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Compiled by

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CONTENTS

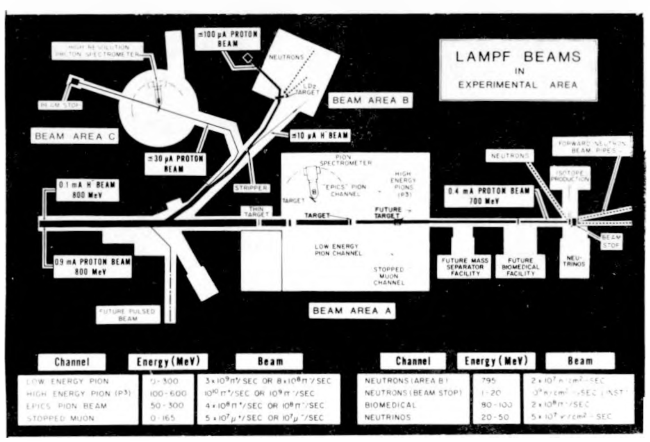
GLOSSARY OF TERMS USED IN THIS REPORT

ADC – Analog Digital Converter
ASCII – American Standard Code for Information Interchange
CCF – LASL Central Computer Facility
CCT – Color Character Terminal
CCR – Computer Control Room
CCTV – Closed Circuit Television
CPU – Central Processing Unit
CRT – Cathode Ray Tube
C-W – Cockcroft-Walton
DACT – Data-Acquisition and Control Terminal
DVM – Digital Volt Meter
EFB – Effective Field Boundary
ETL – Equipment Test Laboratory
fh – Filament Hours
FWSS – Fast-Wire-Scanner System
hfs – Hyperfine Structure
hvh – High-Voltage Hours
IC – Integrated Circuit
ICR – Injector Control Room
IDS – Information Display System
IEC – International Electrotechnical Commission
IFA – Interface Amplifier
I/O – Input/Output
ISIC – Insertable-Strip Ion Chambers
IVR – Induction Volt Regulator
LAM – Look-at-Me Interrupt
LAMPF – Clinton P. Anderson Meson Physics Facility
LCF – Localized Current Fields
LED – Light-Emitting Diode
LEEP – LAMPF Electronics and Equipment Pool
LET – Linear-Energy Transfer
MBD – Microprogrammed Branch Driver
m.i. – Mineral Insulated
MIG – Metal Inert Gas
MSSC – Multistrip Scintillation Chamber
MTBF – Mean Time Between Failures
MWPC – Multiwire Proportional Chamber
NIM – Nuclear Instrumentation Module
NMR – Nuclear Magnetic Resonance
pc – Printed Circuit
PHA – Pulse-Height Analyzer
PLI – Procedural Language Interface
RGB – Red-Green-Blue
RICE – Remote Information and Control Equipment
RIU – RICE Interface Unit
SCC – Serial Crate Controller
SCR – Silicon Control Rectifier
SSD – Serial System Driver
SY – Switchyard
TDC – Time-to-Digital Converter
TDI – Temperature Difference Integrator
TIG – Tungsten Inert Gas
TOF – Time of Flight
TR – Transition Region

Experimental Area

Primary beam lines in experimental area:
- Line A – Main Beam Line
- Line B – Nuclear Chemistry Facility
- Line C – High-Resolution Proton Spectrometer
- Line D – Weapons Neutron Research Facility

Experimental beams:
- Beam Area A:
  - BSA – Beam Stop A
  - EPICS – Energetic Pion Channel and Spectrometers
  - LEP – Low-Energy Pion Channel
  - Neutrino A
  - P^3 – High-Energy Pion Channel
  - RADIP – Radiation Damage and Isotope Production
  - SMC – Stopped Muon Channel
  - TA-1 – Target A-1
  - TA-2 – Target A-2
  - TTA – Thin Target Area
- Beam Area B (Room BR):
  - AB – Neutrons
  - AB – Nuclear Chemistry
  - EPB – External Proton Beam
- Beam Area C:
  - CCH – Area C Control and Counting House
  - HRS – High-Resolution Proton Spectrometer



QUARTERLY REPORT ON THE MEDIUM-ENERGY PHYSICS PROGRAM

FOR THE PERIOD ENDING JULY 31, 1975

I. SUMMARY

Engineering Support

A major portion of the group effort continued in support of the 201-MHz accelerator and transition region improvement program. The accelerating tanks and their ancillary equipment were reassembled into their final configuration and became operational late in the quarter.

Measurements were made of the differences between the mechanical and magnetic axes of all the drift tubes in Tanks 1 and 2, and displacement measurements were made of the transverse and longitudinal motion of representative drift tubes in Tanks 1 and 2 in the presence of their normal driving forces.

Thirty-nine switching triodes were reprocessed, and thirty-six 500- ℓ/s ion pumps were rebuilt and returned to operational status.

A major portion of the alignment effort was directed in support of the main and secondary beam lines. Lines A, B, C, EPB, and X were resurveyed and aligned as necessary. The front ends of P^3 and SMC were resurveyed and considerable work was performed in support of the EPICS installation.

Work on the Biomedical line is continuing; the helium chambers, windows, and dust covers for this line were installed.

Line D through the waterfall has been completed and is ready for tune-up. The modulator for the fast-kicker is being assembled and tested. Half of the pulse-forming network has been tested at 5000 A into a dummy load.

Carbon monofilament harps were developed in a joint effort (MP-4, MP-7, and MP-8) to solve the heat-sag problem. Three of the 25-cm carbon harps needed in Area A have been wound, and the remainder should be finished early in the next quarter.

A small, but significant, level of effort continued in support of the experimental programs. Most of this effort was in support of Exps. 2, 22, 29/64, 31, 90, 130, 179, and 222.

Accelerator Support

This quarter was characterized by continuation and completion of accelerator improvements in preparation for turn-on in midsummer. The improvements to the tanks and rf systems in the front end of the accelerator, along with the new tank-to-tank phase-monitoring system, show promise of a significant step forward in machine reliability and stability. The improvements to the accelerator drive-line-reference system should be another measure of improved stability for the machine.

The latter part of the last quarter was spent turning on and checking out both new and old systems. The emphasis for this stage of turn-on will be on performance of separate accelerator systems rather than beam dynamics. Toward the end of this quarter, beam dynamics will become the primary effort. A method for control of accelerator configuration will be instituted this quarter, which will require prior approval by a Change Control Committee before design changes to operational parts of the accelerator are made. This technique should improve the dissemination of information and reduce the impact of changes on one system that affect associated systems.

An extension to the formal training for LAMPF accelerator operators has been initiated. This training consists of making a temporary reassignment of operators to an accelerator support group section for about eight weeks. The operator will be intensively trained and become the "resident expert" on the operations crew. This will be repeated for other individuals on key accelerator systems until a sufficient number of trained people are obtained. This should reduce the number of "call-ins" of accelerator support personnel and thereby cut the expense and delay inherent in the "call-in" approach to accelerator repair.

Accelerator Systems Development

New insights were found during the retuning of the 201-MHz linac field distributions, which should result in significantly improved longitudinal acceleration properties.

Work continued on the investigation of quadrupole aberrations, vibration problems in the 201-MHz linac, and alignment.

Data-base development progress was significant, including new work on bibliographic compilations and contract accounting.

Diagnostic-equipment development continued.

Injector Systems

The shutdown activities in the injector area were completed this quarter and both injectors were turned on for full time operation at the end of July. The initial operating experience has been quite satisfactory, and beam-tuning tests for the next phase of linac operation have begun.

Five new rectifiers have been installed on the H^+ C-W hv stack and are working properly; additional replacements are on order. Work has started to develop the capability to rebuild these rectifiers locally.

The modifications to the ion source control system in the H^+ injector have been successful in eliminating most of the spurious trips caused by spark interference in the computer control systems. Work is still in progress on the H^- injector to correct binary command failures in the H^- ion source control system.

Extensive tests were conducted on the H^+ C-W generator to improve bouncer operation. Additional state-variable feedback has been incorporated in the control circuits for the bouncer, and dome voltage excursions can be reduced to below 300 V for full-duty-factor 25-mA beams.

The 5-kHz oscillator has been replaced with a phase-locked circuit, thus eliminating the incoherent 5-kHz noise on the beam. The 5-kHz ripple with present bouncer operation is <100 V peak-to-peak.

Anode aperture tests were continued on the H^- ion source, and a new molybdenum-lined aperture unit has been designed and tested and appears capable of withstanding long-term arc impingement with no deterioration.

The beam transport lines were reassembled and realigned to the new linac axis. New beam line apertures were aligned and installed in the final portion of the beam transport system and have functioned as expected. Beam admittance tests to confirm the injector beam line alignment to the new linac axis still remain to be carried out.

Design work on the polarized injector continued, and prototype tests of the cryopumping system were carried out.

The polarized shielded enclosure was completed and the C-W generator for this injector was received. Performance tests carried out at the vendor's plant met all specifications for this power supply.

Electronic Instrumentation and Computer Systems

Two new hardware instructions were developed and installed in the central processor of the control computer. These instructions for saving and restoring registers will improve the efficiency of the central processor by 7%.

A microcomputer was incorporated in a prototype data-link module. When testing is complete, the existing five data links will be upgraded with the new modules to reduce the software overhead on the control computer.

Work continued on the information exchange bus which will be the basis for developing the third console. A bus controller incorporating a microcomputer was designed. The interface for the first device to be connected to the bus, a function-button panel, was designed. Prototyping will commence next quarter.

The emphasis of software developments this quarter was on applications programs. Programs for automatic arcdown recovery, magnet setting, fast-protect analysis, stripper control, blueprint graphics, and control vectors received attention.

Numerous and significant changes were made to the control instrumentation along the primary and secondary beam lines. Most of the capabilities of the Fast-Wire-Scanner System were demonstrated, but final system tests require delivery of additional equipment. Work continued on upgrading the harp system. The burnout protection system and the thermocouple temperature readout systems received attention. The scheduling, installation, and checkout of wiring represented a major effort.

The first phase of upgrading the Terminal computer was completed with the installation of a PDP-11/45 central processor, additional memory, and a second disk. Orders were placed for two additional PDP-11/45 computers for the experimental area data-acquisition system. The first RSX-11M operating system at LAMPF was installed on a PDP-11/20.

The nucleus of the general data-acquisition system software, the Q-Program, was made operational under the RSX-11D operating system. Enhancements to the system will be developed and added as feedback is received from the users.

Approximately $90k was committed for additional electronics equipment for LEEP to support the upcoming series of experiments.

Accelerator Operations

Upgrading of the facility continued throughout the entire quarter. The injectors and drift-tube linac were started up on a rotating-shift basis on July 21. As expected after so long a shutdown and after so much rework, numerous difficulties were encountered. Low-duty H^+ beams were accelerated to 100 MeV by the end of the quarter. Operating crews continued to assist with numerous developmental and support activities. Modification of personnel safety systems in the switchyard and Areas B and C was completed, and a personnel safety system was installed on the WNR line. Documentation of existing safety systems was updated. Analog data systems throughout the accelerator were checked, repaired, and calibrated. Closed-circuit-television systems were maintained and catalogued. Additional television equipment was obtained from government surplus and was made operational. Radiation-hardened television cameras were installed to look at the low-momentum component phosphors in the SY. The experimental area current-monitoring system has been extensively revised and expanded. A current-monitor calibration system was designed, built, and installed. The current monitor system for the accelerator was completely redesigned and rebuilt. The associated electronic circuitry was also redesigned and repackaged to provide more uniform and reliable data throughout the machine.

Experimental Areas

During this quarter, work in the LAMPF experimental areas was devoted almost entirely to the goals of the Great Shutdown. While there was some follow-up design work, most of the activity focused on fabrication and installation of components needed for high-intensity operation of the main and secondary beams in Areas A and A-East. A major rework of the switchyard is in its final stages. The largest amount of work remaining to be done involves the completion of the main proton beam line and the target cells. Completion of the EPICS beam line at Target Cell A-1 is also a major unfinished task. The other secondary beams, which needed upgrading for high intensities but no fundamental changes, have made steady progress, and the renovation work is drawing to a close. Substantial improvements to the process water systems are nearing completion. Planning has started in preparation for the resumption of beam in the switchyard and Beam Area B in August and September.

Large-Spectrometer Systems

Energetic Pion Channel and Spectrometers

All of the major components of the EPICS Beam Line were installed and aligned. Work is now under way to install the slits and vacuum transition pieces in order to complete the line. Considerable progress has been made on taut-wire assembly and installation. The computer controls and associated software are being checked out as devices are installed. At this time we expect to operate the beam line with an α-particle source in early September.

High-Resolution Proton Spectrometer

Several projects were initiated and in some instances completed during this quarter. Another type of multipole magnet was designed and built which can produce essentially any linear combination of multipole fields. The staging area in Aisle D was completed and is now in use. Assembly of the scattering chamber has begun in this area as well as final tests on certain design features associated with the curtain-retractor mechanism. The new NMR system has been installed and successfully checked out in both the beam-line and spectrometer dipoles. The HRS particle-identification system, including the main-frame support structure, has been designed and is now being fabricated. The mapping and optimization of the large 57° analyzing magnets in Line C has been completed, and the measurement and shimming operations on the homogeneous portion of HS-BM-02 has been completed. In both cases, the results are consistent with resolutions on the order of a few parts in 10^{-5}.

With the renewal of accelerator operations and the plans for rigging the HRS dipoles next quarter, there has been a shift in emphasis toward experimental operations. As a result, increased effort has gone into the particle identification system, the scattering chamber, and the Area C counting house. At the same time, we have continued to devote a major portion of the effort to finalizing the spectrometer dipoles for mounting on November 1.

Research

A large effort was expended in preparing Line A and secondary beam-line instrumentation for higher proton-beam intensities. Eleven quadrant secondary emission monitors have been constructed for Line A, and samples have been tested at the Space Radiation Effects Laboratory's external proton beam. A prototype beam-on-target monitor ion chamber was also tested at SREL. Leakage currents in the ion chamber proved troublesome and have necessitated design changes. A fabrication technique was developed for carbon wire Line A harps. A proportional chamber wire-winder was modified to handle the carbon wire, and a soldering procedure, involving local electroplating, was found with which to fasten the wires. The secondary channel beam-profile monitor described in a previous progress report has proved popular: four sets of the new version of this monitor are under construction for a number of experiments.

Analyses have been completed on several muon experiments. Muonic 2p → 1s transition energies have been measured for 16 separated isotopes of iron, cobalt, nickel, copper, and zinc (Exp. 163). Differences in the charge radii of isotopes were measured with the remarkable accuracy of $\pm 10^{-3}$ fm (10^{-16} cm!). Systematic effects in the radii differences, which are not yet understood, show up in a linear decrease with increasing nitrogen for even isotopes, and in a pronounced even-odd staggering. Muonic transitions in osmium and platinum isotopes(Exp. 7) were analyzed in terms of deformed charge distributions. Effects of the intrinsic quadrupole moments in these deformed nuclei have been seen, and a more realistic nuclear-model calculation is in progress. Chemical effects of negative muon capture (Exp. 60) in metal oxides, chloride salts, and various forms of carbon, boron, and nitrogen have been analyzed. For metal oxides, periodic variations correlate with metallic electronegativity; for carbon, the intensity patterns divide into two groups: diamond and graphite, and polyethylene and organic molecules. For nitrogen, there is a similar division to that for carbon.

Spallation products of the interaction of 800-MeV protons with uranium (Exp. 86) have been studied with ΔE,E and TOF telescopes. Energy spectra of boron-to-neon nuclides have been analyzed. With the 201-MHz linac rf pulse as a start signal, a 4.3-m TOF path was utilized to obtain a mass resolution of 1.1% at mass 11. The experiment will be extended to higher mass fragments.

The experimental apparatus for the pion-nucleus total-cross-section measurement (Exp. 2) is being revised for the next data run. A beam-intensity monitor, sensitive to individual macropulses, and a rapid-cycling target mechanism are being installed. A thinner transmission-counter stack suitable for low-energy (20-MeV) pion beams has been fabricated.

A new experiment to search for direct lepton production by 800-MeV protons (Exp. 241) has been scheduled for the EPB. A large, and unexplained, ratio of direct lepton-to-pion production ($\sim 10^{-4}$) has been a feature of proton reactions on various targets from 4 GeV to several hundred GeV. This experiment will look for large transverse-momentum electron or positron production in p-p collisions at energies ranging from 275 to 800 MeV. A sensitivity down to 10^{-34} cm^2/sr is expected.

Optical-model analyses of low-energy pion scattering from light nuclei have been studied for the Kisslinger and local-Laplacian potentials. The resulting wave functions exhibited nonunitary characteristics, suggesting the need for a better theory.

Practical Applications

Numerous hardware and software projects at the biomedical research facility, scheduled for the shutdown period, were completed. These included checkout of a 3-dimensional isodose scanner and of circuitry for operating a channel-slit system; design of a gas-bottle form for delivering, controlling, and monitoring gases for proportional counters, beam monitors, and helium tanks; and development work on magnet-control software, a CAMAC exerciser code, and conversion software for the new RSX-11D operating system. Detailed field mapping of several magnets in the biomedical channel was completed; analysis of the data should allow improvement in predictive capability of channel performance. Construction of helium tanks for the first portion of the channel was completed.

Development continued of software for analysis of dosimetry and microdosimetry data, and equipment for expediting the acquisition of these data is being fabricated. Methods for incorporating both microdosimetry data and pion energy-loss mechanisms into the treatment-planning code were studied.

Data analysis was completed for two targets studied in Exp. 100 (Tissue Chemical Analysis with Mu-Mesic X-rays) and is near completion for Exp. 196 (A Visualization Experiment on a Stopping π-Meson Beam using Charged Particles).

Thermal treatment rf spontaneous animal tumors continued in a collaborative program with the Univ.

of New Mexico School of Medicine. Two human cases were treated in July.

Management

For FY-75, operating costs were held to our budget authorization by deferring about $500k of expenditures to FY-76. Essentially all of our capital equipment authorization was obligated or costed. The work funded out of construction (Accelerator Improvement Project) associated with the upgrading of the facility for operation at high intensity is essentially completed. Work on the Polarized Ion Source is under way. An additional $115,000 of FY-76 construction funds is required to complete this project. This has been allocated. The value of the special process spares inventory was increased by about $518,000. The total current value of this inventory is $958,000.

The NCI contracts for continuing effort on Preclinical Studies for Pion Radiotherapy and Cancer Research and Treatment Center program have been signed and work is under way.

A proposal is being prepared for submittal to NCI for the design of a pion generator for medical applications. Hopefully, authorization for this project will be granted sometime late in this fiscal year.

The average number of employees—full-time equivalents (FTEs)—was 351, about 14% more than forecast for the year.

For the first month of FY-76, accrued operating costs were about 15% higher than forecast. This will present a serious problem if the JCAE authorization for LAMPF is not approved.

A large amount of time was expended by MP-Division personnel in the planning and conduct of the IUPAP-sponsored VI International Conference on High Energy Physics and Nuclear Structure. The conference was well-attended, with participants from 23 countries.

The radiological safety record at LAMPF during work on the accelerator and in the experimental areas was maintained at a satisfactory level. No serious accidents were reported during this period.

We are in the process of implementing use of the System-2000 data base for maintenance of records associated with the Visitors Center, as well as the membership and mailing lists of the Users Group, Inc. The Visitors Center reception area has reached full complement this quarter. Although the housing picture at Los Alamos has been grim, we have been able to fill all requests from LAMPF guests. The apartments that are to be reserved, on a priority basis for LAMPF users, have received a tremendous turnover as have the Los Alamos Medical Center apartments. We are making every effort to obtain long-term leases on two- and three-bedroom apartments at Los Alamos to ease the housing situation for LAMPF guests after accelerator start-up.

The LEP Channel Subcommittee of the PAC held two meetings this quarter to finalize beam-time recommendations for the approved experiments on the LEP channel. As a result of the Subcommittee's final recommendations, it will be necessary for some experimenters to request additional time to complete their experiments. Several experiments were postponed until FY-77. Since its organization, the PAC, or its subcommittees, has considered the scientific merit of 237 proposals for beam time at LAMPF. Fifty-seven of these proposals have not been approved. Of the 180 approved proposals, 24 have received no recommendation for beam-time allocation. To date, 11 proposals have resulted in completed experiments.

The Nominating Committee of LAMPF Users Group, Inc., at its meeting on June 12, 1975, selected a slate of officers for the three vacancies on the Board of Directors during 1976. Herbert L. Anderson will serve as Past-chairman of the organization, with David A. Lind assuming the post of Chairman. Planning is under way for the Ninth LAMPF Users Meeting to be held at LASL on November 10-11, 1975.

Publications

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J. D. Bowman, C. M. Hoffman, C. Hwang, R. E. Mischke, D. E. Nagle, J. M. Potter, D. M. Alde, P. G. Debrunner, H. Frauenfelder, L. B. Sorensen, H. L. Anderson, and R. Talaga, "Limit on Parity Violation in P-Nucleus Scattering at 6 GeV/C," Phys. Rev. Lett. **34**, 1184 (1975).

R. L. Hutson, "*In Vivo* Tissue Analysis Using Mu-Mesic X Rays," Los Alamos Scientific Laboratory report LA-5867-MS (February 1975).

Papers Prepared for Publication: Papers Submitted at Conferences

M. M. Kligerman, C. O. Sternhagen, F. Dobrowolski, H. T. Davis, E. Barnes, T. F. Lane, J. N. Bradbury, E. A. Knapp, and D. F. Petersen, "Initial Comparative Response of Metastatic Superficial Nodules and Surrounding and Underlying Normal Tissue to Peak Pions and X-Rays," American Radium Society Meeting (May 4-9, 1975); to be published in Radiology.

