-pulse basis. For many experimental arrangements, each beam pulse can be made to produce two signal pulses. These pulses would measure parts of the beam spectrum which fall above and below the experimentally acceptable momentum range. Heights or areas of the two pulses, converted into digital form (~5 bits each), may be used to detect sudden beam energy changes.

When the computer detects a sudden downward shift in beam energy, it must select and switch to the "ACCELERATE" mode a suitable Sector 28 klystron within 2.7 milliseconds. (Sector 28 klystrons already have special trigger circuits that make this possible.) Meanwhile, in response to status signals, the computer will set in motion a slower procedure which sets another klystron to accelerate. This second klystron will belong to a normal sector. It will require about one second to select a suitable ordinary klystron and switch it to accelerate. The computer must then detect the resulting sudden increase in beam energy and switch the Sector 28 klystron back to the "STANDBY" mode in 2.7 milliseconds or less.

The "slow" replacement scheme requires only connection of status, relay-tree control, and beam-defining pattern switch settings to the computer. This scheme is now being implemented.

A 360 synch device was designed, constructed and installed in the PDP9 as part of the status input circuitry. After initial check out, a new command (SON = Synch On) was added to increase program flexibility. A test program has also been written and margin checks have been performed on this device.

The PDP9 has a 7-word input multiplexer. 15 bits of each of two of these words have been connected to the status receivers for Sectors 1-30. The computer reads these words after each beam pulse, recognizes frame synchronization, and notes status changes in each frame. A computer program was written for the PDP9 to recognize and to printout status signal changes which are transmitted by the Status Monitoring System. The format of the printout lists in order: The Channel Status (on/off), the Channel Number, the Sector Number, and the time counted in Status Monitoring Frame Cycles ( ≃ 0.7 sec). A 15 hour run was made in December 1968.

The results of the printout were analyzed with special attention to recycling Modulator-Klystron Stations. The Status Monitoring concept permits us to identify several types of station faults. The fault starts in the modulator: a "short" recycle results ( < 2.5 sec), a "long" recycle results ( > 2.5 sec), the station cycles off, or the station circuit breaker trips. The fault starts in the klystron: a short recycle starts ( < 2.5 sec), a long recycle starts ( > 2.5 sec). Other operational events such as the switching of an operating station from maintenance to operate and vice versa can be recognized but have not been analyzed.

These basic types are quite frequent and can be identified easily. Mixed faults also occur and can be analyzed. The printed out time cycle ( = 0.7 sec) is very essential in this case to correlate the events properly for their identification.

The logical events in each of the fault types can be expressed by a standard pattern. However, events happening within one scanning cycle of the status monitoring system (0.7 sec) are not printed out as they happen, but as they are seen by the scan. In the 15 hours run short recycles occurred at an average rate of 1 every two minutes; long recycles at a rate of 1.5 per hour, and modulators went off (requiring reset) at 1.5 per hour. Such data can be useful in revising operational precedures. The list of status changes is formatted but not edited, and is occasionally accumulated faster than the teletype can handle. It is not yet in a form suitable for operational logging.

The third input word has been connected to a scanner which inspects the position of the pattern generator switches. Successful storing of the information in memory has also been demonstrated.

One "word" of relay drivers for output is connected to the relay-tree control system. Five bits identify the sector, eight bits are used to drive the existing control pairs connected to the No. 3 switched-sector panel in CCR, one bit is used for momentary interruption of manual operations through the relay-tree system. A test program which exercises one control function in each sector and checks for correct status response has been written and operates correctly. The remaining job is to complete a program to recognize those status changes which denote a recycling klystron, to determine the identity of a suitable replacement, and to generate and transmit the appropriate "Accelerate" comment. Much of this program is written. It is expected to be operational by Spring 1969.

Future Projects — The next projects to be implemented are presetting of quadrupole currents and status logging.. Quadrupole presetting will require an AD converter interface to the PDP9 and computer control of an existing analog multiplex system. The ADC interface is now being built. Proper editing of status information to produce a readable log requires the large storage space of a disk unit. The disk, a part of the original purchase order for the computer, will be delivered in January, 1969.

B. Communications Systems

In August, responsibility for technical coordination of telephone services within the radiation fence (Accelerator and Research Area) was assigned to the I and C Group. During the remainder of the year, 7 new on-line instruments, one outdoor instrument, and 6 4-line instruments have been installed. Some 120 services were involved in the change from 3-digit to 4-digit numbers.

A major modification was made to the paging system. It is now possible to make warning announcements in the accelerator housing only, in addition to paging both housing and gallery. The warning announcement is carried on a tape recorder. Personnel are warned to leave the housing when a sub-station is about to be turned on.