J. D. Bowman, "Parity Nonconservation in p-p and p-Nucleus Scattering," submitted for presentation and publication in Proc. Symposium on Interaction Studies in Nuclei (Mainz, Germany, February 17-20, 1975).

M. D. Cooper and R. A. Eisenstein, "Low Energy Pion Elastic Scattering from Light Nuclei," submitted to Phys. Rev.

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J. C. Allred and L. Rosen, "First Observation of Fusion Neutrons from a Thermonuclear Weapon Device," submitted for publication in Adventures in Experimental Physics.

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(Parasite experiment) C. J. Orth, W. R. Daniels, and B. J. Dropesky, "Identification of ^{236}Th," submitted to Phys. Rev. C.

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(Exp. 2) G. R. Burleson, K. P. Johnson, J. Calarco, M. Cooper, D. C. Hagerman, H. O. Merey, R. P. Redwine, I. Halpern, L. Knutson, R. Marrs, J. M. Jakobson, and R. H. Jepperson, "Measurements of $\pi^{\pm}$ Nucleus Total Cross Sections at Energies Below 20 MeV," prepared for the Intern. Conf. on High Energy Physics and Nuclear Structure (Santa Fe, NM, June 9-14, 1975).

(Exp. 7) J. P. Davidson, E. B. Shera, L. K. Wagner, and R. M. Steffen, "Muonic X-Rays from the Transition Nuclei $^{194,195,196}Pt$," prepared for the Conf. of the Amer. Phys. Soc. (Washington, D.C., April 28-May 1, 1975); submitted to the Bull. Am. Phys. Soc.

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II. ENGINEERING SUPPORT

LAMPF Accelerator

Accelerator Support

Renovation of the remainder of the 201-MHz linac was completed in this quarter. The drift tubes in Tank 1 were installed and aligned. The Tank 1 tuning bars were adjusted, and new, fixed tuning slugs were fabricated and installed in Tanks 2, 3, and 4. These modifications were necessary due to the change in tank volume with the new bellows.

The intertank spacer for the downstream end of Tank 1 was assembled and installed. A 1.5-mm, aluminum-wire seal was used to join the spacer and the tank. The entire assembly was twice rolled into position and installed onto the upstream end of Tank 2—first for a bead pull, and again after the removal of the adjustable drift tube and the installation of the permanent drift tube.

The reliability of the vacuum seals on the intertank spacer was improved considerably with the addition of Viton 0-rings and Belleville washers to the downstream flanged joint. This will reduce the bending moment on the upstream wire seal caused by thermal excursions and tank position drift.

All tuning slugs, monitor loops, post couplers, water manifolds, and drift-tube power connections were installed on Tanks 1 and 2.

Radiofrequency baffles were soldered in all drift-tube end plates. The tank-head assemblies were then assembled with adjustable half-drift tubes for the bead pulls and installed on the tanks. After the bead-pull tests, the head assemblies were removed, disassembled, reassembled (with final half-drift tubes) and temporarily installed for additional tank tests. Later, the head assemblies were removed and final vacuum-tight installation was accomplished. During this time, various tank dimensions were measured as required.

The cold traps and mechanical refrigeration system for the soft vacuum systems in Tanks 1 through 4 were received and installed.

After installation and alignment of the drift tubes, the quadrupole magnet interlocks and controls were checked out and the magnets were powered. Magnet measurements, using a Hall gaussmeter probe in a special fixture, were made to check the position of the magnetic center with respect to the bore of the drift tubes in Tanks 1 and 2. Similar measurements had been performed on the Tanks 3 and 4 drift tubes last September.

The smaller bore of the drift tubes and closer gap spacings in Tanks 1 and 2 reduce the accuracy of the measurements in these tanks compared to Tanks 3 and 4. The errors are tabulated in Table II-I.

It had been observed that the proton beam had a horizontal oscillation with a period of a few seconds. It had been hypothesized that the oscillation was the accumulative consequence of the drift tubes being driven at their natural frequency by one or more of the water systems. During the shutdown, three drift tubes in Tank 1 and four drift tubes in Tank 2 representing end and middle positions were instrumented with accelerometers to measure their transverse and longitudinal motion. In the absence of any obvious driving force (water, pumps, fans, etc.), the drift tubes were observed to oscillate at their natural frequencies ($\sim$10 Hz) with an amplitude of $\sim$0.005 mm. Under normal operating conditions (water, pumps, fans, etc.—but no rf), the transverse amplitude was found to be of the order of 0.080 mm, with the longitudinal motion about a third of this. No single driving force was found, although the water systems clearly were the dominant contributors. These systems (outer cavity wall, drift tube, and drift-tube quadrupole magnet) seemed to be roughly equally effective in providing a driving force.

The proper alignment of the beam line from the injector to the 201-MHz linac was verified. The magnets in the downstream portion of the TR have been rearranged, aligned, and tested. All components in the TR were checked for alignment, and most components were realigned.

A transparent vinyl door has been installed in the truck-access opening of the TR. The new door will reduce the infiltration of outside air into the beam channel when the large roll-up door is opened and, consequently, improve the stability of the accelerator tanks in the vicinity. The beam boxes on the 805-MHz accelerator were measured, using a specially designed alignment fixture. The positions were recorded in the LAMPF coordinate system.

TABLE II-I

MAGNITUDE OF ERROR BETWEEN THE MECHANICAL AND MAGNETIC AXES

Error	(in mm) Tank 1	Tank 2	Tank 3	Tank 4
Average Horizontal	0.038	0.025	0.020	0.018
Average Vertical	0.064	0.038	0.036	0.041
Maximum Horizontal	0.112	0.112	0.096	0.066
Maximum Vertical	0.206	0.104	0.076	0.104

Precise length measurements were made on module 13.

Eight actuators were ordered for spares, and some actuator parts, including stepping motors, precision screw shafts, and bellows, were also ordered.

Thirty-four H_2 furnace heats were run this quarter. Most of the heats (17) were in support of the accelerator improvement activities, such as the new, high-emittance jaws, and collimator parts for the injector portion of the accelerator. Twelve heats were for the ion pump and the klystron-rebuild program, and five heats were in support of the secondary beam lines and Line A.

Fabrication activities (108 total) consisted mainly of TIG welding of beam pipes and vacuum manifolds for the injector area and the accelerator switchyard, and machined parts for magnet supports in the accelerator transition area.

805-MHz RF System

The klystrons were operated for ~9299 hvh and 16 852 fh in this quarter, and no klystrons failed. In the past year, 39 LPT-44 switching triodes failed, primarily because of excessive interpulse current. These triodes were all reprocessed in this quarter, and 35 of them are now acceptable; the remaining 4 have been discarded.

Klystron-Repair Facility

No klystrons were rebuilt in this quarter, but one, which had been previously rebuilt, was tested at full power and 6% duty factor. This klystron is an L-5120 (S/N 2026R1) which had originally been accepted with a 6% duty factor restriction because of a window-heating problem. The window was removed, cleaned, and recoated as part of the rebuild process, and now the window runs cool, 10°C over room temperature, at 6% duty factor.

Four of the five most recent klystron rebuilds have been successful, and these four rebuilt klystrons have accumulated over 5200 hvh and 6600 fh. Two of these are installed on the accelerator, and the others are being run at ETL.

The klystron gun assembly room and its filtered air system have been received, and installation of these components at the ETL has begun. The furniture and work benches for this room have been ordered.

A welded joint to attach a new weld flange onto an old klystron body has been designed and successfully tested. The welded joint replaces a brazed joint, which is not practical to make on an assembled klystron.

Ion Pump Rebuilding

Thirty-six 805-MHz ion pumps (500 ℓ/s) were rebuilt during this reporting period, bringing the total quantity of overhauled pumps to 140. All of the 201-MHz (2400 ℓ/s) ion pumps, including two spares, have now been overhauled, and ten of these were installed and put in service. A pressure of $\sim 3 \times 10^{-8}$ torr has been achieved in Tanks 3 and 4.

Magnet Testing and Metrology Lab

Two collimator boxes (P^3-MS-01 and -02) for the P^3 line, and an EPICS collimator (IP-FJ-05) were measured and given alignment targets for future installation and alignment.

The HRS magnet-measuring cart was measured and realigned in the tooling dock.

Experimental Lines

Weapons Neutron Research Facility—Line D

All of the bending and quadrupole magnets required for the switchyard and waterfall portion of this line have been tested, installed, and aligned. The first quadrupole triplet magnet (LDQT-01-02-03) was replaced with a temporary beam stop to be used for line tune-up. Three of the twenty steering magnets were completed and installed. Figure II-1 is a picture of one of these completed assemblies which are designed such that they may be installed or removed without disturbing the vacuum or line components. Machining of the beam-position monitors and vacuum wire-scanner boxes is now complete. Field clamps for the fifteen 6.8° bending magnets were modified to provide beam-tube-positioning capability and reinstalled in their proper position. The vacuum system between the Line A junction point and the temporary beam stop was completed and is now under high vacuum, ready for beam.

The modulator for the fast-kicker magnet is being assembled and tested into a dummy load. Half the delay line has been energized, and current pulses of 5000 A have been produced in the dummy load. The pulse shape is within design limits. The 6000-A tests will occur early in the next quarter.

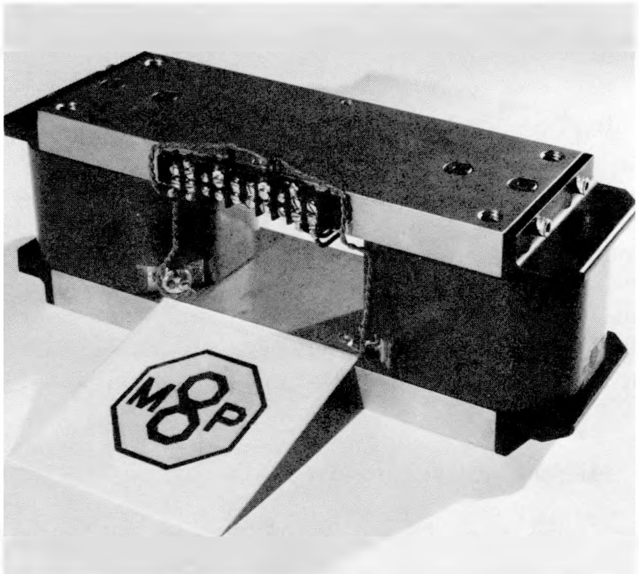


Fig. II-1.
Line D steering-magnet assembly.

Biomedical Beam Line

Helium chambers for the triplet and bending magnets, dust covers, and additional shielding near the bending magnets were installed in this quarter. The design of a remotely operable flange clamp was accomplished, and the fabrication has been started. The bending-magnet assembly is now installed, and work is proceeding on the two slits. Some preliminary survey and layout work was done to guide the installation of magnets and stands in this area. Four scintillators were completed and placed in a projection cabinet.

Energetic Pion Channel and Spectrometers

The EPICS separator shield plug was set in place, checked for proper fit, and cut accordingly. The 25-mm base plate and internal tracks were cut, installed, leveled, and bolted in place. The external track system was positioned and leveled. A method of anchoring the tracks to the main shielding was designed; the parts were fabricated and installed. Finally, the lower plug weldment was positioned, filled with shielding, and bolted to the upper plug weldment.

The design of the shield-plug actuator was completed. Components were ordered and received, parts were fabricated and assembled, and the actuator has been installed. Temporary methods are now being used to move the plug. The design of a permanent transport mechanism was started and is about 50% complete.

A special crane-mounted pallet lifter (for installation of the target-mechanism shield plugs) has been ordered.

Although many problems were encountered in the installation and alignment of the EPICS channel, the line is now essentially aligned.

Other Beam-Line Support

A complete survey and realignment of Lines A and X was accomplished, and Lines B and EPB were checked for alignment. A precise alignment of Line C up to the twister magnets was accomplished. The front ends of the P^3 and SMC have been realigned.

Instrumentation

Eighteen variable-gain preamplifiers were built and calibrated for the experimental area current monitors. All the voltage-to-frequency converters and signal processors were tested, repaired as necessary, and recalibrated.

A solution to the thermal sag in harp wires was found in carbon-monofilament material. This material has low density, high strength, and excellent thermal emissivity. These properties minimize the temperature rise of the harp wires. Furthermore, the monofilament can be stretched ~1% before it breaks. Thus, it was practical to eliminate the springs in building harp planes. The wire winder was modified to produce a harp with four close-spaced carbon wires on each land. A tin-plating method was developed to solder these wires reliably to the lands. Three complete assemblies have been made, and the remaining frames will be wound in August.

A complete harp assembly, consisting of two perpendicular signal grids and three hv planes, is shown in Fig. II-2.

A total of 26 harp planes and 13 complete 1° light-pipe assemblies were manufactured in the quarter.

Experiment Support

The order has been placed for the coils for the spectrometer magnet "Bicentennial" which will be used for Exp. 29/64. The conductor has been ordered and delivery promised in late September. Final drafting of the magnet stand is under way, and the

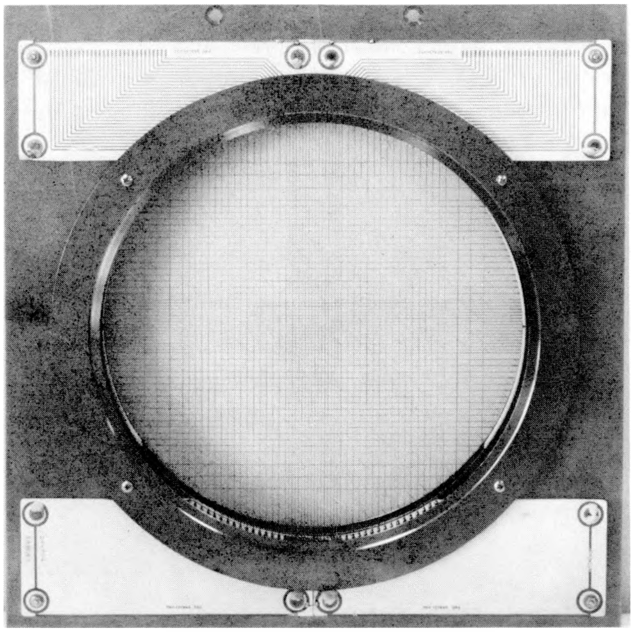


Fig. II-2.
Carbon monofilament harp-board assembly for Area A.

drawings of the main structural support for this stand have been sent out for bids.

The heavy water dump-and-recovery system for Exp. 31 is near completion. The four anticounter support stands have been placed in the neutrino house.

The chamber for Exp. 179 is being designed for construction in August.

Design and drawings are complete for replacement coils for the Ames "C" magnet. Each of the two coil sections is made up of five separate pancakes that can be removed (sacrificing magnetic field) to permit an increased gap if required.

The hodoscope magnet for Exps. 22 and 222 is being built. The core is now complete and the cores are being renovated.

The position mechanism for the cryogenic target for Exp. 2 is being assembled. All purchased parts are on hand, and the assembly is ~75% complete.

Twelve new mirrors are being prepared for mounting in the large-aperture, Cerenkov chamber for Exp. 130. These mirrors are made from aluminum blanks and will replace acrylic mirrors, which were dimensionally unstable.

A design has been initiated for a rotation pedestal for use on the "Kontiki" spectrometer stand for Exp. 90. The pedestal will support the tritium-gas target chamber, and will be located in the P^3-East cave.

III. ACCELERATOR SUPPORT

201-MHz RF System

An average of 315 h was accumulated on each of the 201.25-MHz rf stands during the quarter.

Most of the quarter was devoted to finishing modifications and preventive maintenance that were in progress at the end of the last period. The remaining two 7835 cavities were cleaned and refurbished.

A short heat run of 20 h at 8.4% duty was made into Tank 4; no problems developed.

The 7835 that failed during the heat run of the previous quarter was returned to RCA for "test, cut, and analysis." After opening the tube, RCA reported that the failure was of a two-part nature; three filament strands had failed and had caused the grid cathode short; there was also a vacuum leak at the anode seal of the tube.

The crowbar resistor-cooling modification was completed and appears to work completely satisfactorily. The capacitor rooms were cleaned, and connections were checked and cleaned.

Conditioning of tubes continued during the quarter. All 4664s on hand have been processed. One rebuilt 4664 arrived with a grid short. An RCA representative came to LASL to assist in clearing the short. The clearing of the short was successful, and the tube ran into a resistive load at full power. It is now in service powering Tank 1. A rebuilt 7835 was received but has not been tested.

The test run on the Belden 8871 cable showed evidence of damage, due to corona, beginning after some 400 h of hv time. It appeared that the cable would have continued to run for several hundred more hours before it failed. A 1000- to 1500-h run before failure would be a significant improvement in life over the existing cable, so we plan to go ahead with the changeover to the Belden cable. Work will continue on improving the termination design to extend the MTBF of the cable.

The new closed-loop control for the hv power supplies in the 201.25-MHz area were installed and are working satisfactorily, although there was one semiconductor failure during a crowbar.

The bias supply for the tubes in the power-amplifier modulator was upgraded to make it more reliable.

The last month of the quarter has been devoted to start-up of the tanks. Considerable effort was put into mechanically aligning the transmission lines to the tanks and the installation of the coupling loops. Coupling measurements were made on all the loops, and no detectable deviations from the original data were noted. Much effort was put into setup of the equipment and into debugging problems caused by modifications and mistakes in assembly, etc., that had been made during the shutdown.

805-MHz RF System

The modification of all vacuum-pump power supplies to prevent any recurrence of fires in the units has been completed. All sectors have been run with full rf power in the tanks. This run-in period has revealed many minor problems which have been corrected. All system calibrations have been completed. The Belden 8871 hv cable under test at ETL has 4811 hvh and 3420 h drawing current.

Low-Level RF System

Upgrading of source room equipment continued during this period. The tuning and loading controls of 805-MHz amplifiers were mechanically modified to facilitate smoother operating. The amplifier interlock systems were modified for increased reliability, and the systems were recalibrated. The method of monitoring 805- and 201-MHz output power was modified to eliminate false indications of power changes on the output recorders.

Insulation was replaced on the master drive line where couplers had been reinstalled after maintenance during the last report period. All couplers were rechecked and appear to be in good shape after several months of operation since the new resistors and isolators were installed.

Bunchers I and II have been modified for temperature control and are now operating. All rf equipment associated with the bunchers received preventive maintenance.

The chopper rf system has been moved "downstairs" into a new rack, installed beside the buncher rf system.

Phase-and-Amplitude Control System

As in the previous quarter, considerable time was spent on the "Redundant Phase Monitor" system. Chassis have been built for, and installed in, the bunchers, 201-MHz, and bucket rotator regions. We are in the process of adjusting rf drive levels to the units, and the units should be functional soon. Additional testing of the units installed in the 805-MHz areas indicates all units are functioning properly.

A 40-point calibration has been performed on all 805-MHz phase subsystems. This task was performed with the help of accelerator operations personnel. Although this test was to provide calibration data for the slow-phase-shift subsystem, it also revealed several noisy subsystems. Therefore, four more subsystems have been replaced in addition to the nine systems replaced during the previous quarter.

Separate 24V-dc power supplies have been installed on all fast-phase shifters. This should eliminate many of the noise problems associated with the previous "shared power supply" setup.

The reference-line temperature-controller interlock has been fabricated and installed in all sectors. The system has been checked out and is functioning properly in all areas.

Power Supplies

The modification program on the Ling-built and Acme-built power supplies is continuing. The SY power supply modifications are finished except for the new interlock relay board and the modified reversing switches; bending-magnet power supplies in Lines B and C will have modifications completed by August 15, 1975, with the same exceptions. The iron-core water-cooled choke needed for the Ling-built 1-MW power supply in EPICS has been received and installed. Modifications in this power supply are complete.

The new power supply for Exp. 37 has been installed and is operating on the 75% voltage tap. A 1200-A, 480-V breaker will be installed in the power panel which feeds this unit. It will be changed to the 100% tap at the time of installation so the experimenters can reach full design field.

The three new power supplies for the SMC have been received and are being installed. The installation of these units begins the complete rearrangement of the SMC power-supply area.

Work is continuing on the magnet by-pass shunt systems for EPICS, LEP, and WNR.

The drift-tube quad-magnet power supply and shunt system are operating.

The transition region quad-magnet power supply system and the bending-magnet power supply and shunt system have been checked out at full power levels. These systems are operational.

The 2000-A reversing switches have been redesigned and are now installed on the Acme-built 1-MW power supply in EPICS. If operational experience uncovers no design faults, all 2000-A reversing switches will have the same modifications performed.

Beam Diagnostics

The activities of the beam-diagnostics section during the last quarter have been essentially in three areas: 1) preventive maintenance of existing beam-diagnostics equipment, 2) organization and procurement of spare equipment, and 3) design, development, fabrication, installation, and checkout of new systems.

The task of performing preventive maintenance on beam-diagnostics equipment was continued during this quarter. The frequency tuner assemblies and control system were inspected and maintained. The preventive maintenance of the 55 actuators which are used in the scraper, absorber/collector, etc., systems was completed. Approximately 30 linear-actuator driver modules were modified, repaired, and checked out during this period.

The procurement of spare parts has continued. Essentially all spare equipment being manufactured at the Missouri Research Laboratories has been received. Progress on the writing of maintenance procedures, system descriptions, etc., was limited this quarter by the lack of sufficient manpower.

A large amount of time during this quarter was devoted to the design, fabrication, installation, and checkout of new beam-diagnostics systems. The fabrication was completed on beam scrapers, high-power emittance jaws, absorber/collector jaws, EM-7 and EM-11 fixed-slit emittance jaws, and the 201 viewing screen. The devices were placed on linear actuators, and the actuators were installed in beam boxes and were checked out. Twelve control bins which control the new beam-diagnostics devices were fabricated, installed and checked out. Installation of the cables which are required to move the emittance switch from the beam line to the equipment aisle was completed. An interlock system was designed which will prevent devices in the same box from interfering with each other. Interlock boxes and cables were fabricated, installed, and checked out. Bias supplies for biasing the emittance jaws, absorber/collectors, scrapers, etc., were designed and tested. Five of the fifteen required have been fabricated, installed, and checked out at this time.

The search continued for a flat cable with insulation that has better vacuum, temperature, and radiation characteristics for the harp system and emittance collectors, and also for single wires with the same characteristics for use with many of the other beam-diagnostics devices. Fourteen wire manufacturers were asked to bid on the flat cable. Only one company bid, but offered a product which did not meet the specifications. Other manufacturers will be contacted. Two types of single wires were ordered. One type (with Fiberglas insulation) has been received but cannot be used because of installation problems. The other type (with Kapton insulation) has not been received.

The drilling of the beam boxes, actuator flanges, and cover plates for alignment pins was completed during this quarter. The wiring of 25 new actuators was completed. The motors on all actuators were replaced except the wire-scanner actuators. The control chassis changes resulting from this motor change were made to the five emittance chassis. Amplifiers which provide for individual beam-current signals from beam-diagnostics devices were fabricated and installed.

Vacuum Systems

201 Linac

The vacuum section support for the 201-linac reassembly has continued to be heavy through the whole report period. As the report period ended, the reassembly was completed and the tanks evacuated to pressure low in the 10^{-7} scale. No particularly difficult vacuum problems were encountered.

Transition Region

Installation of the new beam components in the TR was completed late in the period. The necessary leak checks were made, and the TR was returned to vacuum with the ion pump running at 1.8 mA.

805 Linac

The return of the 805 tanks to vacuum after rebuilding the valves, pump, and current monitors is complete. Some rework was required on four current monitors, two beam boxes, and several valves.

Switchyard

All of the reworked components and vacuum hardware that are available have been reinstalled in the SY, including two new turbo pumps at the end of Line A. The final vacuum closures are awaiting alignment requirements and a few parts that are still in the shops.

Area B

The final modifications have been completed to reassemble the vacuum hardware in the Nuclear Chemistry Cave in Area B. Line B should be ready for vacuum in a week or two.

EPB Line

Some vacuum support has been provided for reassembly of the EPB line, but the final completion awaits three major components still to be fabricated.

Areas A and C

Time did not permit vacuum support in Areas A and C this period.

Mechanical Support

Oil tanks for 201-MHz crowbar resistor cooling, associated pumps, heat exchangers, water supply, and instrumentation were installed and checked out. Preliminary and subsequent test results indicate this system is expected to eliminate the continual deterioration and ultimate self-destruction of overheated crowbar resistors.

Drive loops in Tanks 2, 3, and 4 were reworked, installed, and tested. It is too early to know if the improved mechanical assembly and cooling will result in any significant electrical improvement.

Installation of the WNR cooling system is complete. Future effort on this system is expected to be limited to troubleshooting and consultation.

Rework of beam diagnostics is complete. All equipment has been installed and checked out. Redesign of existing harps is being considered. However, all inputs to date are preliminary.

Mechanical support has been a continuing effort. Considerable effort has also been dedicated to accelerator systems development personnel in mechanical support of bead pull and general fabrication.

IV. ACCELERATOR SYSTEMS DEVELOPMENT

Accelerator Beam Performance

201-MHz Linac Field Distribution

After reassembly and alignment of the drift-tube linac, the field distribution was retuned using the bead-pull technique.

In the post-coupled sections, it was found that insufficient clamping of the post couplers allowed them to move enough to significantly affect the field distribution and stop-band closure. The introduction of adjustable drift tubes to check the effect of perturbations on the stop-band, and the removal and replacing of the end walls, also caused errors. Measurement with the final configuration and a revised perturbation technique corrected these problems.

Vibration of the components in the first two tanks of the linac introduced noise in the bead-pull measurements to a troublesome degree. This problem in the past has led to the use of larger bead sizes to increase the signal-to-noise ratio. However, this introduces an error in the results. Information was gathered for three different bead sizes. Also, a base-line "signature" produced by the string was measured for use in future data analysis. A series of measurements was made on the first tank to show the effect of the frequency tuners and the end-cell adjustments on the field distribution. A large amount of data reduction will be necessary to remove the above errors. Considerable programming to process the data into formats compatible with off-line computers was completed.

Study of the effects of the actual field distributions on the longitudinal dynamics continued.

The original intent was to arrive at a new design particle which would minimize the oscillation in Tank 1. As the problem expanded, it became evident that it would be necessary to evolve a compromise design encompassing the four tanks of the 201 linac. This design is necessary not only because the field distribution varies from design but also because the gap lengths deviate from design; both effects contribute to longitudinal oscillation. These variations lead to a new design input phase and energy for each tank which will then serve as a basis on which to make a compromise which will optimally produce the minimum longitudinal oscillation in the whole 201 linac. This program depends intimately on the knowledge of the Tank 1 field distribution. The analytical program also involves cavity studies using several computer programs, including a very useful geometrical calculation code from BNL.

Effect of Quadrupole-Field Multipole Components and Vibrations in the 201-MHz Linac

The study into effects on beam quality caused by quadrupole aberrations has continued. Fringing fields, which contribute systematic multipole forces, are being added to make the calculation complete. The quadrupole aberration code has been added to SIMILAC, which calculates beam dynamics in the side-coupled linac. The effects due to the steering windings (sextupole moments) are also being added.

Data from the final alignment check of Tanks 1 and 2 were added to PARMILA to check for any oscillations which might be induced in the centroid of the beam. The low-energy drift tubes are the most difficult to align accurately, and are also those which affect the beam the most if misaligned. Although all but a very few of the drift tubes are within the ±0.125-mm tolerance, the centroid of both proton and H^- beams suffer oscillations of 2 mm horizontally (see Fig. IV-1). These are initiated primarily by systematic patterns in the alignment.

The drift tubes were also found to have inherent vibrations of ±0.05 mm in amplitude, which can

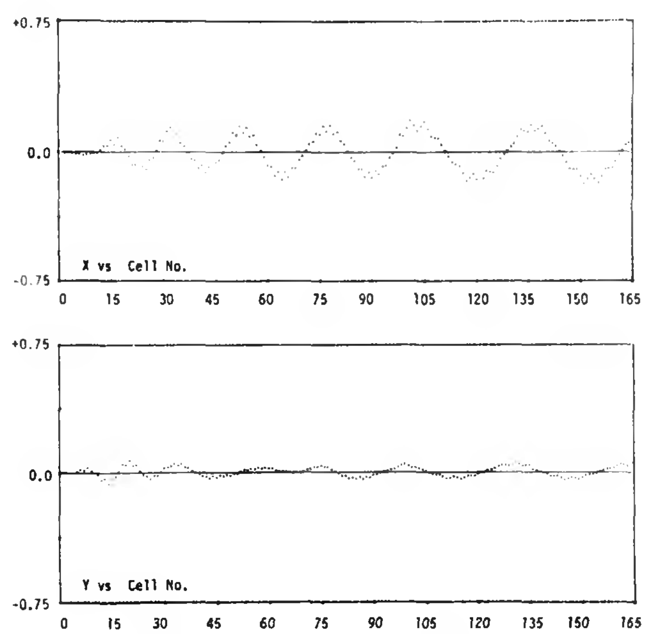


Fig. IV-1.
Particle trajectories in the drift-tube linac with July 1975 alignment.

cause an increase in the effective oscillation amplitude of the beam centroid. Figure IV-2 shows a vibration simulation, where trajectories of central particles in the drift-tube linac for 100 random sets of quadrupole-position errors, caused by vibration, are superimposed on their nominal alignment. These results show that the beam centroid can oscillate in time within an envelope of ±4 mm horizontally. This in turn can contribute to the generation of halos, and complicate the steering problem.

Low-Energy Linac Structures—Alternating Phase Focusing

Investigation continued into the properties of this new type of structure.[1] Application of this structure plays a major role in the proposal under preparation for the design of linacs suitable for medical applications.

201-MHz Linac Alignment

Alignment of all elements from the injectors through the 201-MHz linac was completed this quarter with the reassembly and realignment of the Tank 1 drift tubes as shown in Figs. IV-3 and IV-4. (Note that the scales for horizontal and vertical dis-

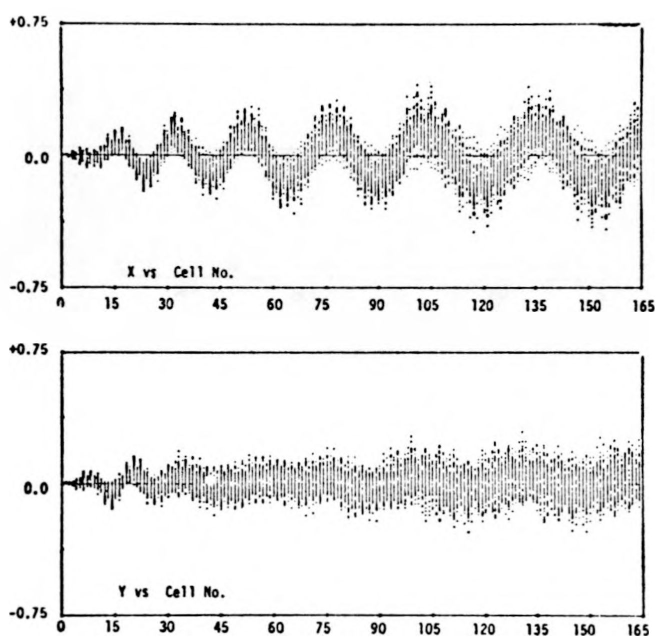


Fig. IV-2.
Particle trajectories in the drift-tube linac with July 1975 alignment plus 0.05-mm vibration.

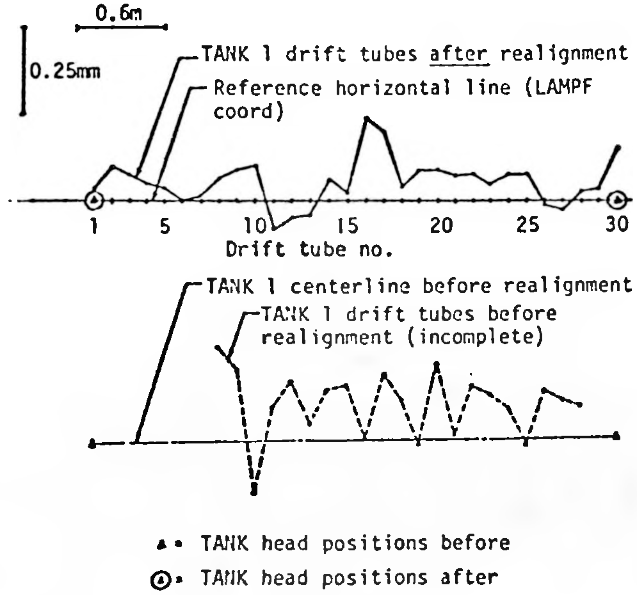


Fig. IV-3.
Comparison of Tank 1 before and after realignment—horizontal plane.

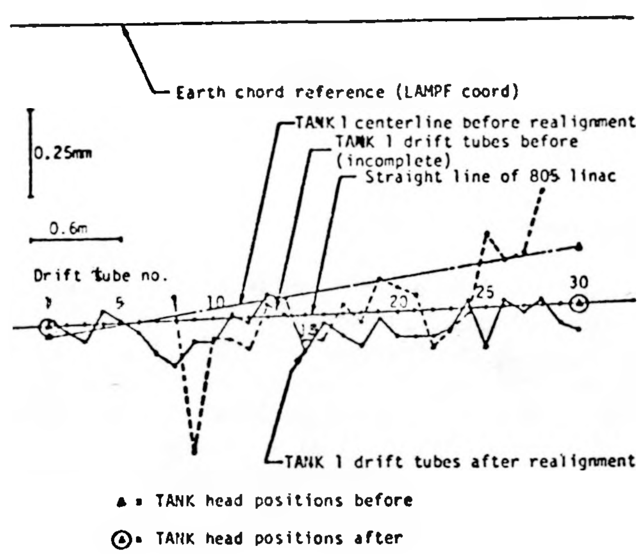


Fig. IV-4.
Comparison of Tank 1 before and after realignment—vertical plane.

placements are identical to those appearing in the April 30, 1975 Quarterly Progress Report for alignment of Tanks 2-4.) The transition region was also reassembled, with the TR quad doublets being placed on-line using the established wall- and floor-alignment monuments. After initial turn-on of beam following the shutdown, the first indications are that transmission through the realigned 201 linac is significantly improved.

This completes the realignment of the facility from the injectors through the 805 linac. A comprehensive data-base listing is being compiled which will provide LAMPF-coordinate alignment information for all linac components and alignment monuments. This listing will be available for rapid and flexible call-up to aid beam-steering codes.

805-MHz Linac Length Corrections

Bead-pull measurements of field distribution were completed for modules 12 and 13. The measurements on module 12 were to check the settings of one set of bridge-coupler posts that had been temporarily removed. The measurements on module 13 were to set the notched post in the new bridge coupler such as to make the tank-amplitude averages agree. Comparison of these vacuum bead-pull measurements with measurements made three years ago shows that there has been no detectable change in field distribution within the tanks of these modules. (The bead-pull measurement is done at a very low power level, of course.)

Accelerator Systems Development

Operations Support Development

Operations/Maintenance Data Base. Procedures have been modified to allow the equipment action cards to be filled out using device codes for equipment in the experimental areas. The necessary files have been created and programs written to access them for daily reporting. The data base has been redefined to store device information.

Programming for comparing shift supervisor estimates of beam downtime with the totals from the equipment action reports was completed. This will help insure the accuracy of the data-base information when used to estimate reliability and other factors.

A presentation was made to the Technician Training Class on the methods for card preparation and the uses made of the information. Viewgraphs and handouts are available for repeating this training for new personnel.

Experimental Schedule Data Base. Modifications to this data base were made to add new features for keeping track of the state of proposals and for compiling PAC-hour statistics.

Visitors Center Data Base. This data base was completed and put into operation. Training material was compiled and training provided for the visitor-center personnel. Documentation of the data-base formats and production retrieval capabilities was prepared.

PDP-11 Maintenance Data Base. Four retrieval programs were written, and training was provided in the use of this data base.

Form B Data Base. String retrieval commands were written to aid in the Budget Office monthly updating procedures, and training was provided in the use of the interactive update procedures.

Outside Contracts Data Base. A new data base for handling the accounting for outside fabrication contracts was designed and defined, and considerable programming completed.

Users Group, Inc. Data Base. Transfer of this system to the System-2000 format was initiated. Some improvements will be incorporated.

Bibliographic Data Base. A very satisfactory beginning was made on the compilation of a bibliographic data base covering technical material related to the LAMPF facility and the physics research accomplished here. The Master Control Program (MCP) is being used, with external programming as necessary to handle the transfer of data from the terminal cassette system to the required formats. Over 600 documents have been abstracted, of which 400 have been entered in the data base, and work on organization of the information into convenient categories and dictionaries has begun.

Diagnostic Equipment Development

Work on improvements to the Δt system were essentially completed during the quarter, and work on several instrumentation projects for the injector systems continued. A new 5-kHz oscillator, which is locked to the 120-Hz beam gate and has automatic gain control, was prototyped. A simple temperature-control system was added to the beam-position monitor electronics enclosure, and several units were prepared for evaluation with the beam.

Computer-Control Programming

The beam-plot programs have been rewritten. One set of changes was to make the character-scope displays and operator interactions more self-explanatory, thus making the programs easier to use. Another set of changes was to convert the start-up and update programs to table-driven form. The set of current monitors for each option is now specified by tables in a separate file. These tables are easy to modify as beam-line configurations change with the growth of LAMPF.

A data-scan routine, which only records data when the data differs from the previous recorded value and only when the rf equipment is on, has been written. The routine permits one to save more information for long-term stability studies than was possible previously. The routine is currently being used to collect all data available which may help one understand drifts in module-to-module phase.

Code Development

A Tektronix 4015 interactive graphics terminal was received and interfaced to the central computing facility. This tool will greatly increase the power of the analytical program with suitable code development. This work began with the conversion of several existing codes to operation under the terminal system, and preliminary design of the changes necessary to structure the codes for interactive use.

Collaborative Programs

Energetic Pion Channel and Spectrometer

The vacuum flux box which is now installed in the EPICS line required substantial finishing work to improve the 0-ring seal. Subsequent tests showed that the rewaxed seal will hold the vacuum required in the EPICS line, and the box was installed. The empty shield plug has been inserted over the box and fits properly.

The hv line has been modified to allow removal of a cover plate to clean the oil reservoir. This greatly facilitates maintenance and inspection of the most critical section of the hv delivery system. The termination has been tested to 220 kV in SF_6 using concentric acrylic cylinders.

The SAMES hv cable has been installed in the shielding, and the spare cable mounted in such a way that both can reach the permanent position of the Cockcroft-Walton, which is located against the west wall of Area A. The permanent electronics racks, mounted against the same wall, are being wired to accept the electronic gear necessary to run the system. The SF_6 gas lines are also installed in the shielding.

The separator system is ready for the α-test to begin next quarter. Requirements on the system will be moderate; namely, full magnetic field and an electrode voltage of only $\sim$130 kV. This will be the first test of two effects of the unsymmetrical fringing field brought about by using a single powered electrode.

Troublesome leaks in the magnet cooling water system have been traced to faulty braze joints and repairs have been made. If time permits in the future, the cooling manifold system will be completely modified to utilize vacuum flanges instead of swage fittings.

All long-lead spare parts have been received to supplement the separator hardware and electronics.

Biomed Pion Range Shifter

The jib-boom drive train has been tested and functions properly. The drive mechanism has been installed on the steel column in the Biomed treatment room. Some finish machining to the boom is being done to match the range shifter which is completely assembled. The complete unit will be assembled in place in the treatment room to allow technicians to inspect and evaluate the system from the point of view of manipulation.

Only slight progress has been made on the hydraulic power supply; additional mechanical technician assistance is required.

REFERENCE

1. Donald A. Swenson, "Alternating Phase Focused Linacs," unpublished.

V. INJECTOR SYSTEMS

Hydrogen Ion Sources

H^+ Ion Source

The modifications to the control systems for the H^+ ion source have been completed and have eliminated the spurious ion-source trips that were previously present. These trips were initiated by sparking in the injector, which resulted in faults in the computer control system presumably because of inadequate shielding and ground loops in the computer and interface circuits. A hardwire control and interlock chain has been used on the present ion source control system with only local ON/OFF controls provided. Only the modulator and extractor power supplies have been kept with the original computer control system. Analog command capability and data readout have been retained for all systems, with modifications made only to the binary command channels.

The fast-protect systems for the H^+ injector necessary for high duty factor operation have been installed and checked. These systems sense excessive beam impingement on the accelerating column or voltage transients on the equipment dome and turn off the ion beam through the fast-protect system. For high-voltage faults, a time delay has been incorporated in the fast-protect module which keeps the beam off (for a fixed time interval) to allow the voltage to recover on the equipment dome. High-power tests over extended periods of running time have not yet been conducted because of rectifier problems in the C-W stack.

Work has started in securing background information to design a feedback control system for the H^+ ion source to reduce changes in beam current from the source when changes are made in the instantaneous duty factor. It is proposed to reduce the filament current on the ion source as the duty factor is increased in order to maintain a constant extracted current. Tests have been carried out with a thermocouple attached to the ion source filament which show that the cathode temperature increases from 923°C to 995°C when the beam duty factor is increased from essentially 0 to 6%; the time for this change to occur is several minutes. A feedback loop to maintain constant filament temperature is now being implemented.

Work has continued on implementing a gas-flow system with a mechanical leak. This system has a faster response time than the existing palladium leak but still has considerable backlash. Modifications to the gear train in this unit are in progress to reduce the backlash to an acceptable amount.

The design of a variable-aperture Pierce anode ion source was deferred this quarter because of priority of the shutdown activities.

The H^+ injector was turned on for full-time operation at the end of July.

H^- Ion Source

Work has continued on studying anode apertures suitable for long-term operation with the high-arc power in the H^- duoplasmatron. The copper-iron laminate units still showed some melting damage under prolonged operation so tests were initiated with aperture units having molybdenum inserts. To date, these units have shown no melting damage.

Considerable effort was spent on trying to adjust termination cards in the light links to computer interface in the H^- injector in order to eliminate binary command failures. Some success was achieved, but binary command failures continue to give trouble in several of the H^- ion source systems. Since sparking faults are much less frequent in this injector than in the H^+ injector, no modification to the computer control system has been necessary, and work is continuing to resolve the control problems.

The H^- injector was turned on for full-time operation at the end of July.

Polarized Ion Source

The construction of the shielded enclosure for the C-W generator was completed except for minor details. Work is now starting on modifying floor structure to mount the base plate for the equipment dome.