A new operations intercom system has been installed, linking CCR, DAB, experimenters, and selected points in the gallery. The equipment was chosen to provide fairly high audio fidelity and to minimize level changes when up to five stations are talking on one circuit. Nearly all units installed have a 25-station capacity; 24 stations are already in use; the DAB stations will be expanded to a 40-station capacity.

C. Data Transmission System

The remote switching of video signals from each sector to CCR was completed. Two video channels run the length of the gallery; each channel may be siezed at any sector (interrupting signals from upstream sectors from 0 - 27, downstream from 28 - 30) and switched to view signals from the beam current toroid and from the phasing system. Further modifications in the phasing system make it possible to view the rf envelope of each klystron in CCR. Video signals for monitoring injector/BS performance are transmitted through these channels when all sectors are cleared.

Additional control and status transmission facilities were installed at the injector to allow for upcoming needs.

Although the status transmitters are synchronized with the 360 pps clock at each sector, it was found that the delay at the receivers in CCR varied from 0.4 msec to 1.8 msec. It was found that the local synch generators were over-driven; when the drive from the local bit synch generator was reduced, the delay became more uniform. This was the first step in synchronizing all status transmitters so that the computer could scan thirty sectors simultaneously. The second step was to synchronize the scanning frames. A frame synch signal was derived from the Sector 28 status receiver and transmitted through the looped cable system to all transmitters in Sectors 1 - 30. Satisfactory synchronization has been obtained.

## D. Personnel and Machine Protection

### 1. Long Ion Chamber

To protect the accelerator from damage caused by its own electron beam, a single ion chamber runs the whole length of the accelerator. The pulse train from the ion chamber is displayed on an oscilloscope, giving a representation of beam power loss along the machine as a function of distance from the injector. It also operates a system that shuts off the electron beam within 1 msec whenever the signal level exceeds a preset value. Whenever local beam power loss exceeds a preset value, typically 2 V for 360 pps operation, the discriminator system turns off the electron beam by operating the 1 msec tone loop system. A pulse generator and logical gating circuits test several properties of the ion chamber system during each interpulse interval. In the test, a pulse is transmitted along the cable, its transit time to the injector end and back is measured, and it is verified that the reflected pulse indeed operates the discriminator.

The main PLIC discriminator system normally opens the CCR Tone Interrupt Unit, which shuts off all "L" triggers at the injector when any of the following occurs:

(a) Ion chamber HV or dc load current is out of tolerance.

(b) Discriminator Voltmeter is out of tolerance. This circuit monitors the interpulse test system operation.

(c) PLIC signal pulse exceeds 2 volts.

(d) Interpulse test fails. This test requires a pulse to propagate along the PLIC cable, to return, and to trigger the discriminator.

In the "12 volt" mode the system works as described above, except that a keyswitch operates a circuit so that:

(a) The PLIC signal pulse must exceed 12 volts to operate the main PLIC discriminator, and shut off the beam.

(b) The CCR operator in charge is responsible that this mode is only used when the total beam repetition rate is 60 pps or less.

(c) When this mode has been selected, red lights flash on the back up console in CCR.

(d) A latching circuit opens the CCR Tone Interrupt Unit whenever the "12 volt" mode has been selected and the total injector "L" repetition rate exceeds about 60 pps. This circuit is not fail safe.

In the "disabled" mode another keyswitch operates to supply dummy inputs to the CCR tone interrupt unit. This mode may be used with the permission of the CCR operator in charge in certain unusual circumstances, such as circuit tests, or for beams having very low ($\sim$1 pps) repetition rates. The PLIC oscilloscope display will work in the disabled mode. The flashing lights ((c) above) will flash when the disabled mode is selected.

The Beam Line Selective Shut Off System responds to a PLIC signal pulse which exceeds 1.75 volts, by subsequently withholding the gun "L" pattern signal for the beam which produced that pulse. This system prevents shutting off inoffensive beams, but only if the PLIC signal always remains below 2 volts. This system is provided for convenience. It is not very secure. It may be disabled easily when desired.

Positron operation produces a large signal pulse from the positron source. This was originally handled by inhibiting the discriminator for about 2.5 $\mu$sec at the time of arrival at the positron source signal.

The Positron Gate circuit has now been removed. A lead shield has been installed to prevent radiation from the positron target from shutting off the beam.