The C-W 850-kV power supply and ion source terminal for the polarized ion injector were inspected and tested at the vendor's plant. The power supply differs from those in the H^+ and H^- injectors in several significant aspects. First, there is no bouncer since ion currents <1 mA would not cause significant voltage droop. Second, the power supply will deliver only 2-mA average current, compared with 14 mA for the H^+/H^- machines. This lower current requirement led to a power supply design with a seven-stage C-W, operating at 9 kHz and with a coupling capacity of 300 pF, whereas the H^+/H^- machines have 10 stages operating at 5 kHz with a coupling capacity of 3300 pF. The lower capacity has allowed the power supply to be placed directly under the ion source terminal with no protective surge resistor.

A model power supply operating at 1/1000 the full voltage was built and tested and confirmed the electrical performance of this design. These tests showed that low ripple (0.01% could easily be achieved for 0- to 2-mA load.

Inspection of the machine at the vendor's plant showed a nicely built unit with a much improved electrical control system. The low-voltage controls are nearly identical with those employed in many other modern high-voltage generators and are all solid-state design. During the tests, all systems performed well except for two choke coils in the rectifier stack which had considerable corona and overheating. Relocation of one coil in an oil tank substantially reduced the problem for that coil, and design changes were then undertaken to solve this problem on the other coil. The vendor reports that the changes were successful.

Much of the time was spent reviewing circuit details with the project engineers. The measurements made for acceptance included long-term stability test ($\pm3 \times 10^{-5}$ in 8 h), a delivery of 2 mA at 850 kV using a corona load on the terminal, proper recovery after several induced sparkdowns, ripple test (±0.02% at 2-mA load, and ±0.01% at 0.4-mA load), and observation of many circuit waveforms and operating parameters. No problems were encountered other than that previously indicated with the choke coils.

This generator has now been received at LASL. Installation can begin as soon as the Faraday cage I-beam modifications are completed. The spare parts have not been ordered, but the vendor is preparing a list of recommended units.

Tests were carried out using the argon cryopump on LASL's tandem Van de Graaff polarized ion source. Some difficulties have been experienced in maintaining good gas connections on the high-pressure nylon lines for the compressed helium. The general design of the argon cell region has now been established.

Cockcroft-Walton Generators

The H^+ C-W generator has been working reasonably well after all the changes were incorporated in the last quarter. The feedback signal derived from the compensated leg for the slow-stabilizer loop was improved by matching the time constant with that of the compensated leg. It was also apparent that the gain of slow-stabilizer loop was low. Suitable adjustments were made to increase this gain and yet preclude oscillation in the slow stabilizer. The detailed checks of each component in this slow-stabilizer control loop were carried out.

Tests on the bouncer control circuits showed that the drive signal in the initial part of beam pulse was inadequate. The theoretical work carried out for the bouncer loop shows the need of additional state feedback. Experimental tests then indicated that significant improvements in the dome-voltage droop, and considerable reduction in the drive-to-bouncer loop, could be effected with such feedback. In particular, the integral signal feedback marked improvements in the tail edge of the dome-voltage pulse. Further tests will be carried out to reduce the voltage error for the middle part of the beam pulse.

The H^+ rectifier stack was disassembled for tests on the rectifiers and capacitors. The rectifiers were reverse-biased at voltages up to 200 kV for measurement of the leakage current. Nine rectifiers were found to exceed the 400-μA maximum specified by the vendor. Five new rectifiers were received, tested, and installed; additional rectifiers are on order to complete the replacement. The possibility of rebuilding the rectifier units locally is being explored. The capacitors in the rectifier stack were tested for leakage current at 200 kV, and all units checked out normally. Additional work was done on the H^+ generator to facilitate better operation and serviceability. The run-permit system was changed such that the ion source and modulator must be on for run-permit to be made. Also, modifications were made so that in all modes (except C-W-off mode) a command for the compensated-leg DVM reading drops the run-permit chain. This change will prevent the loading effect of the DVM instruments from interfering with operational beams or inducing arc-downs in the injector.

Unit 14, which contains the calibration network of the input to the slow stabilizer, was rebuilt and calibrated. The oscillator-modulator chassis was modified to accept an external oscillator module which has been fabricated and is currently under test. This is a continuation of the effort to synchronize the 5-kHz drive voltage to the 60-Hz line frequency. This module has functioned without fault for several weeks and will be permanently installed in this generator.

Vacuum Systems

Work was carried on to complete the system for startup of linac operation. Beam apertures, valves, and other hardware were installed and leak-checked. A large roughing bypass pumping line was designed and installed in the EM3 region for faster pump-down. This bypass line was necessitated by the incorporation of several fixed apertures in the final section of the transport beam line. Work is progressing on the large stationary roughing system for pumping the transport area.

VI. ELECTRONIC INSTRUMENTATION AND COMPUTER SYSTEMS

The activities reported in this section relate to the computer control system for the LAMPF accelerator and experimental areas and to the computerized data-acquisition systems being developed to support the program of experimental physics.

Accelerator Control and Instrumentation Systems

Data-Acquisition System

Each remote data-terminal (RICE) throughout the accelerator and experimental area is electrically coupled to the control computer interface unit (RIU) by a pulse-code-modulated, serial-data transmitter and receiver. Experience has shown that the present receivers are critical in adjustment and tend to exhibit long-term tune drifts, which cause an ever increasing error rate on data transmission.

A new receiver technique has been incorporated into a prototype data receiver and installed into seven data terminals along the accelerator. Companion receivers were installed in the RIU for test purposes. As predicted, the receivers were easy to adjust and required no special terminations because of line length or quality differences in the transmission lines. Testing will continue over the next quarter prior to changeover in every data terminal and RIU. A total of 80 receiver pairs, at a cost of $48.00 per receiver, will be involved in the changeover. Installation of the new receiver will be accomplished during one maintenance period of the facility.

CAMAC Data Links

Communications between the central control computer and several satellite processors in remote areas of the facility are accomplished through CAMAC-based data-link modules.

A microcomputer controlled data link (reported on last quarter) was completed and will undergo test and evaluation next quarter. The module, which will cost approximately $1500 to produce, will contain the control and communications algorithms necessary to handle link traffic between two separate computer systems. The previous data-link design required each computer to control every data-link action, thereby creating a large software overhead. Initially, the microcontrolled link will be used in central control, thus freeing the control computer of a heavy software burden in communications with five satellite processors.

Software developments for the microcomputer data link and initial checkout will be accomplished through a cross-assembler and cross-compiler operating on the Laboratory's 6600 KRONOS timeshare system, and a Control Logic development system configured to replace the link internal processor by direct wire connection.

Master Timer

Projected operational requirements for a facility with three ion sources and experience with experimental area timing needs have dictated a fresh look at the existing Master Timer.

A new Master Timer, constructed in standard modular packages, will allow for future expansion as required by operational needs. It is estimated that 4-6 man months will be required to settle on, design, fabricate, and check out the timer.

The first attempt at compiling a set of specifications for the new Master Timer succeeded only in eliciting a new class of requirements involving pulse-to-pulse programming of the beam. These requirements were similar to those met by the timing system at the Stanford Linear Accelerator Center. A visit to SLAC helped crystallize some ideas. A new attempt at a set of specifications will be made next quarter, and their implications on the hardware design will be studied.

Central Control

Control Computer

The SEL-840MP system was operational throughout the quarter for system and application program development except for scheduled interruptions to modify and upgrade the computer hardware.

The installation of the new hardware for saving and restoring registers was completed. Software diagnostics and hardware documentation were completed.

Work continued on the second multidisk controller with the aid of the SEL-810A computer used in an off-line mode. Disk-controller maintenance has been greatly simplified through the use of the offline computer.

A back-up CAMAC crate controller for the control computer was completed and tested. The CAMAC system interfaced to the 840 has provided a computer-independent means for coupling satellite processors into the control computer via CAMAC data-link modules.

Training sessions were conducted on CCR computer and related systems and on microprocessor design techniques.

Control Consoles

The CCTV scan converter was repaired and returned to service. The new patch panels for the CCR CCTV system are 50% complete. The second CCR console was retrofitted with a new communications system.

Development of the third console and a new generation of man-machine interface devices hinges on the IEC/IEEE ASCII Interface Bus. The CAMAC microcomputer bus-controller design was completed last quarter, and fabrication of a prototype module was initiated. Testing of the device and software developments for the microcomputer will take place next quarter.

Initial design of the new Function Button panel to be connected to the ASCII bus was completed along with the state machine necessary to couple the panel, through a microcomputer, to the ASCII bus. The controller, together with the prototype Function Button panel, will provide the means to evaluate the entire concept of standard bus interfacing of console devices. The system will find use in other control areas in the LAMPF Experimental Area.

A PDP-11/20 mainframe was allocated to the CCR development laboratory for equipment development and testing. The computer is interfaced to a scaled-down CAMAC crate and a teletypewriter with paper tape input/output capability.

Information Display System

The hardware and software for write-through cursors and joysticks on the Tektronix 611 console displays were installed and made operational.

Computer System Software

The work on system software tapered off significantly as compared to the previous quarter as more effort was put into applications programs. The following work was done:

1. The software which controls the assignment of the Tektronix 611 displays was modified to permit a single program to be assigned to different displays on different consoles. Additional modifications were made to permit the assignment of displays at new consoles, in particular, the remote console at HRS.
2. Software was provided to facilitate the accumulation of data, especially that resulting from accelerator-development experiments, on magnetic tape.
3. The SEL-840 color-display handler was modified to support remote displays operated on other computers connected to the 840 by data links.
4. A system subroutine which converts a hardware channel number to operator designator was provided.
5. The FORTRAN input/output package was modified to accept 6-bit truncated ASCII formats.
6. The system facility for controlling the access of remote consoles to accelerator command channels was tested with the remote console at HRS. The protection scheme appears to be working satisfactorily.
7. The interface to the system program which corrects errors in disk reservations and assignments was made simpler and more foolproof.

Accelerator Applications Programs

The magnet tables and the standard channel tables were corrected so as to give identical values in engineering units as far as possible. An audit program was written to check the internal consistency of entries in the magnet tables.

The fast-protect programs were modified to reflect changes made in the hardware during the shutdown. At the same time, a data base was set up to permit operations personnel to modify the list of channels used in the analysis and display of fast-protect faults.

Checkout of the new version of the magnet-setting program proceeded to the point that a magnet in Line D, interfaced via a serial CAMAC system to a Modcomp II computer and data link to the SEL-840 computer, was controlled properly. The console-knob portion of the program was modified so that a knob can make compensating adjustments in the bypass shunts of magnets in a string when controlling a magnet with no shunt. Checkout of this system continues to be paced by hardware availability.

A new version of the arcdown recovery program was written to make the software correspond with recent changes in the hardware. Checkout of this program also awaits hardware availability.

An option to permit the exercise and test program to read timed analog data was provided. Improved operator controls and a capability for restoring tested channels to their original settings, whatever the mode of termination of the test, were also added.

The new wirescan program for handling fast-wire scanners and Line D wire scanners was checked as far as the hardware would permit. Checkout is estimated to be 90% complete. Certain features requested by users of the program, including a retrace option and scale-factor control, were also added.

An initial implementation of the core of the control vector software was completed. Design work was initiated on a translator which would permit convenient entry of information into the control vector tables.

Design of the data structure for the accelerator device displays was completed, and programs were written to do the management of the data. Collection of the information to be contained in the data base was begun.

An initial version of a program to control the new strippers was designed, written, and checked out.

Experimental Area Controls and Instrumentation

Communications

Work is nearly complete on an extension of the LAMPF Communications System into Area A Hot Cells, WNR Beam Tunnel, and HRS. A modification to the Area A Public Address system is 90% complete.

Switchyard

Checkout of components of the Fast-Wire-Scan System (FWSS) was completed along with the initial testing of the central control and satellite PDP-11/10 software. All system wiring was completed and tested. Final system testing will occur during the next quarter when the linear actuators and FWSS signal amplifiers are installed. This system will provide rapid updating of beam-profile information for operations personnel in the CCR.

Other activities in the SY involved the design, installation, and checkout of controls for various new systems or modifications to controls of existing systems. Three pairs of steering magnets were added, one was deleted, and two were moved. Power supplies for the new magnets were built and installed. Two quadrupole doublet magnets were added and a triplet was removed. Radiation-resistant wiring was installed on the leading bending magnets in the SY. The shunt on magnet LX-BM-02 was removed.

One vacuum valve was added to the SY vacuum system and a second was rewired. An ion pump was moved. Two turbo pumps were added in association with valves LA-SV-07 and -08. Additional instrumentation was added to the SY water systems.

Two strippers were added in former harp locations along Line A. Five strippers were moved. Two halo scrapers were added.

Two beam stops were added—one in Line A, the other in Line X. Both were instrumented with six Chromel/Alumel temperature transducers. A two-out-of-three logic interlock on temperature and flow was added to the Line A graphite beam stop. Several modifications were made in the SY Run-Permit system.

It appears that all of the required installations and modifications to the SY instrumentation will be completed and checked out by the time beam is delivered to the SY.

Area A

Work continued on upgrading the harp system. The testing and repair of existing cables was completed. Fabrication of cables for the new harps will begin soon; this work requires the joining of m.i. and RG-174/U cables and the attaching of ceramic harp connectors. Locations for all of the T-boxes were designated; placement will begin when the shielding has been stacked. The required duct work is being installed as fast as the shield-stacking allows. The rack for the multiplexers on the north side of the shield is ready for installation.

Several burn-out protection systems reported last quarter have received attention. The transmission monitor was specified in terms of hardware and software. Design work was initiated on the Watch-Dog Timer module which will reside in the Area A CAMAC installation. Conceptual design of the magnet-current monitor system was begun. An order was placed for two digital panel meters to begin a study of the shunt amplifiers. The cabling requirements for the Secondary Emission Guard Ring system were defined; fabrication of the cables will start soon. The cable system for the Beam-On-Target monitoring system was specified, and the necessary 2-kV m.i. coax was procured. Fabrication of the cables will start soon although the cables cannot be installed until the shield-stacking permits.

Three 12-channel temperature readout systems for the shielding thermocouples were installed. The amplifiers for all 36 channels were tested and calibrated. Thermocouple locations in the shielding have yet to be specified. Design work was completed on the system to monitor with thermocouples the temperature in the collimators. The amplifiers and associated over-temperature trip circuits are being fabricated. When the pc boards are delivered, they will be installed in the seven bins mounted in various racks in the experimental area.

Wiring books were given to the electricians for the A-2 target collimator for P^3, the A-4 vacuum valves, and the vacuum-controlled water valves. The cables to the A-3 steering magnet were installed and connected to the magnet. One of three Harvey Boxes was wired, and work on the second box is nearing completion. The rack and junction box for the data-acquisition terminal in the Isotope Production Area were delivered by the vendor. All of the pressure transducers for the X0 water system were received and installed in the SY.

EPICS

Work on the controls and instrumentation for EPICS continued toward the goal of supporting the α-particle test. The RSX-11D operating system was installed on the EPICS computer and is now the primary system in use on that machine. The general data-acquisition program was made operational on the system and will be used for the beam-line test.

Drawings and wirelists were prepared for connecting the magnet shunts. Modifications to the magnet-control program were begun so that strings of magnets can be set using these shunts. Design was started on a more sophisticated magnet-control package modeled after the magnet-control software in CCR. Thermal switches were installed on magnet BM-01 and checked. The wiring between BM-07 and its power supply was completed.

Systems drawings for the NMR system were completed. The cables for the system were constructed and installed. Two of four NMR probe multiplexer chassis were received. One probe was made to work in its final configuration. A program was written to control the NMR probes in the beam-line magnets.

Schematics of the wiring for control of the EPICS separator were prepared. Installation of the cables is 50% complete. Two racks were installed to hold the separator controls. Drawings of the rack layout were completed and the separator interlock chassis was installed. A design was completed for a device to detect sparks resulting from a soft vacuum.

Numerous other tasks were completed. Two more four-jaw systems were tested. A test channel for the DVMs was installed. Several problems with the multipole magnets were solved. The overcurrent protection chassis for these magnets was tested and a design deficiency was corrected. The pull-up-resistor modification to the CAMAC binary data modules was checked. The 24-V distribution system in the control racks was reworked and documented. The EPICS channel list was updated.

LEP

The LEP devices which will be in a radiation environment were rewired with radiation-resistant cables. The interlocks, collimators, and modified beam plug were checked with the newly installed wiring. Cables were added for the vacuum valves and associated pressure switches. The channel list was updated to reflect the changes.

P^3

The changes to the wiring and controls for the P^3 line were documented. The channel list was updated to conform to the standard format for CAMAC channels.

SMC

The work on this line was related mainly to the installation of radiation-hardened wiring on the magnets at the beginning of the line, and to preparations for major changes in the power-supply regulators during the coming months. The cables which were rerouted to prevent radiation damage were dressed for connection to radiation-hardened wiring. The interlocks on magnets BM-02, QM-02, QM-05, and QM-06 were revised. The power supplies were reconnected to shunts on the magnets instead of to shunts internal to the power supplies. Controls were added for a new magnet. The layout of modules in the CAMAC crate was revised in anticipation of the new power-supply regulators.

Test Channel

The interlock system protecting all the magnets was checked.

Area B/C

A variety of devices received attention along Lines B and C (LB and LC). Two steering magnets were added to LB. Power supplies were built and installed for these two magnets plus three others already located in LB. Two isolating vacuum valves were added to the EPB line. Six television phosphor actuator controls were added to LB and EPB. One set of stripper controls was removed from LB. Several modifications were made to the Run-Permit system along LB and EPB. Controls were installed for the trombone for the nuclear chemistry target. The cables associated with the LC portion of the taut-wire system were installed.

HRS

The software for interpreting plotting commands intended for CCR-611 displays and for Tektronix 4010s was written and checked.

A keyboard handler which permits a Tektronix 4010 keyboard to be used with either the 4010 display or the Kinetic Systems color display was completed. A handler for the console knobs and shaft encoders was written and is ready for checking.

The bin of controls for the spectrometer magnet BM-01 was revised. Additional cables were installed for the TOF signals. Cables were provided in Aisle D for an NMR test stand.

WNR

The Line D control system prototype Serial CAMAC System was installed with commercial SCCs and a LAMPF-designed-and-constructed Serial Driver. The Modcomp II computer, together with a CAMAC System Crate and data link to CCR, is undergoing test and development.

During the initial tests of LINE D leading to the WNR area, the kicker magnet will be energized by a pulsed-power system. Controls for this power supply were installed and checked. As a back-up to the pulsed system, controls for a dc power supply were also installed and tested. The associated interconnections to the chopper in the Injector Area were made.

Limit switches were installed on the beam plug, and the device was installed along with its control wiring. The bending magnets LD-BM-01-2 were connected into the accelerator control system. The devices which are fundamental to the safety in Line D were connected to the Run-Permit and fast-protect systems.

Experimental Area Data-Acquisition Systems

Experimental Area Computers

The remainder of the equipment for the upgrading of the Terminal Computer arrived and was installed. This system now consists of a PDP-11/45 with 64k words of core memory, 1.2M-word RK03 disk drive, 2.4M-word IMS disk drive, card reader, line printer, paper-tape unit, DEC-tape unit, two DEC seven-track magnetic-tape units, two DECwriters, a Tektronix 4010, and an MBD Model-2 CAMAC branch driver. Its intended use is for software development in support of experiments, for quick-look data analysis and data-tape checking, and for utility work such as storage-media conversion. As presently configured, it can support three simultaneous users when running RSX-11D.

Procurement was initiated for two additional data-acquisition computers. These machines will be PDP-11/45s with 64k of core, capable of running under RSX-11D.

Distribution kits for RSX-11M arrived, and the system was installed on one of the data-acquisition PDP-11/20s. This system should provide a large degree of software compatibility with the RSX-11D systems running on the PDP-11/45s.

Procurement of an additional 8k of NOVA memory and a nine-track magnetic tape unit was initiated for the NOVA computer system being used for neutrino experiments.

Data-Acquisition Software

The nucleus of the general data-acquisition software system was made operational under RSX-11D during this reporting period. The major, currently operational components consist of the simplest class of MBD code, the I/O handler, the event-description translator, the MBD-loading and start-up processor, operator control modules, core histogramming, and plotting of total histograms with automatic scaling.

The data-acquisition program requires a special event-trigger module. Four such modules have been constructed to date. Usage of the prototype and discussions with potential users of the program suggested a valuable new feature which was added to the module. It can now use crate LAMs to generate event triggers and can return a graded-L word to the crate controller.

Work on making the data-acquisition software operational under RSX-11M has begun. The I/O handler and the core histogramming task have been rewritten for this system and are ready for checkout.

Interface Hardware

A temporary CAMAC readout for the CCR Knob and Readout Panel was designed and fabricated for the HRS control room.

The multichannel harp reset module was modified to reject 120-pps beam-gate information and to respond to every other gate (60 pps). Beam gates below 120 pps are accepted. Equipment reset is then synchronized to a specific zero crossing of the power mains for noise-rejection purposes.

The design of a CAMAC interface for the Fabri-Tek Model 1074 signal-averaging unit was started last quarter. The signal-averaging device will be utilized in a LAMPF experiment in conjunction with other data-acquisition devices and a LAMPF Data-Acquisition Computer System.

Nuclear Instrumentation

A remotely switched, nanosecond delay box was specified and released for bid to several nuclear instrumentation manufacturers.

A power-control-unit design was modified to handle ±6V dc, in addition to the ±24V dc and ±12V dc. The device is used in control of NIM bin power for experimental installations.

Work began on a fast but inexpensive multichannel pulse discriminator for particle physics.

Electronics support was provided to numerous experimenters in preparation for beam in the experimental area, and commencement of the physics program.

LAMPF Electronics and Equipment Pool

Equipment purchases for FY-76 were initiated during the last quarter. Approximately $90k has been committed for electronics equipment needed by physicists for the next series of experiments at LAMPF.

Purchase requests now specify IC sockets, as well as documentation dealing with test and calibration procedures in order that equipment repair can be more rapidly and easily effected.

All LEEP NIM bins were modified to include a bin gate distributed to each station.

Users may now request a 16-hit capability on LAMPF MWPC encoders as the result of work done this quarter.

The development of programs was continued for testing CAMAC modules using a digital computer. The procedures are written in the BASIC language and are executed on a NOVA computer.

Miscellaneous

Sharing of LAMPF Technology

A member of the staff attended the International Purdue Workshop on industrial computer control and contributed in subgroup meetings on Human Factors Engineering. Two members of the staff attended the NIM/CAMAC working group meetings on hardware and software. Both the Purdue and NIM/CAMAC organizations represent an internationally recognized effort in equipment and systems standardization.

VII. ACCELERATOR OPERATIONS

Upgrading of the facility continued throughout the entire quarter. The injectors and drift-tube linac were started up on a rotating-shift basis on July 21. As expected after so long a shutdown and after so much rework, numerous difficulties were encountered. There was progress, however, and low-duty H^+ beams were accelerated to 100 MeV by the end of the quarter.

Operating crews continued to assist with numerous developmental and support activities, participating in bead-pull measurements and check-out of rf-amplifier, cooling-water, and vacuum systems. Quadrupole magnets and bypass shunts were checked throughout the accelerator, with numerous faults found and repaired. The 201-MHz cavities were conditioned, phase shifters were calibrated, and run-permissive interlocks were checked. Instrumentation and control wiring for all of the new beam-diagnostic gear in the 201-MHz area was installed and checked out.

Modification of personnel safety systems in the switchyard and Areas B and C was completed, and a personnel safety system was installed on the WNR line. Documentation of existing safety systems was updated.

Analog data systems throughout the accelerator were checked, repaired, and calibrated. These systems are now being maintained to provide raw data accurate to 0.3% of full scale, a factor of 4 improvement over their previous performance.

Closed-circuit television systems were maintained and catalogued. Additional television equipment was obtained from government surplus and was made operational. Radiation-hardened television cameras were installed to look at the low-momentum component phosphors in the SY.

The experimental area current-monitoring system has been extensively revised and expanded. New current monitors have been added in Lines X and A. Voltage-to-frequency converters have been installed at many current-monitoring stations, providing a capability for improved accuracy in measuring average and integrated beam currents. At several locations (Line B, Area A, and Area A-East), circuitry has been installed that uses the beam-current signals to provide a relay closure when the beam is on. This closure can be used to provide audible and visible "beam on" indications.

A current-monitor calibration system was designed, built, and installed. This system provides three different calibration pulses, each going to different portions of the machine and experimental areas, matching operating conditions for H^+ and H^- beams. All three pulses can be monitored and compared on a CCR oscilloscope. Time-and-amplitude dimensions of these calibration pulses are under CCR program control.

The current monitor system for the accelerator was completely redesigned and rebuilt. This included rewinding 48 toroids and potting them in epoxy to minimize vibrational noise pickup. The associated electronic circuitry was also redesigned and repackaged to provide more uniform and reliable data throughout the machine.

VIII. EXPERIMENTAL AREAS

Experimental Area Operations

Criteria studies have been carried out for an Experimental Area Operations Office to replace the temporary quarters in the computer terminal building. Space requirements and equipment layouts have been prepared to support a request for a leased building to be installed at the south side of Area A.

A remote computer terminal to monitor the major service systems and experimental setups has been received and tested. With this terminal interfaced with the CCR computer and with closed-circuit video units to monitor any special situations, the Area Manager's Office will be able to maintain an effective vigil on critical experimental area systems.

The staff shop is in good working condition. A Bridgeport Mill and a South Bend Lathe have been added to the operating equipment. The tool crib has been enlarged and fully stocked. A senior technician has been added to the staff to take charge of the operation of the machine shop and tool crib, and to provide expert support and assistance to all users of the staff shop.

Water Systems

Modifications are being made to the radioactive cooling-water systems to improve their operation. The basic pump/heat exchanger packages have been modified on the X03, X04, and X06 systems to improve the alignment of the pump and the supports of the system. Major changes include lowering the suction line, installing centering devices for the pumps, and anchoring the support frame in the pits. A larger motor was installed on the X03 pump. Modifications of the X05 system have started and should be completed early next quarter.

Extensive modifications and additions are being made in the valve caves along Line A. Valve plugs and seat assemblies in the supply lines have been replaced in all but two caves. Flowmeters have been installed in all return lines. Strainers have been installed in the supply lines of four caves. Remote valve mechanisms are installed in all areas where caves will be covered with shielding.

Fabrication is continuing on three nonradioactive process water packages. On two of these, to serve the HRS and EPICS, heat-exchanger fabrication has been completed and assembly of the units is under way. Final completion is expected in September. The third system being fabricated is a semiportable unit that will serve experimental setups in Area A.

Cryogenics

A new CTI-1022 refrigerator has been purchased for Exp. 96, and a new LH_2 target-flask system was designed for that experiment. New flasks are also being designed for Exps. 99 and 144. A new vacuum chamber has been designed and is being built for the LH_2 target for Exp. 176.

The target for Exp. 2 has been checked and some leaks have been found. Repairs are in progress.

An Air Products 10-W/20-K refrigerator has been obtained as a demonstrator, and performance tests are being made.

Final designs are nearly complete for a ventilation system for Exp. 90 which uses tritium. Modular components which can be used for enclosing cryogenic target systems on the experimental floor have been purchased. Additional hydrogen gas-detection equipment for the experimental areas has also been purchased.

A visit was made to LBL and SLAC to look at target systems and discuss safety and operating problems.

Main Beam Lines

Switchyard

An extensive realignment of the switchyard has taken place, including the new Line D to WNR. All front-end components are in place, with the exception of the three fast-wire scanners, and the line has been under vacuum; final leak-checking has not been completed. The two turbo-molecular pumps intended to provide the vacuum gradient from target cell A-1 are installed, as is the insertable vacuum window (mounted in a valve gate). The 1.25×10^5 kg movable shield door that provides truck access to the switchyard has been assembled and checked out.

Two new water-cooled beam stops have been installed on Line A and Line X. Preliminary Monte Carlo radiation transport studies have been initiated, modeling the graphite beam stop in Line A. Using the codes NMTC (**N**ucleon-**M**eson **T**ransport **C**ode) and MCN (**M**onte **C**arlo - **N**eutrons), escaping particle spectra for neutrons and protons have been calculated for 800-MeV incident protons. Additional statistics and more specific analysis of the escaping spectra characteristics will be necessary before conclusions can be made.

Switchyard Beam Optics

Beam optics studies have continued. The final switchyard stripper configuration has sufficient flexibility to permit tuning of the switchyard front end for optimum Line A conditions. A new tune was therefore calculated to meet the ideal Line A requirements, which are: 1) superposition of the stripped H^- phase space onto the H^+ phase space, and 2) emittance matching into the 2.8π-cm-mrad acceptance of Line A.

The corresponding new tune of the Line X output quads was easily recomputed. The new magnet values are being installed in MAGSET for start-up operations.

An analysis showed that the emittance of Line X should be measurable on the three wire scanners past the Line X output quads, provided the profiles are of good quality. Tuning plans for Line X have been formulated using these measurements. For this purpose, as well as for Line A tuning, a programming project was initiated on the CCR computer to provide emittance computation from any three or four wire scanners in a drift space.

The Line X optics were also studied with respect to admittance ($\sim\pi/2$ cm-mrad), stability requirements on the magnets (better than 1% on the quadrupoles), and chromatic aberrations (non-negligible).

In further studies of Line X optics, a set of stripper sizes were chosen for the phase-space tailoring in Line X. The stripper sizes allow preparation of beams with transverse phase spaces limited to $\pi/3$ and $\pi/10$ cm-mrad, and a "zero" phase-space beam. Specifications were given for a Stripper Control Program. The Stripper Control Program will include a complete catalog of all stripper foils available in Lines A, X, and B. A display can be called that will give the status of all the strippers. An operator in the CCR can control each stripper to pick the desired hole size and then to make some small position adjustments in the case of the disc-type strippers. The same program will operate both disc-type and curtain-type strippers.

A tune-up procedure for Line X has been established with an initial set of magnet fields determined for production runs in Lines C and B. The stripper sizes and tune-up procedure for producing a zero-phase-space beam in Line X for Line C tuneup were established.

A brief study of a possible Line X spectrometer mode of operation was made. The nominal tune for Line X operation gives a momentum resolution of 0.061% for a $\pi/3$ cm-mrad beam at LX-WS-07. This is quite adequate for all the uses of a Line X spectrometer proposed at this time. At LX-WS-01, the resolution is 1%, which is $\sim$15 MeV/c at 800 MeV. This is equivalent to about one module of the accelerator. Possible steering errors do not contribute significantly to the calculated centroid shifts of the beam spot at LX-WS-01, which are $\sim$0.5 cm for a 1% momentum shift at 800 MeV. If the wire scanners can measure centroids to 0.1 cm, then momentum shifts of $\sim$20% of one module at 800 MeV are observable. No further studies are planned on the Line X spectrometer at this time.

Line B Optics

Line B optics were studied to seek an improved tune and to evaluate new quadrupole arrangements. The line can be tuned to give approximately the right spot size and small dispersion at either of the two principal target locations, but requires retuning for change of target station. In addition, the line acceptance is marginal and the tunes appear to be very touchy, an observation backed up by past operations.

Instrumentation

Assembly is continuing on fast-wire scanners, harps, and strippers. Final assembly of the switchyard wire scanners is in progress. Most parts for the Line A 300-mm-diam harps are on hand, and three card assemblies (on ceramic substrates) have been strung with carbon wires. The m.i. cable preparation for the leads through the shielding from the main beam line has been completed, and application of the connectors and RG-174 extensions has been started.

Two curtain-type strippers for the front end of Line A have been assembled. Aluminum foil has been used for initial installation, and the mating edges have been made slightly concave to ensure that the first opening appears at the center of the stripper aperture.

Studies are continuing of ceramic materials for harp boards, and of techniques for applying circuit overlays to them, especially in large sizes (0.5 × 0.5 m).

Line A Harps

The entire Line A harp system has finally taken shape. The use of ribbons was abandoned because of the difficulty in obtaining the springs required to counteract beam-induced heat sag. It was decided to use a number of carbon wires instead. A method of applying copper plate to the carbon wires was developed. This made it a simple matter to solder the carbon wires to the ceramic board. In addition, a way to spot-weld a carbon wire to the stainless-steel collection voltage planes was found. Once these techniques were developed, the construction of the harps proceeded without too many problems. The first six harps were completed on time; the remaining eight are also expected to be finished on schedule.

The harp prototype electronics have also proceeded without too much difficulty. Amplifiers for one harp will be ready for testing in September.

Extensive tests were conducted on the carbon wire which is being used for the harps. The wire was heated in a vacuum bell jar, and studies were made using an optical pyrometer and optical transit. The coefficient of thermal expansion, the creep rate as a function of temperature, and Young's Modulus were measured. These measurements allowed us to determine the amount of prestressing that was needed on the harps in order to prevent sagging under high-current beam conditions.

Investigations of secondary emission characteristics for a number of materials were carried out at the LASL Van de Graaff. The puzzling results that were obtained previously are now believed to be due to secondary emission from the collector electrode cancelling out some of the secondary emission from the primary electrode. Applying high voltage suppressed this cancellation. It is anticipated that more tests on SEM characteristics will be performed when the switchyard becomes operational.

Another task completed this quarter was cable testing. All 1000 harp cables were tested for continuity and cable resistance. Those that had a resistance less than 10^{10} Ω were replaced.

Secondary Beam Lines

Work to prepare the P^3, SMC, and LEP secondary beam lines for high-intensity beam operation has continued. In addition, with the plan to start experimental operations in Area B before Area A, increased effort has been put into preparing Area B for beam. The most significant accomplishments are:

1. Checkout, installation, calibration, and alignment of the upstream horizontal and vertical adjustable jaws for P^3 are complete.

2. The four 4-jaw collimators in LEP have been reinstalled and realigned. Calibration is complete.

3. The entire SMC vacuum system, including the pump package and isolation valve, has been installed; reworking of the vacuum boxes in BM-02 and BM-04 was required to complete this task. Vacuum window problems appear to have been resolved.

4. The upstream components of LEP, P^3, and SMC have been modified for maintenance and replacement by remote-handling methods. These components are now fully radiation hardened.

5. Alignment checks of P^3, SMC, and LEP upstream ends are complete.

6. More "canyon fill" special shielding has been designed and installed for the beam lines. Final installation awaits k-seal installation and electrical checkout of magnets.

7. K-seal installation is proceeding on all three lines. Trouble has been encountered with k-seal surface coating, flange warping, and clamp assembly. These problems are being worked out.

8. LEP has been completely recabled (both dc magnet cabling and interlock cabling) to facilitate improvements in the shielding.

9. Final bulk-shielding designs and covers for LEP, SMC, and P^3 and the test channel have been worked out.

10. The revised Line B beam-stop shielding has been designed and partially installed.

11. Work has progressed in preparing Line B for beam, including vacuum installation (MP-11), instrumentation and controls (MP-1), and some realignment (MP-8). Modifications on the nuclear chemistry irradiation station (CNC-11) and the LD_2 target (P-DOR and Q-26) in Area B have begun.

12. Some support is being rendered to Area B experimenters to help them get ready for beam, especially the direct lepton production experiment (Exp. 241).

Calculations of a different tune for the SMC have been under way throughout this period. At the third bend, the results appear to be a factor of 2 better than previous attempts. The transport of this beam through the remainder of the channel is currently under study.

Checks have been made of the alignment of the magnets in the SMC, and no significant discrepancies were found. An effort is under way to standardize the nomenclature and wiring for the channel components.

In addition to the above accomplishments, work is progressing in preparation for testing and running the SMC-East beam (formerly called the SMC parasite beam). It is expected to provide an intense beam of muons and pions, and there is considerable interest in the possibility that it will be useful for bent-crystal-spectrometer experiments. The final configuration will involve adding two large-aperture (35 cm) quadrupoles and installing a new vacuum box with a large exit window at the beginning of the new beam leg. Until these tasks can be completed, an interim configuration will utilize the existing vacuum box and two existing quadrupoles (with 20- and 30-cm apertures). Cave layouts are being worked out, and beam plugs are being designed.

Three new power supplies for SMC magnets have been procured and are being made ready for use in the channel.

Magnets

All the new and modified SY magnets are in place and operable. New steering magnets have been provided in Lines X, B, and EPB, to give more flexibility in the tuning of these lines. The power-supply installation for the two new Line X quadrupoles is nearing completion. In addition, all SY magnets were checked out for polarity and operation of their interlocks and warning lights.

In Area A, radiation-hardened jumpers, and their supports, have been fabricated for all three triplet quadrupoles in target cells A-1 and A-2. The rad-hard wiring for two of these magnets has been installed, and for the third is 80% complete.

The lead pieces for halo shields in the bores of the Line A quadrupoles have been cast and machined, and installation has begun. Water-leak detectors are being fitted to all these target-cell magnets, since visual observation will not be possible.

Field measurements have been made on a Line D magnet, the first two bending magnets from the Biomed line, and the last quadrupole in the Biomed line *in situ* . In this last case, the interaction with its upstream neighbors, and the effect of the final field clamp, were of interest.

Polarized Proton Target Development

Through the findings from many shakedown experimental runs, the following minor but essential alterations were made which significantly improved the performance of the Roubeau section of the prototype cryostat:

1. A 1.2-liter L^4He reservoir replaced the original 15-cm^3-size reservoir.
2. Stainless stand-offs were used for mounting resistance thermometers in the separator.
3. The radiation shielding was improved by use of super-insulation in the vacuum spaces.
4. The vacuum gap between the LN_2 radiation shield and the condenser plate was increased.
5. The defective L^4He flexible transfer line was replaced by a rigid transfer line of correct dimensions.
6. The pumping speed of the L^4He system was increased to 0.142 m^3/s STP by inserting a Roots blower in series with the forepump.

After these modifications, the condenser plate showed a satisfactory heat load of $\sim$ 1.5 W with the ^3He space near room temperature. The average consumption rate of liquid helium is now $\sim$ 9 ℓ/h including cool-down, which is commensurate with the expected performance. The operation of the cryostat is still hampered by the existing ^4He pumping speed of only $\sim$0.142 m^3/s. The coldest temperature of the condenser plate was found to be $\sim$2.5 K whereas 1.4 K or less would be far more desirable. After the 0.944-m^3/s pump arrives in October 1975, it is expected that lower condenser-plate temperatures should result.

The first attempt to condense ^3He at this condenser-plate temperature resulted in a non-recoverable loss of 25 STP liters of ^3He gas. This loss was caused by a freakish defect in an 800-mm absolute-pressure gauge used to monitor the pressure of the condensing ^3He. No leak was detectable when the ^3He pressure was less than 700 mm, but a leak occurred rapidly above 700 mm, simulating the ^3He condensation process. At present there is not enough ^3He gas on hand to operate the cryostat at the higher condenser-plate temperature. Even with the condenser plate at 1.4 K, the remaining supply of ^3He will be only marginally sufficient; a replenishing of ^3He gas would therefore seem to be necessary if the polarized target work is to proceed as planned.

The NMR rig was tested by electronic means and found to be functioning. However, a full test of the NMR system must be made at cryogenic temperatures in a 2.5-T magnetic field. Further investigation must therefore wait for the integration of the cryostat with the magnet.

A microwave stabilization and frequency measurement program has been started. Various components are now being checked out and assembled into the final configuration by a summer graduate student; this work cannot be completed before his departure.

Modification of the gap width of the Varian magnet (for transverse polarization) awaits the delivery of the new pole caps and the fabrication of soft-iron pole pieces. The cryostat for the superconducting solenoid (for longitudinal polarization) is in its final stages of assembly, but the testing of this cryostat will be delayed because of a shortage of manpower.

Radiation-Effects and Isotope-Production Facility

Stringers have been fitted to all of the positions in both the isotope-production and the radiation-effects parts of the facility. Filling of the stringers with shielding (grout or lead) is proceeding. The lead reflector for the radiation-effects cavity below the main beam stop is ready for installation, and shielding is being stacked around the south stringer housing as fast as modifications to the beam line, collimator, and beam stop itself allow.

The revised plumbing is in, with the exception of remote operators for some valves—these will shut off the isotope-production stringer water in the event that a leak is detected.

Designs for the isotope-production stringer drive, transfer cart drive, and for the paved pad north of the facility to ease handling of stringers, are all available.

Remote-Handling Systems

Merrimac

Installation work and general improvements are continuing on Merrimac, the mobile, self-propelled hot cell intended for target-cell and beam-stop maintenance at the highest activation levels.

Special cables have been made up for the installation of the new control chassis and television system. The TV cameras to be mounted on the Merrimac B52 wheel units have just arrived. These will be used to relay visual information to the operator, i.e., steering angles, oleo heights, guide lines, etc.

All the shield plugs have been taken from the roof of the Merrimac box and are being sandblasted and painted. A jib crane intended for use on top of the Merrimac box for lifting plugs, etc., has arrived, and some design modifications for it are under review.

Monitor

Monitor, the trailer-mounted boom/manipulator system intended for general beam-line repair and maintenance, was taken for its first outing (July 31), and the occasion was used to check out the work performed the previous month.

1. The 3.2 kg of steel ballast added to the rear of the trailer proved exactly correct for stability of the system in three active modes. These are: 1) when Monitor is towed by a vehicle, 2) when Monitor is being lifted by a crane, and 3) when Monitor is operating with wheels retracted and boom at maximum extension.

2. The hydraulic system for the wheels is now functioning well, and the tow bar can be easily attached to a vehicle trailer hitch. "Nose weight" can be trimmed by extending or retracting the boom.

3. The four movements commanded by the remote control are working reliably, and some trimming work is under way to make them smoother.

4. The self-leveling system for the PAR-150 manipulator works well at any angle of elevation or declination of the Monitor boom. A resonance problem where a certain extension of the Monitor boom had a natural frequency identical to the mercury switches has been cured.

5. The various cables permitting the whole system to be operated from 40 m away are connected and stored on the trailer. A 12-V battery and charging system has been installed on the trailer for the remote control and television pan, tilt, illumination, and zoom lens circuits.

6. The PAR-150 manipulator gives minor troubles, and these have been sufficient for us to think of transferring the manipulator-control cabinet from its present place on the Monitor trailer to a position near the control station so that troubleshooting can be carried out (in operational conditions) away from the radiation zone. This would mean a more complex control station, and will make quick deployment more difficult. This step, and other methods to improve the reliability of the PAR-150, are under active consideration.

7. A further problem is the nonuniformity of phase corrections and sockets in the 440-V service in various locations. In certain circumstances, this could represent a safety hazard.

Work will now start on the television system (using the "stem" telescopic units) and the scheme to place the Area A crane under remote control.

Shielding

The major design effort for the massive shielding in the experimental areas has been completed. Detailing of envelopes and cutting drawings for steel pieces are being completed.

At target station A-1 in Experimental Area A, all designs, detailing, and fabrication of the bulk shielding has been finished. The large horizontal shield plug box for the EPICS separator access is assembled on the final track system. Movement and fit of the plug box has been tested, along with the positioning of the upper shield cover. The steel boxes for the Merrimac doors above A-1 have been fabricated and delivered, along with the strongbacks that tie them together. Specifications and drawings for installation of these doors have been made. Some canyon fill and in-cell steel shielding have been installed, mostly around the LEP line and at the front end of EPICS. Most of the fill around the hardware must wait until components are fully checked out.