A system has been installed to inhibit the response of the main PLIC discriminator to intense but very low repetition rate beams, so that they do not interfere with acceptable beams. The system uses a modified positron gate card, with the gate period extended to $\sim 30\,\mu$sec, to cover the whole period when PLIC signals are possible. This modified card is triggered by pulses from the pattern generator. When triggered, it inhibits any shut off action by the main PLIC discriminator for one pulse. The circuit has been designed so that it can respond at only a limited rate, about 3 pps. Any higher trigger rate stops the gate pulses, and restores normal PLIC operation. The inhibit system is controlled by a column of pattern switches in CCR labeled "3 PPS PLIC INHIBIT".

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 on 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.

2. Personnel Protection System

End Station 'C' — A portion of the control beam area of the switchyard and a small portion of the research yard between End Station A and B have been enclosed and defined to be End Station 'C'. A complete set of relay logic circuits has been installed for this end station. The circuits were modelled after the circuits used for BSY, ESA and ESB, but incorporate a few improvements proved desirable in operation. The installation was completed in September and has been operating satisfactory.

Beam Switchyard — All of the emergency off switches within the switchyard were replaced by a more rugged model during the fall. In December the relay logic circuits were replaced. The BSY interlock circuits are now electrically similar to the circuits for the end stations. The new circuits are mechanically similar to the ESC circuits.

The'B' target room was removed from the BSY interlock system and connected into the ESB system.

Keybank Modifications — At the end of the fourth quarter of 1968, a total of 31 keybanks had been modified and reinstalled in the Klystron Gallery, Switchyard and End Stations. Scheduled for the following quarter are four keybanks for the Data Assemby Building and one for the Central Control Building. Also scheduled, subject to manpower availability, is the modification of fifteen spare keybanks.

The modifications undertaken were to improve the reliability of the keybanks and make them easier to service. These modifications are briefly stated as follows:

(a) Provide a support frame to stiffen the front panel that supports the mechanism bearing plates.

(b) Hinge the new front assembly to the existing mounting box and provide a hasp and padlock for easy but controlled service access.

(c) Couple the actuation of the switch bar to that of remote actuation of the key release bar.

(d) Provide an additional key release stop by putting lugs on the switch bar for each of the eight key cams. These lugs also eliminate the former close tolerance requirements of the adjustment of the switch cam.

(e) Replace set screws that drive shafts with positive yet adjustable connections.

These changes were built into a single keybank and evaluated by energizing the solenoid in excess of 70,000 times. Even though these tests were considered adequate, it was later found in actual operation that the pins in the key release bar hubs were inclined to work out after relatively few operations. This condition has been corrected in all the installed keybanks and all the spare hubs.

Service requirements on the keybanks since modification have been minimal even considering the above-mentioned trouble.

Miscellaneous — The interlock circuit status and controls were connected to new panels in the DAB console area.

A keybank for control of the portable VVS in the gallery was installed.

Extra gates and television circuit for closer control of access to the position source area were installed.

Beam stopper interlock circuits were reconnected from slits to bending magnets according to operational requirements.

E. Positron Source

CCR control and readout of four steering power supply pairs, essential for steering positron beam, was requested and installed. The problem was somewhat involved due to the dual control requirements from Sector 11 and CCR, and the fact that 3 power supplies were of the pulsed type, having two levels of operation. The system is checked out and working.

In a similar project, control of the special quadrupoles S1-S13 in Sectors 11 to 14, has been added to the switched sector panels in CCR.

Some follow-up work had to be done on the wheel control system, after it had been operated for sometime. The change improved the control logic between brake and motor control. A new wand drive motor was installed for the wand run in June. This required a new control panel and changes in the pattern system. Instead of the wand being timed from CCR, the wand now transmits a synch signal to the pattern generator as a reference for the subsequent events. The motor drive for the wand system is successful and will stay. The electronics for the former piston drive has been removed.

A test was made of a system for additional machine protection for positron operation by wrapping indium wire around the accelerator pipe in Sectors 11 and 12. Each wire was monitored by a relay circuit operating into the tone interrupt unit in Sector 11. Melting of the indium wire was to shut off the beam in case of excessive heat dissipation. The system was too sensitive, however, and was removed. A new protection system for the pipe is under study.

## F. Trigger System

### 1. Master Trigger Generator

The master trigger generators were modified (pursuant to tests in late 1967) to provide a -1000 microsecond pretrigger by means of a highly stable magnetostrictive delay line. This was later modified to provide a -1025 microsecond pretrigger by means of a combination of the magnetostrictive delay line and the formerly used 25 microsecond transmission line in cascade, thus providing a -25 microsecond local pretrigger for requirements in the injector area only, and enabling the 1000 microsecond magnetostrictive delay line to be used as a project-wide standard wherever a -25 microsecond local pretrigger is required. At the same time, 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.

### 2. Injector Trigger Generator

Specifications for a new ITG have been completed and design has started. An important element in this redesign is the fact that a large number of functions of the present ITG have been incorporated in the new gun modulator. The existing injector trigger generator was modified for check-out operation of a new gun modulator. The 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.

A new trigger channel was added to the ITG for the 6-20 MHz BKO unit.

### 3. Pattern Generator

The pattern generator controls were relocated in a new panel on the operating console. The relocation provides greater operating convenience; the new panel contains provision for computer sensing of switch positions.

## G. Beam Guidance

### 1. Position Monitors

During the summer the installation was completed on the remotely controlled balancing system for the beam position monitor. This permits the operator in CCR to re-zero the dots representing beam position by using the steering controls to operate motors in the beam position detector panels in the sectors. Although this system was designed principally to permit readjustment of diode balance, it also is a powerful centrally located aid in determining when diodes need replacing without having to physically visit each detector panel along the accelerator.

A new beam position monitor was tested in Sector 1. It has 4 ion chambers mounted close to the accelerator waveguide, and balanced circuits to compare signals between opposed ion chambers. Some difficulty has been experienced with circuit balance due to the very large dynamic range of the signals.

2. Pulsed Steering and Quads

A new design for a pulsed power supply for steering was developed. The power supply will be capable of operating on six levels and will utilize the existing dc power supplies. This provides a power amplifier, with approximately 1 msec response time, whose input is switched by the beam pattern to one of six remotely controlled potentiometers. A prototype will be installed in drift Sector 12 for check-out.

A quadrupole power supply and quadrupole for pulsed operation has been developed. The I and C concept for controlling and monitoring this supply will be checked out on the prototype to be installed in Sector 28.

H. General Interface Work

1. Gun Modulator

The I and C portion of the new gun modulator installation has been completed. The new gun modulator is now operable from CCR. The I and C portion of the enlarged BKO system is installed and working. Analog, control, and status information for operation at 40 mc and 20 mc is provided. A pulse phase closure system was installed in Sector 0. I and C provided the analog and control signals to CCR and all pattern connections.

A new control panel for injector controls was installed in CCR. The new panel provides separate lever switches for each of 6 pulse height adjustments. The older panel, which contains a 23-position selector switch and one pair of control buttons, remains in use for other functions. Controls and monitors for the Beam Knockout System are now connected throught the old panel.

2. Phasing

During this quarter all automatic phasing system programmer units were modified to permit a number of additional controls and indications at Central Control. The operator may now "Hold" the programmer on a given klystron in the sector. He also has a "Phase/Don't" option which permits a klystron to be passed over during the phasing process with its accelerate/standby status left unchanged.

With the use of the above controls a single klystron can be phased in a sector without disturbing other klystrons. If the accelerate/standby status of the other klystrons is not changed, however, then there is no indication of which klystron the programmer is currently stepping through. Therefore, a monitor system was added to the phasing programmers and CCR-switched sector panels to show which klystron is currently being operated on by the programmer. This also permits the operator to know which klystron the video system is viewing.

Temperature tests were made of a beam presence detector to be used in conjunction with the "automatic phasing system". The purpose of this is to stop the phasing operation on loss of the beam and then resume it after the beam has reappeared. The detector being tested showed a sensitivity of 5 mV which could vary by $\times \pm 1$mV over a range of 65 to 140$^{o}$F. Work is proceeding in modification of an rf detector panel to work in conjunction with this detector.

3. VVS Controller

A prototype of a controller that permits the selection of any one of 6 preset reference voltage levels from CCR was installed in Sector 26. Its operation is satisfactory and arrangements have been made to build 15 more units.

4. Linear Q Gain Control

Design and installation of a ganged linear Q gain switching scheme was completed. This addition enables the CCR operator to change the gain of all the beam current monitors simultaneously. It was formerly necessary to select and adjust the 30-odd controls separately.

5. Molulator Fire Alarm

The modulator fire detector circuits have been disconnected from the fire department's network, and connected to CCR through the status monitoring system. The CCR operator in charge now has responsibility to see that each modulator fire alarm is promptly investigated. When an alarm occurs, an electronic siren sounds and red lights flash in CCR. An amber light shows in the CCR sector summary panel, indicating the affected sector.

6. Pulsed Phase Closure

A pulsed phase closure system was installed in Sector 0. I and C provided the analog and control signals to CCR and all pattern connections.