The mass shielding, separate from the Merrimac doors, has been completed from A-1 to A-2. At target station A-2, the Merrimac door parts have been fabricated and delivered. Considerable beam-line canyon fill and some in-cell fill has been installed at A-2, both along the P^3 and SMC lines. Installation of the balance of steel shielding in these channels and the target cell will be made when beam-line components are ready.

Extensive reworking of the shielding at Target Station A-5 has been carried out. Much of this was due to relocation of major components of the main beam line and replacement of temporary shielding at the upper level of the Biomed beam line. Much of the original material has been removed and, where needed, recut to new configuration. As hardware is installed, the final shielding masses are being placed.

At the Line A beam stop, considerable steel shielding was removed to take out the beam-stop hardware. The material below the beam line has been reinstalled. The shielding directly around the beam-stop components is being installed as the hardware goes in. Considerable shielding has been fabricated and installed in the isotope-production area, particularly along the south stringer housing near the beam stop.

The installation of steel shielding around the water tank beam stop is the major Great Shutdown shielding job for Area B. Design and fabrication have been completed and installation has started. Included are steel and lead masses at the sides, downstream, and above the water tank.

Other major shielding work presently under way includes the fabrication of the removable ways above EPICS and LEP, and the assembly and installation of the Merrimac doors at A-1 and A-2. Additional shielding material needed for the experimental area is on hand. The latest acquisition was 8.4×10^5 kg of steel, mostly in 5.4×10^4-kg pieces, received from the Carnegie-Mellon NRC facility.

High-Intensity Modification Program

As of July 24, 1975, the PERT system contained 450 work packages that need to be accomplished before beam can be put into Area A and A-East. This is a reduction of 150 activities (25%) during the seven weeks since June 5. The manpower requirements are now 40 500 man-hours; a reduction of 18 000 (31%).

An examination of critical paths indicates a possibility of first beam by October 17, 1975, and this has become the new goal. However, an extrapolation of PERT experience to date, especially in manpower utilization and the rate of removal of PERT activities, predicts completion a month or so later. The longest paths are through the EPICS channel and target-cell component installations.

The PERT networks depicting the work required for completion of the in-cell main-beam-line components are being completely redrawn. The new networks will be used as an aid in the day-to-day direction of installation activities. The total number of activities in PERT will be increased considerably as ~ 400 detailed activities will replace ~ 100 coarser activities. Hopefully, estimates of critical path lengths and manpower requirements for the revised PERT will not change.

IX. LARGE-SPECTROMETER SYSTEMS

Energetic Pion Channel and Spectrometer

Magnet Construction

The four EPICS channel magnets, 1P-BM-01 through 1P-BM-04, and the separator box were installed and aligned. Vacuum tests were made of the seals between the separator box and the adjacent magnets, and all leaks were corrected. Installation of the remaining components is under way with completion of the channel planned for late August.

Progress on construction of the spectrometer has been slow because most of the available manpower has been tied up working on the channel hardware. The vacuum chamber for EA-BM-05 was leak checked and several leaks were found in the welds. Correction of these leaks has been delayed by the need to complete the flange welds required for the channel. One of the coils for EA-BM-05 was repaired successfully. The second coil was damaged during the attempted repair, and a water leak occurred in the termination section. We believe that the damage can be repaired; however, a spare coil is being ordered as a precautionary measure.

Magnet Measuring, Shimming, and Analysis

Multipole magnets 1P-FM-02 and 1P-FM-03 were delivered by the Univ. of Colorado group. Magnet 1P-FM-02 was mapped and found to be essentially identical to 1P-FM-01. The mapping of 1P-FM-03 is awaiting termination of the m.i. conductors.

The α-particle test data from 1P-BM-02 was analyzed, and satisfactory agreement with ray tracing using the field map was obtained. An α-particle test of 1P-BM-03 was also completed. Satisfactory agreement with tracing in this case was not obtained. It is likely that the difficulty resulted from the helical chamber used in these tests, since the various runs at different momenta were internally inconsistent. Because it was necessary to tear down the setup to install 1P-BM-03 in the channel, this problem will have to be resolved during the α test of the whole beam line.

The final maps at 18 kG were completed for BM-02 and BM-03. This completed a full set of maps at six different field strengths in all four channel magnets. The mapping equipment required considerable modification for making maps of the spectrometer magnets. These modifications are now substantially complete. Considerable work remains in defining mapper alignment procedures, and in modifying the computer codes used to take and analyze map data.

Taut-Wire System

During this past summer, 60 taut-wire-sensing units were assembled and delivered to EPICS for use on the channel magnets. These sensors now include additional fixed wires for calibration purposes. Experiments were conducted to demonstrate that the calibration wires can be used to correct taut-wire readings for any voltage shifts due to the electronic readout circuits. Several modifications were also made to the sensors to improve their range and stability. Final assembly of six taut wires for the EPICS channel is now under way, and installation and testing of the system should be completed in August.

Channel Controls

Three levels of computer programs for control of all of the devices comprising EPICS are being written. The lowest level of controls consists of short codes which issue commands to only one or two CAMAC modules. These general codes have been written and are available in the RSX-11D operating system. The intermediate level of controls programs combines all of the CAMAC functions associated with a particular device. Such codes have been written for the four-jaw slits, the multipole magnets, the beam plug, the NMRs, and the magnet power supplies. These codes are intended for use in the checkout of devices and cabling between the devices, control racks, and counting house.

The third level of controls programs is that which would be used in actual operation of the channel. These codes are more detailed in the actual operation of devices. For example, the four-jaw code will update a disk file which keeps track of the current position of each jaw. It will also move the jaws in a manner which eliminates position errors caused by backlash in the mechanical system. The requirements for these codes are being defined.

Calibrations of position vs potentiometer reading have been completed for FJ-01, FJ-02, and FJ-05. Current vs shunt-voltage calibrations have been made for FM-01 and FM-02.

Particle Separator

The new vacuum box for the separator was delivered. Some rework was needed to allow the old lid to mate to the new box and achieve a good vacuum seal. Alignment measurements have been made with the new box, which is now installed in the line.

Several new components for the hv system have been fabricated and are ready for installation and testing. The controls for the C-W power supply are being extensively modified to allow more convenient operation and troubleshooting. At the same time, the controls are being made compatible with computer control and the more complete interlock and safety systems required for routine operation. Early operation of the separator will be done manually, with computer-controlled operation not expected this year.

High-Resolution Proton Spectrometer

Area C

The staging area in Aisle D has been completed so that we now have a hand-operated, 3000-kg chain hoist available over an area of ~3 × 6 m with a height capacity of more than 4.5 m. The cryogenic target for Exp. 4, the Line C multipole, and the scattering chamber, are currently being assembled in this area.

The HRS shop area at the end of Aisle D has also been installed and has proved most useful. Besides the usual odd jobs, the Line C multipole was fabricated there, and the HRS multipole and Line C taut-wire-support system is being done there.

The scattering chamber is now being assembled in the staging area. Based on a number of discussions, several design changes are being made. All of the basic hardware is either on hand or in the final stages of machining. One of the major uncertainties here is the curtain retractor mechanism which we hope to test in September. Target elevation, rotation and table hardware, and electronics have been assembled and will be installed and tested after the initial trial assembly and testing in September.

The design of the particle-identification system has been finalized and all electronics are available with the exception of the remote delay boxes. The detector frames, scintillation and Cerenkov counters, as well as phototubes and bases, are on hand and being assembled. We expect to test the complete system with the first beam to Area C this fall. In addition, all tests on the BNL MWPC system have been favorable from the standpoint of noise levels which have been observed so that we expect to test the complete HRS data-acquisition setup before the rigging of the dipoles in November. This will be done remotely from CCH with essentially the final controls and readout system so that any modifications can be implemented during the rigging period.

Area C Counting House

Data-link communications are now possible between the PDPs 11/45 and 11/10 or the 11/45 and the LAMPF operations SEL-840 computer.

The remote CCI interface has been completed, and programs that run on the 840 can write on the character scope at CCH and can be interacted with through a keyboard which can be connected to either a 4010 or the character scope. Assignment of the keyboard to either device is under software control. Remote plotting is also possible, and programs running in the 840 can request that plots be done on the 4010s at CCH. Knob hardware and software have been developed and are ready to be checked out.

As a result, we now have the basics of the first fully remote, CAMAC-driven console with a completely independent computer control and data-acquisition system. It is a "friendly" system in that most of the intercommunication between computers is transparent to the user, making it quite simple to use.

Beam Line C

The basic support structure for the taut-wire pickups has been designed, and the prototype system is being installed on LC-BM-03. The complete system upstream of the Line C shield wall will be installed before first beam is run into the line after the shutdown. Essentially all of the hardware and electronics for the complete system is now in hand with the exception of some cabling at the end of the beam line.

The supplies LC-MP-01/02 are in final form, and the new transductors for the quad supplies, together with the modifications to the safety lights and personnel safety system, are being installed. With the calibration of these magnets and installation of the taut-wire system, Line C will have been completed. Initial beam tests of the line will consist of determining the resolution and checking the optimization software. This should begin with the first available beam in the fall.

The analyzing section, consisting of the two 57° dipoles, has been optimized so that the EFB agrees with design to $\sim 2 \times 10^{-5}$ from 4-15 kG with systematic offset errors of $\sim 1 \times 10^{-4}$; H_t currents were needed to obtain about a factor of 5 improvement at the higher fields. The highest current in any of these windings, however, was ~35 A. The new NMRs have been installed in these magnets and are being checked out.

In this same area, the Line C multipole magnet has been designed, built, and measured with good results. The magnet is capable of producing any multipole field up to tenth order with a field of 200 G at 10.0 cm from the centerline. It will be powered with essentially the same system of power supplies and regulators as used with the H_t windings. This magnet, together with the H_ts, essentially assures achieving the design resolution for the beam line.

Status of HRS 75° Dipoles

The major effort on the spectrometer dipoles HS-BM-01 and -02, and reassembly of HS-BM-01 reported last quarter, has been to adjust the remaining mechanical and electromagnetic characteristics for optimal field behavior. Specifically, we have concentrated on minimizing that fraction of the difference between design and measured virtual field boundaries which is caused by the homogeneous region of the magnet. Most of the remaining fraction (caused by the fringe fields) will be corrected by machining the nosepieces of the field clamps.

The significance of our results rests upon the assumption that median-plane-line integrals, along arcs of constant radius, determine the limiting optics of the system. We have attempted to make the distribution of these integrals uniform as a function of the primary field setting. To accomplish this, we have carried out the following operations, with the following results:

1) Shimming the leg pieces separating the yoke blocks (1010 steel shims) by amounts calculated from the average slopes of the line-integral distributions has removed the coarse radial gradients in the field distributions. The resulting fine structure of the field distributions was then 1-2 $\times$ 10^{-4}. In addition, the envelope of the fine structure varied with field by an amount 1-2 $\times$ 10^{-4}, which was roughly equivalent to its variation at any one field.

2) A series of measurements of the differential motion between opposing yoke sections of the magnet were made as a function of field excitation. These measurements indicated a correlation between the yoke motion and the shape changes of the fine structure as a function of the primary field setting. Varying the torque on the through-bolts (which hold the yoke structure together) produced a maximum effect of $2{:}10^5$ on the fine structure, but only at the extreme radii for the allowable torque on these bolts. Accordingly, a series of welded tabs were attached across all mating interfaces. Subsequent field measurements showed a significant reduction ($\gtrsim 1 \times 10^{-4}$) in the variation of the fine structure with field excitation.

3) Varying the torque on the tie-bolts (which hold the poles to the yoke) produced effects as large as $1{:}10^4$ on the resulting fine structure. However, in order to cancel out this structure, a significant fraction of the tie-bolts had to be loosened. Subsequent measurements under real conditions, i.e., vacuum loading of the poles, showed a loss of much that had been gained because of the additional pole motion under vacuum. This motion can be adequately constrained with acceptable torques on these bolts but with virtually no freedom left for variation such as required here.

4) Three tie-bolts were then added (which amounts to drilling 2.5-cm-diam holes through 56 cm of steel) near a crucial region where other tie-bolts had to be loosened. The subsequent field measurements indicated that the number of additional tie-bolts required to simultaneously remove the fine structure and control the differential pole motion under vacuum was large enough to discourage this enterprise.

5) A symmetric-pair, pole-face shim was designed using the 14-kG field distribution obtained for HS-BM-02. A removable, leaf-spring-loaded crate was designed and constructed to hold the pair of shims against the poles. After one iteration in the shim shape, a 14-kG field distribution, flat to $\pm 2 \times 10^{-5}$ was achieved. Subsequent measurements at 4 kG and 10 kG were not as good at the inner and outer radii, but were reasonably flat ($\lesssim 1 \times 10^{-4}$) in the center region.

Measurements are still in progress on magnet HS-BM-01. To date, we have completed the leg shimming and the tab operations on both dipoles leaving only item (5) to be done on HS-BM-01.

Remaining items to be studied that influence the homogeneous field results are magnet-cycling procedures (rates, flat-top times, and overshoots) and the use of H_t excitations. For higher resolution experiments, there is some optimism that the H_t coils will prove useful. Primarily, this follows from the improved field uniformity which allows a reduction in the magnitude of the expected currents by a factor of $\simeq 15$ from those for previous attempts which means that the nonlinearity of the system is significantly reduced. Moreover, a method exists by which the integral distributions can be easily converted to an equivalent current distribution for the H_t coils (a test calculation has indicated a peak H_t current of 26 A for HS-BM-02 at 14 kG). The usefulness of the H_t coils is that they provide the possibility of a dynamic shim which is effectively spread over the entire azimuth of the magnet. While this is generally better than a fixed shim, it is also more time-consuming to set up. We have mechanically shimmed at 14 kG, since a worsening of resolution with a decrease in momentum is often acceptable. A multipole magnet HS-MU-01 currently being fabricated will be used in a similar way as the H_t currents as well as to effectively induce field-boundary curvatures on HS-BM-01/02.

The field curvatures, through fourth order, will be induced through the nosepieces on the field clamps. Pole-tip curvatures at all four boundaries were machined as simple radii whose magnitudes were specified by minimizing certain of the transfer coefficients. Subsequent ray-tracing runs with optimization searches (MOTOR) have yielded better solutions with only second-order curvatures. Generally, we have not been able to improve the resolution by more than ~25% with the addition of higher order curvature. The nosepieces for all magnets are currently in the shop for final machining.

Insofar as other hardware developments for these magnets are concerned, we have installed the new NMRs in HS-BM-02 and run them remotely from CCH in their final configuration. This system represents a significant improvement over the old one in many respects—including the use of rad-hard reliable probes. We have also achieved full vacuum in both dipoles several times subsequent to their reassembly and operation. Vacuum and field loading of the poles has been measured and shown to yield an acceptable amount of compression of the 0-rings well inside their elastic limits. With the addition of the tabs, we now feel that these magnets will be ready for mounting as soon as the field clamps are optimized. The date for this operation is November 1, based on preliminary discussions with the rigging company.

X. RESEARCH

Tests, Data Runs, and Analyses of Experiments

Total Pion Cross Sections (Exp. 2) (Univ. of Montana, Univ. of Washington, New Mexico State Univ., LASL, Univ. of Basel, Stanford Univ.)

The major effort in the past months of the personnel associated with total pion-nucleus cross-section measurements has been to prepare for the data run which begins after the Great Shutdown. Preliminary results from the first run were reported at the VI International Conference on High Energy Physics and Nuclear Structure.

Since a transmission experiment depends largely on beam conditions remaining constant between target in-and-out measurements, several improvements have been made which are intended to reduce any systematic errors. These improvements include a beam-intensity monitor which will investigate the steadiness of the beam on a macropulse level. A computer-controlled target mechanism which will allow rapid cycling of target in-and-out measurements has been constructed. It operates most easily with normal targets, but a special actuator-driven support is being constructed to have this capability with cryogenic helium and holmium targets.

Other improvements to the apparatus include: 1) a counter, capable of rejecting events, which consists of two particles coming within a given time spread; 2) a smaller and thinner transmission stack which is appropriate for measurements near 20-MeV pion energy; and 3) a program of our data-analysis routines on the 6600-KRONOS remote terminal which will permit the analysis of scaler data in the counting house, with quick turn around.

Two other changes which are under way rely heavily on development work by other MP groups: our data-acquisition program is being rewritten to take advantage of the features of the program Q; the MWPCs are being changed to have delay-line readout, which eliminates the problem of adjusting an amplifier per wire and the need for a complicated encoder.

Nuclear Structure Physics Using Stopped Muons (Exp. 7) (LASL, Purdue Univ.)

The preliminary muonic x-ray data on ^{192}Os, ^{194}Pt, ^{195}Pt, and ^{196}Pt that were obtained just before the big shutdown of LAMPF have been analyzed in terms of a deformed charged distribution of the nuclear ground state. For the even-even isotopes, the mixing of muonic states and excited nuclear states has been taken into account on the basis of the rigid rotor model, which seems to be a fair approximation for the 0^+, 2^+, and 4^+ levels of ^{192}Os, but less so for ^{194}Pt and ^{196}Pt, the latter nuclei displaying more vibrational aspects in their excited states.

In strongly deformed nuclei, the $2p \rightarrow 1s$ transition energies have distinguishing features for positive and negative intrinsic quadrupole moments Q_0. For example, the transition energies for ^{194} Pt can be satisfactorily fitted ($\chi^2 < 1$) for both $Q_0 < 0$ and $Q_0 > 0$; the data of ^{196}Pt seem to favor slightly $Q_0 < 0$ rather than $Q_0 > 0$, which is in agreement with coulomb reorientation effect data. No satisfactory fit has been obtained yet for the ^{192}Os data ($\chi^2 > 14$). Clearly a less model-oriented computer program is needed for a satisfactory analysis. A very general computer program is being developed at LASL that will allow us to compute the muonic spectra of any muonic atom by taking into account the mixing of muonic and nuclear states without resorting to a particular nuclear model. The input data for this program are the energies, the reduced electromagnetic nuclear transition matrix elements, and the diagonal nuclear multipole moments.

The muonic x-ray spectra of ^{195}Pt display strong effects of mixing of nuclear and muonic states, involving several excited nuclear states. The data have not yet been explained in terms of a consistent nuclear model. The single-particle core-coupling model of de Shalit, for example, does not explain all known data of the ^{195}Pt states. An attempt is in progress to explain the data on the basis of mixed "de Shalit states."

It should be noted that the above discussion concerns preliminary data on only a small subset of the targets planned for this study. Systematic studies of the transition region (platinum-osmium) will be completed during the next running period.

Elastic Scattering of π^+ from Deuterium (Exp. 34) (Univ. of Virginia, LASL)

We have continued to analyze data obtained for elastic scattering of π^+ on deuterium. The experiment has been described in previous progress reports. Briefly, pions from the P^3 beam were scattered from CD_2 and D_2O targets and detected in a magnet spectrometer. The recoil deuterons were also detected and identified with an $E-\Delta E$ system.

The trajectories of the scattered pion and recoil deuteron were measured with helical wound-wire proportional chambers. The data were normalized to an ion-chamber monitor calibrated against πp scattering, using the same apparatus with CH_2 and H_2O targets.

We have developed an analysis procedure that gives results consistent with the known πp cross sections to 10% or better at 350 MeV/c, and at 450 MeV/c for our πp data. We are just beginning the analysis at 550 MeV/c; so far it appears to be equally consistent. Our main uncertainty at the present time is the determination of the beam size, which in turn affects the solid angles calculated for the system using a Monte Carlo routine. We hope to improve on the 10% consistency by obtaining more accurate maps of the target plane by using specially chosen subsets of the data. These subsets will be chosen by using data to select those events in which the helical chambers are guaranteed to have worked well and have no contamination from noise or background. In addition, we will pick angles at which the mapping of the target is most accurate.

We still have not made corrections for pion decay, deuteron breakup, and nuclear interactions in the apparatus. These corrections should be <5% in most cases.

Cross sections at 350 MeV/c and 450 MeV/c are presented in Fig. X-1. We must emphasize that these cross sections are only preliminary and subject to corrections for improvements in the beam size, as well as other corrections mentioned above. The angle bins are about 6° wide (FWHM), and the data are taken with $\Delta p/ \cong \pm 4\%$. The error bars are only approximate representations of the errors.

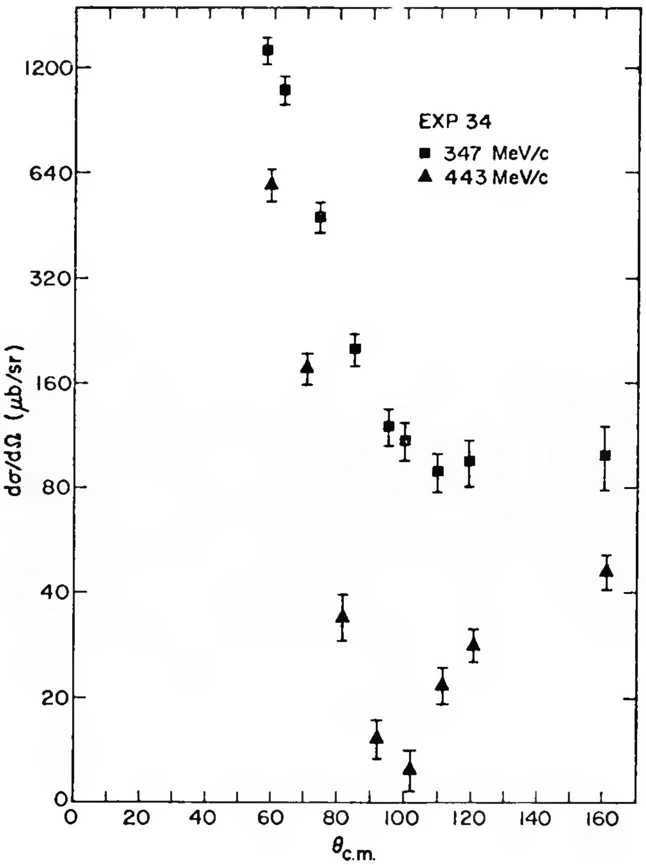


Fig. X-1.
Center-of-mass cross section for elastic scattering of π^+ on deuterium. The squares are at 347 MeV/c, and the crosses are at 443 MeV/c. Data are preliminary.

Medium - Energy Neutron Experiments at LAMPF (Exps. 56, 125, 129, and 205) (Texas A&M Univ., Univ. of Texas, Univ. of New Mexico, LASL)

The past quarter has generally been occupied with continuation of data analysis on these experiments. Further effort has gone into evaluation of events where more than one event registers in several of the MWPC planes. Under certain circumstances, corrections of 5% may be incurred if such events are not handled properly in the off-line computer programs. The analysis of data on the n-p differential cross section at 647 MeV (Exp. 125) is proceeding in a very satisfactory manner. We expect to have final data by the end of the summer covering the angular range 60 to 179° c.m. Concerning evaluation of neutron spectra from proton bombardment of light nuclei (Exp. 56), we are evaluating the normalizing quantity which relates to the n-p charge-exchange scattering: $\int (d\sigma/d\Omega)\varepsilon(\theta)d(\cos\theta)$, where $\varepsilon(\theta)$ is a geometrical efficiency function. The values of $(d\sigma/d\Omega)$n-p are being derived from examination of existing data. Analysis is almost complete on preliminary data of pion production in n-p collisions. Numerical estimates of pion-decay losses are being made by Monte Carlo methods. Analysis continues on neutron spectra associated with pion production in the process $n + p \rightarrow n + \pi^+ + p$. Attention has centered on certain normalization problems concerning data obtained at different currents of the spectrometer magnet. These data come under Exp. 56. Analysis has also continued on certain neutron spectra associated with Exp. 205.

Fabrication of the polarized target cryostat for Exp. 65 continues in the main shop. The important central pump-out cylinder assembly has not yet been welded, but we remain optimistic that we will have established vacuum integrity of this part and of the entire cryostat during the next quarter. The electromagnet has been put into operation and is now undergoing performance measurements.

Three papers were presented at the VI Intern. Conf. on High Energy Physics and Nuclear Structures: G. Glass, "Neutron Production at 0° from the Reaction pp → $np\pi^+$ at Medium Energies"; P. Riley, "(n-p), (n,d), and (n,t) Reactions on ^{9}Be and ^{12}C at 800 MeV"; and J. Simmons, "Some Topics Concerning N-N and N-D Experiments at Medium Energies."

Chemical Effects in μ^- Capture (Exp. 60) (LASL, Princeton Univ. Munich Tech. Univ., Washington State Univ.)

All of our muonic x-ray data obtained in 1974 have been analyzed, and our results are now being prepared for publication. The capture power data are summarized in the following figures (final results may change slightly from those given here). In Fig. X-2, the relative capture probability for metals in metal oxides (CaO, TiO_2, V_2O_5, Cr_2O_3, Y_2O_3, and CdO) is plotted against the atomic number of the metal. Our data qualitatively agree with the periodic variation reported by Zinov *et al.*[1] (solid curve); however, quantitative agreement is only fair. In Fig. X-3, we plot the relative capture power for metals in both metal oxides and metal chlorides divided by the Fermi-Teller Z-law ratio vs the electronegativity of the pure metal (as given by Pauling[2]) divided by the metal's atomic number. Thus,it seems that the periodic variation in capture power observed in Fig. X-2 is due primarily to a periodic variation in the electronegativity of the metal.

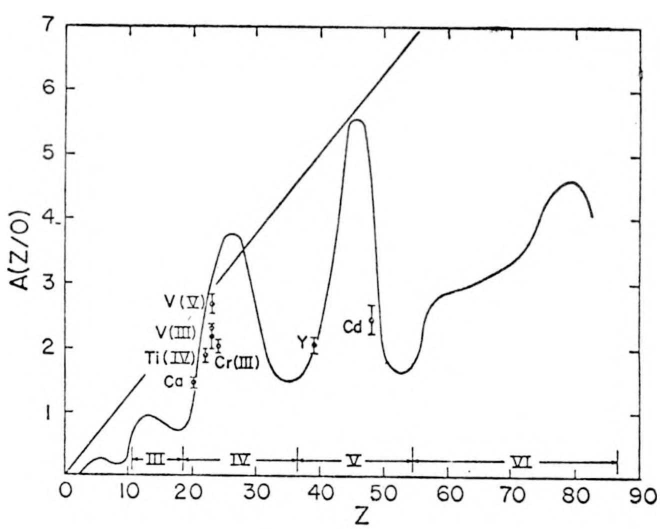


Fig. X-2.
Relative capture power per atom for metal oxides ($Z_m O_n$). The solid curve represents data of Zinov et al.[1]

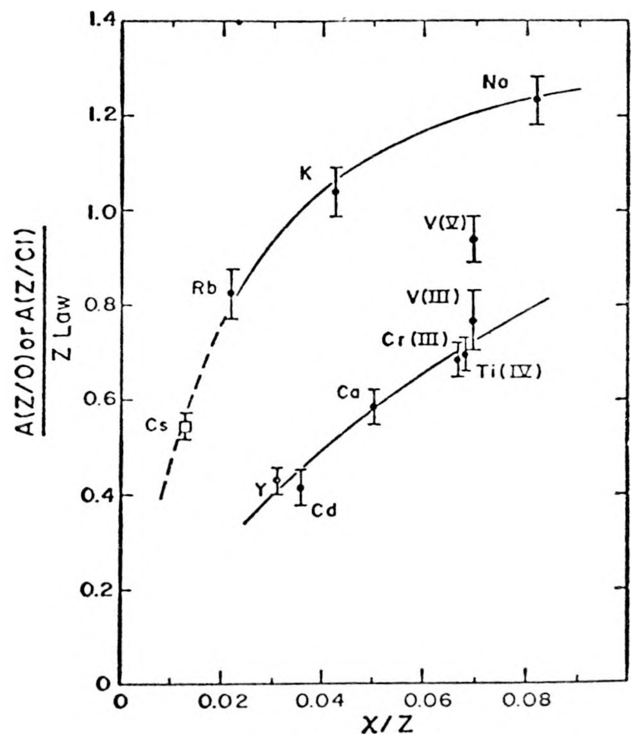


Fig. X-3.
Electronegativity dependence of relative capture power per atom for metal oxides and chlorides. The CsCl point is from Bobrov et al.[3] *The solid curves are drawn to aid the eye and have no physical significance.*

The capture fraction for simple chloride salts (solid) is illustrated in Fig. X-4. On this graph, curves are drawn depicting the expected results based on the Fermi-Teller Z-law and the square root of the Z-law, which, inexplicably, follow the data rather well. Figure X-5 refers to the capture power of ions in solution (normalized to 2M concentration) relative to oxygen in water. Only the ionic K_α line is used since higher lines were not consistently present. In general, the relative capture power of an ion in solution, as well as that of its oppositely charged ionic partner, is independent of concentration.

No significant differences were observed between the diamond and graphitic forms of both carbon and boron nitride. The relative capture ratio W(B)/W(N) was found to be about one-third of the Z-law prediction. For a series of organic molecules—$CO(NH_2)_2$, $CH_3(C_6H_4)NO_2$, $C\ell(C_6H_4)NO_2$—relative capture ratios were close to the Z-law predictions; however, systematic differences seem to be present.

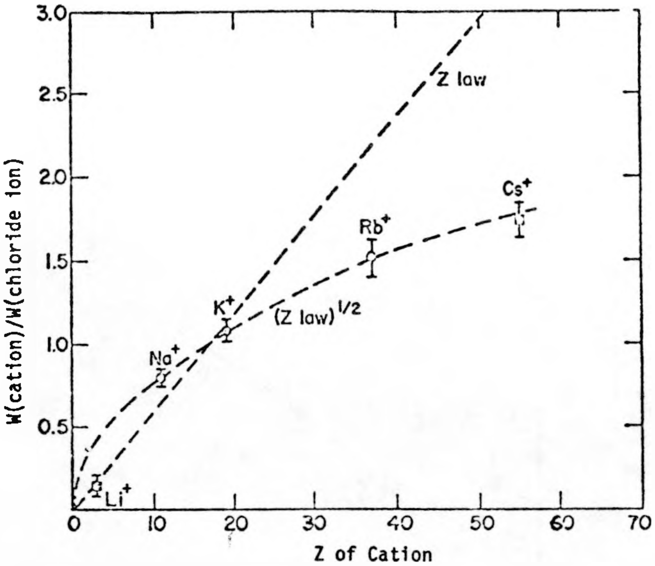


Fig. X-4.
Capture ratios for some simple chloride salts. The Cs^+ and Li^+ points are from Bobrov et al.[3]

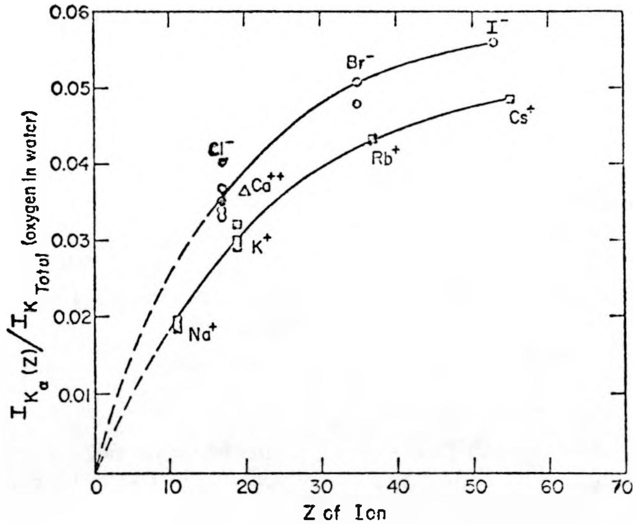


Fig. X-5.
Capture power relative to oxygen in water of ions in aqueous solution, normalized to 2M concentration.

Data on specific line intensities are too lengthy to present in this report, but will appear in publication. This data may be summarized as follows: 1) for metal oxides, both the metal and oxygen lines follow a periodic variation such as is illustrated in Fig. X-2; 2) for carbon, the muonic intensity patterns, broadly speaking, divide into two groups, one characterized by diamond and graphite, and the other by polyethylene and organic molecules; and 3) for nitrogen, a similar division as that described for carbon occurs, though not as strong, with regard to boron nitride and organic molecules.

Gamma Spectra from Pion- and Proton-Induced Reactions (Exp. 62/121)
(Utah State Univ., Univ. of Texas, LASL, Florida State Univ., Coll. of William and Mary, ANL, Iowa State Univ.)

Analysis of the data and dissemination of the results have continued. A paper on the systematics of pair and proton interactions with M and a comment on the $\pi^{\pm}$-Ca cross sections have been submitted to Physical Review Letters. Papers on these and related subjects have been given at the Santa Fe meeting and at a Gordon conference.

Forward Elastic Scattering of π^+ and π^- from ^{12}C, ^{16}O, ^{40}Ca, and ^{208}Pb (Exp. 80)
(Rice Univ., Univ. of Houston, Washington Univ.)

Preliminary analysis of the small-angle elastic-scattering data of Exp. 80 is now complete. Differential cross sections have been obtained for ^{40}Ca at 204, 174, 145, and 88 MeV, while cross sections for ^{12}C and ^{208}Pb were obtained at 145 and 88 MeV. In order to ascertain α, the ratio of $\mathrm{Re}f_n(0^0)/\mathrm{Im}f_n(0^0)$, the data are fit with the theoretical model described by Binon *et al.*[4] This model assumes a phenomenological form for the pure nuclear amplitude f_n of

$$f_n = \frac{K}{4\pi}\,\sigma(i + \alpha)\,e^{\frac{-R_s^2|t|}{6}}$$

where σ is the total cross section, R_s is a strong-interaction radius that is varied to fit the data, and t is the momentum transfer. The total differential cross section is given by

$$\frac{d\sigma}{d\Omega} = \left| f_n\, e^{-2i\delta} + |f_c| \right|^2$$

where f_c is the π-nucleus coulomb amplitude and δ is the relative phase of the two amplitudes. The phase was originally derived by West and Yennie[5] for large s, small t scattering. In order to fit their $\pi^- - {}^{12}C$ data, Binon *et al*. modified the original form for f_n to read:

$$f_n' = f_n \, e^{\frac{-i\kappa|t|}{6}} .$$

This allows the overall phase to vary as a function of t. If we write $\delta = \phi_1 + i\phi_2$ then

$$\phi_1 = -\eta\left[2\,\ell n(\sin\theta/2) + C + \ell n(4p^2\rho) - \sum_n \frac{(|t|\rho)^n}{n\cdot n!}\cos(n\omega)\right],$$

$$\phi_2 = -\eta\left[\omega - \sum_n \frac{(|t|\rho)^n}{n\cdot n!}\sin(n\omega)\right],$$

where

$$\rho = \frac{1}{6}\sqrt{\left(R_s^2 + r_\pi^2 + r_c^2\right)^2 + \kappa^2} ,$$

$$\omega = \text{ton}^{-1}\left(\frac{\kappa}{R_s^2 + r_\pi^2 + r_c^2}\right),$$

$r\pi, r_c$ = coulomb form factor of pion, nucleus

$C = 0.5722$,

$$\eta = \frac{Z_1 Z_2 \alpha\left[s + (m^2 - M^2)\right]}{\left[s - (m+M)^2\right]^{1/2}\left[s - (m-M)^2\right]^{1/2}}$$

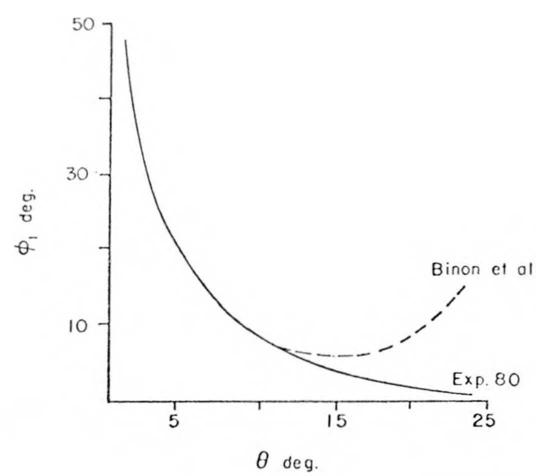
m, M = mass of pion, nucleus.

For large values of t, it is seen that the sum in the equation for ϕ_1 is divergent.

This model (with $\kappa = 0$) was originally used in fitting our small-angle data. The fits were not entirely satisfactory because theory and experiment differed significantly at large t. Careful analysis revealed that the small-t approximations used in calculating δ are not valid for calcium and lead. Starting with Eq. (23) of Ref. 5, an alternative calculation which does not depend upon $t << 1$ was developed. Any theoretical uncertainties in this calculation are due solely to the validity of Eq. (23). Figure X-6 is a graph of the new and old predictions of ϕ_1. The divergent behavior of the original method for large t is evident. The computer algorithm used in our calculation of ϕ is valid to 40° for calcium and lead at energies about the 3,3 resonance.

Proton-Deuteron Quasifree and Elastic Scattering at 800 MeV (Exp. 81) (Rice Univ., Univ. of Houston)

The analysis of the p-d and p-p data of Exp. 81 is at the stage where the final corrections are being made. The data will be analyzed one last time to include all known effects. The analysis of some of the neutron quasifree-scattering (QSF) data from the reaction ${}^2H(p,pn)p$ has been completed since the last report. The proton momentum spectrum is shown in Fig. X-7. The proton and neutron were each detected at 40° on opposite sides of the beam. The solid curve is the prediction of the spectator model using the Hulthén wave function. The geometrical smearing of the theory has been included by a Monte Carlo program. Also the deuteron D-state has been included. The deviation of the data for spectator momenta above 150 MeV/c is possibly due to difficulties in background subtraction, which is larger than in the case where two protons are



Fix. X-6.
Plot of $Re(\alpha) = \phi_1$ vs scattering angle θ for π^+-${}^{40}Ca$, $T = 174$.

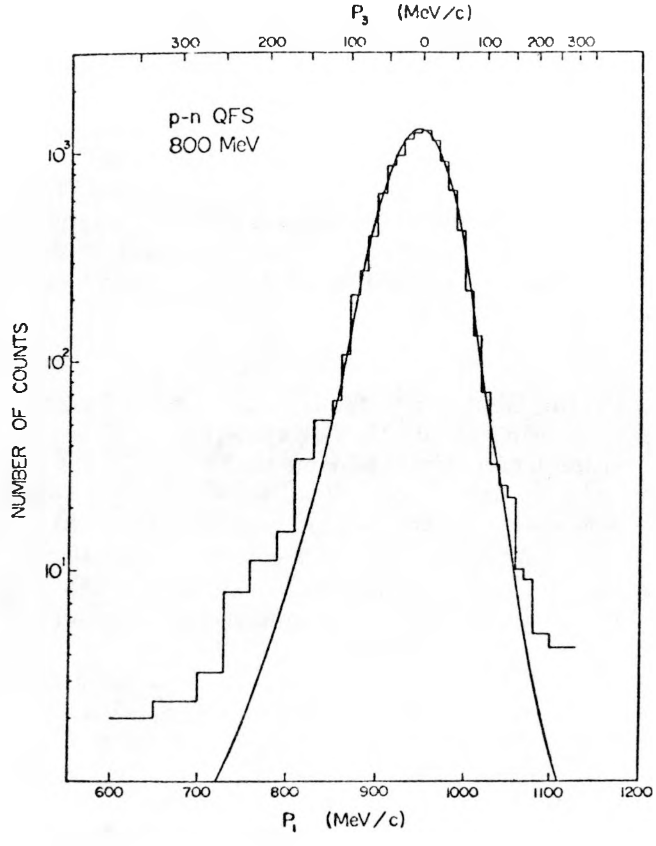


Fig. X-7.
Proton momentum for the reaction $^2H(p,pn)p$ at 800 MeV. The proton and neutron were detected at symmetrical angles of 40°. The spectator momentum (P_3) scale is shown at the top. The spectator model prediction is given by the solid line which includes geometrical smearing.

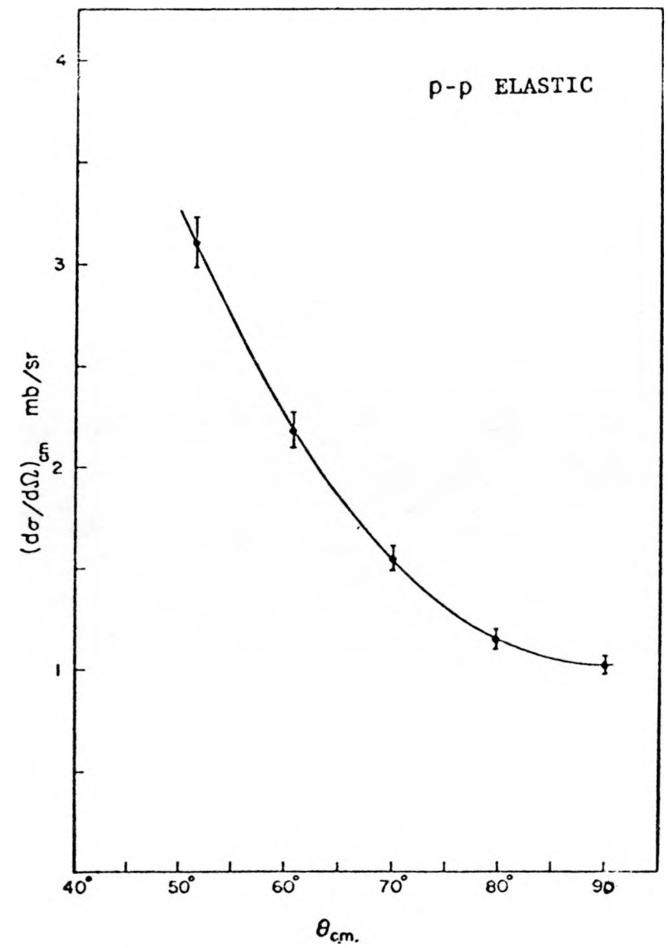


Fig. X-8.
Preliminary results of p-p elastic-scattering cross-section measurements at 800 MeV. The solid curve is a guide to the eye.

detected. This p-p QSF data is given in the last quarterly report.

Over a limited angular region we have detected both p-p and p-d elastic scattering. The p-p data is shown in Fig. X-8. It agrees well with the 800-MeV data of Case Western Reserve Univ. Figure X-9 gives the p-d elastic data along with previous results at 600 and 1000 MeV. These results are preliminary.

Fragment Production in the Interaction of 800-MeV Protons with Uranium (Exp. 86) (LASL, LBL, Texas A&M Univ., ORNL, BNL)

The energy spectra of boron-neon nuclides produced in the interaction of 800-MeV protons with a thin uranium target have been determined at 90° (lab) by means of a combination of dE/dx and TOF techniques with a silicon-detector telescope. The experiment was done in the LAMPF Thin Target Area at an average proton beam intensity of 10 μA. Fragment flight times were determined over the 25-cm distance between the ΔE and E detectors, and simultaneously over the 4.3-m distance from the target to the ΔE detector, utilizing the 201-MHz linac rf pulse as one of the timing signals. The nuclear charge (Z) of the fragments was determined from the dE/dx information, and the mass (A) of the fragments was determined from both the TOF and the energy information. The time resolution over the 25-cm flight path was 0.22 ns (FWHM), which corresponds to a mass resolution of 5.2% at mass 11 (see Fig. X-10). The time resolution over the 4.3-m flight path was 0.80 ns (FWHM), corresponding to a mass resolution of 1.1% at mass 11 (see Fig. X-11). A window was set on the calculated zero time of the latter

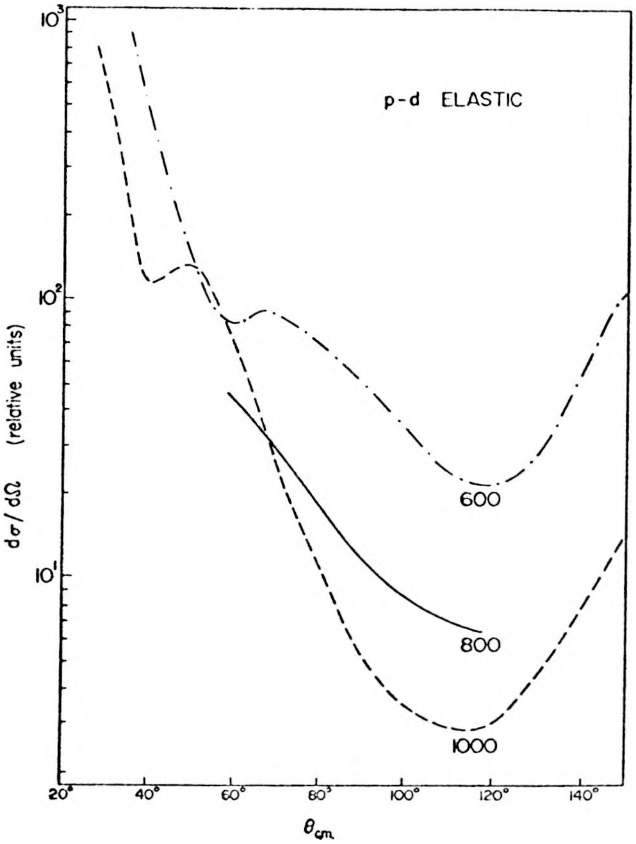


Fig. X-9.
Preliminary results of p-d elastic-scattering cross-section measurements at 800 MeV. Previous results at 600 MeV and 1000 MeV are included for comparison.

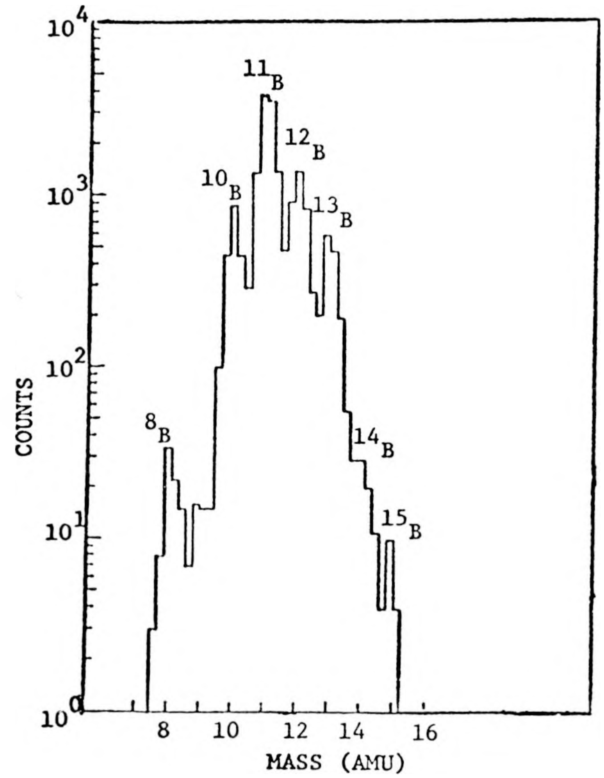


Fig. X-10.
Boron mass spectrum resulting from a TOF determination over a 25-cm flight path.

determination corresponding to full width at quarter maximum of 1.20 ns, and therefore the data in Fig. X-11 represents 74% of the data in Fig. X-10 above mass 9. Although the time resolution in Fig. X-11 was apparently limited by the time spread of the proton beam with respect to the rf signal, this successful test of our TOF equipment will enable us to extend our studies of high-energy nuclear reactions to those involving higher mass nuclear fragments.

Time-Reversal Invariance in Strong Interactions, and Elastic Scattering of Pions from Tritium and ^{3}He (Exp. 90)
(LBL, LASL, Univ. of California at Los Angeles, Univ. of Virginia)

Aspects of the apparatus for this experiment have been tested using only ^{3}He in the target. In preparation for the next exposure in the P^3 pion beam, development of the systems and safety features necessary for the introduction of tritium to the gas target cell has been pursued. The large MWPCs, which detect the ^{3}He ions and gammas of the final state of the reactions of interest, have been further studied at UCLA to improve their efficiency, and modifications have been started. The use of the magnetic spectrometer, as developed by the Univ. of Virginia group, for detection of small-angle elastic scattering, has continued to evolve as the most appropriate means to complete the coverage in elastic reactions. The collaboration with the Univ. of Virginia group has continued since the run of last December, and redesign and modification are under way of the target stand and spectrometer pivot to make them compatible in the best possible configuration.

Low-Energy π-p Elastic Scattering (Exp. 96)
(LASL, Arizona State Univ.)

Preparations are under way for the continuation of data-taking for $\pi^{\pm}p$ elastic-scattering differential cross sections from 30 to 90 MeV. The delay-line

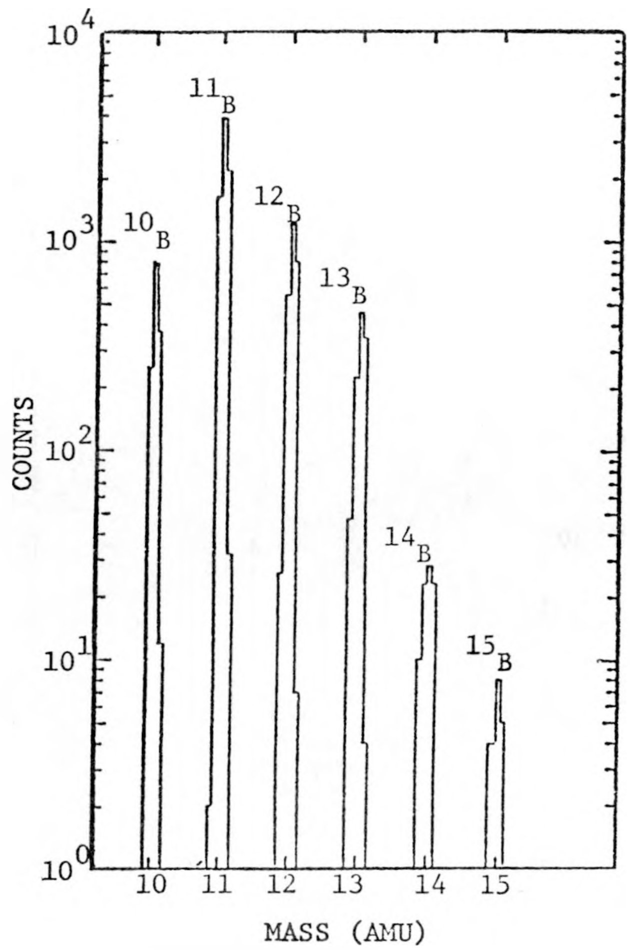


Fig. X-11.
Boron mass spectrum from the simultaneous TOF determination over a 4.3-m flight path. The accelerator rf signal was used as one of the timing signals.

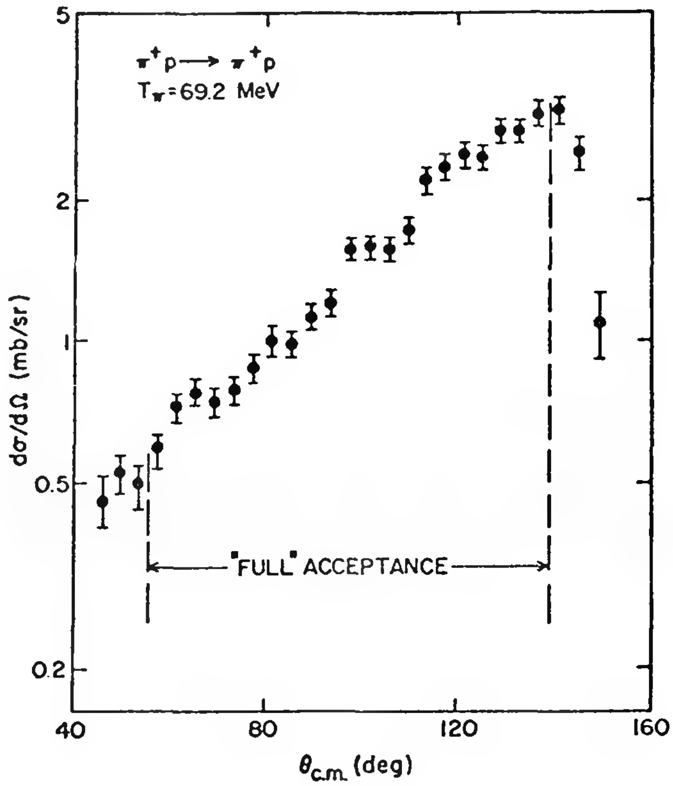


Fig. X-12.
Preliminary differential cross sections for 69-MeV $\pi^+p \to \pi^+p$.

MWPC readout system has been incorporated into a chamber and looks good. To further reduce the several percent correction which must be applied to the present data set because of multiple firings and chamber inefficiencies, four chambers, each with two orthogonal readout planes, will be used on each side of the target. New designs for the energy loss vs total energy scintillation counter systems are being studied. The target-temperature-sensing system is about ready for testing.

The data analysis of our previous run is proceeding. Figures X-12, X-13, and X-14 show some preliminary elastic differential cross sections. The error bars are presently dominated by Monte Carlo uncertainties. There is approximately a 10% uncertainty in normalization at present. Preliminary results of the experiment were presented at the VI Intern. Conf. on High Energy Physics and Nuclear Structure in a paper entitled, "The Elastic Scattering of Low-Energy Pions on Protons."

Measurement of the Cross Section for $\pi^- + p \to \pi^- + \pi^+ + n$ with a Magnetic Spectrometer (Exp. 99)
Colorado Coll., Univ. of Virginia, LASL, MIT, Univ. of Wyoming, LBL)

As we have described in previous reports, the data collected during a shakedown run of the spectrometer produced a useful measurement of $\pi^+ - {}^{12}C$ elastic-scattering cross sections. (Sample momentum spectra were shown last quarter.) They have also provided a useful shakedown of our data-analysis procedure. Preliminary results of our measurement are shown in Figs. X-15 and X-16. In both figures, absolute cross section is plotted as a function of angle. In Fig. X-15 we compare our results at 147 MeV with the $\pi^- - {}^{12}C$ data of Binon *et al*.[6] taken at 150 MeV. By plotting cross sections against c.m. angle, we reduce the kinematic difference between the two sets of data; they are

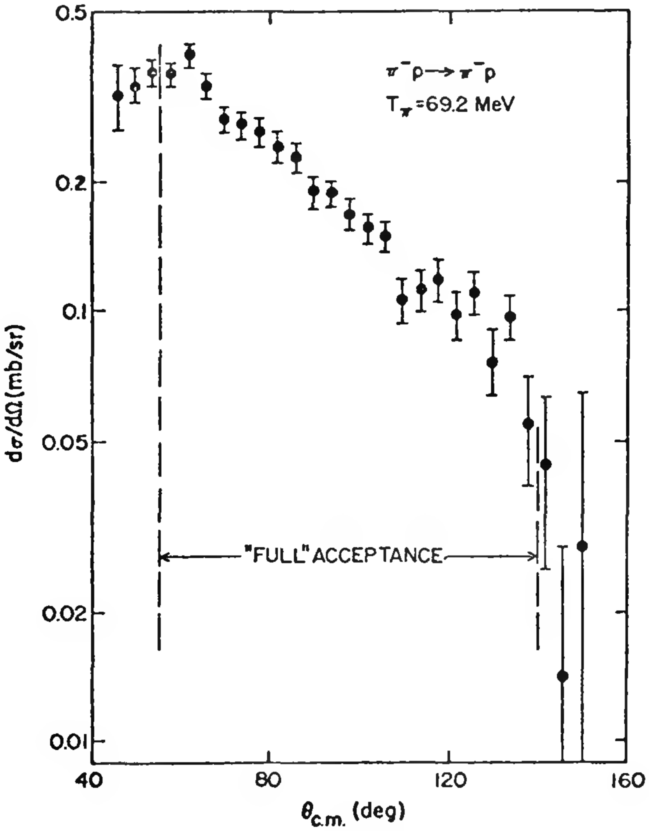


Fig. X-13.
Preliminary differential cross sections for 69-MeV $\pi^-p \to \pi^-p$.

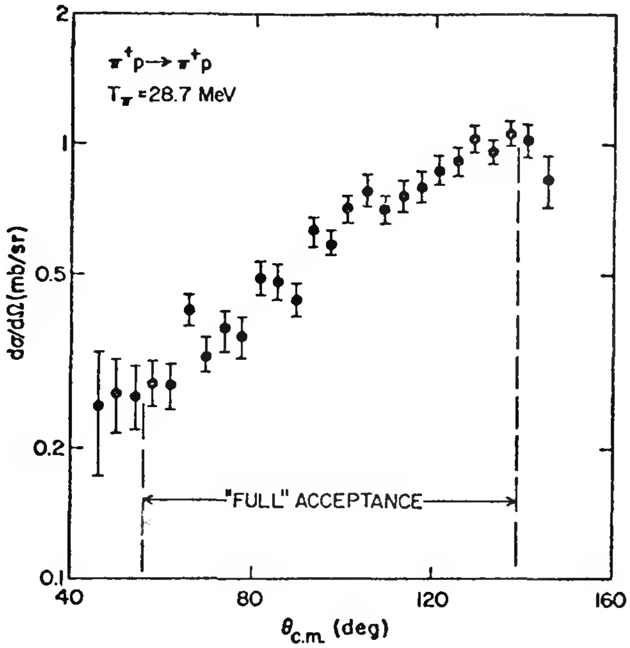


Fig. X-14.
Preliminary differential cross sections for 29-MeV $\pi^+p \to \pi^+p$.

quite similar. The errors, particularly in our data, are too large to allow a meaningful discussion of the quantity $(\sigma^- - \sigma^+ / \sigma^- + \sigma^+)$. We anticipate that certain of the large error bars will have been reduced when our data are in final form.

Figure X-16 shows work we have done using the optical-model code FITPI[7] to fit our angular distribution. The fit appears less adequate at angles greater than the diffraction minimum than in the small-angle region.

The task of automating our data-analysis procedure has occupied most of the time expended during this quarter. Data acquired at a variety of magnet momentum settings must be merged, taking into account the variation (mainly due to geometry) in detector efficiency near the edges of the array. To extract the elastic-scattering cross section, a peak-fitting program is used to fit the momentum spectrum. Peaks caused by the inelastic levels we know are there, but cannot reliably resolve in our spectra, are included in the fitting routine. Setting the widths of these peaks is done by scaling the observed width of the elastic $\pi^\pm$p peak we have in each spectrum. This has involved correcting for several partly countervailing kinematic and target-thickness effects. We believe the data-anlysis routine is evolving to its final form. It will be of great utility in the upcoming runs, because it will allow us to "see where we are" in a few hours time.

Proton-Proton Elastic Scattering
(Exp. 132/160/42)
(LASL, Virginia Polytech. Inst. and State Univ., State Univ. of New York at Geneseo, Texas A&M Univ., Univ. of California at Santa Barbara)

The ultimate resolution of the helical wire chambers could not be extracted from the data obtained during the preliminary runs of Exp. 132/160 in late 1974. The run data showed that the three lowest order bits of the TDC conversions failed a significant fraction of the time, resulting in a worsening of the extracted resolution to 2-4 mm. It is anticipated that these data-transmission difficulties can be corrected, and that resolutions close to the intrinsic values of 0.5 mm will be achieved during data collection for Exp. 42. Periodic checks on the dataway and related links by hardware and software

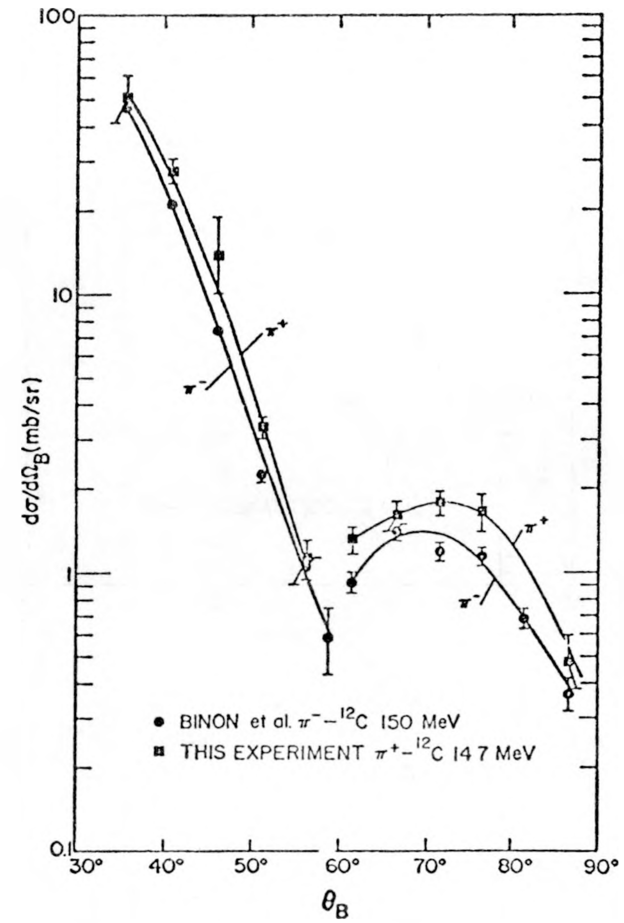


Fig. X-15.
Comparison of π^+-C and π^--C elastic-scattering cross sections at ~150 MeV.

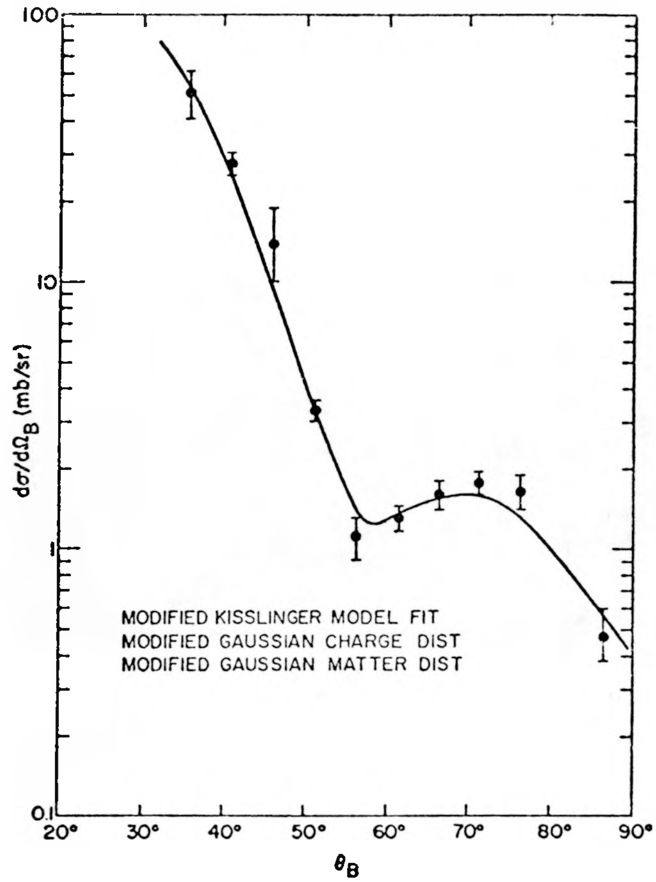


Fig. X-16.
Optical model fit to π^+-C elastic-scattering data.

combinations during data runs are being considered as a safeguard against future difficulties of this nature.

Other improvements on the spectrometer now in progress are: 1) reproducible positioning of the pivot arms, 2) reproducible positioning of helical chambers on the pivot arms, and 3) new casters for better motion of the back pivot arm.

These activities are expected to be completed prior to the beginning of Exp. 42.

In addition to improvements of the spectrometer, the following activities have been initiated for Exp. 42: 1) three 8-cm by 15-cm helical chambers for the determination of heavy-ion trajectory and for the incoming trajectory to the spectrometer magnet; 2) two 20-cm by 50-cm helical chambers for the outgoing trajectory from the spectrometer magnet, and 3) adaptation of the Exp. 132/160 data-acquisition program to Exp. 42.

Testing of the experimental equipment (principally the germanium stack counter and the helical wire chambers) and associated electronics is currently going on. Installation of the apparatus will start about mid-August. The USC/UC-SB members of the group are preparing the ^{6}Li, ^{7}Li, deuterium, and tritium targets and modifying the scattering chamber.

Parity Violation in p-p Scattering at 15 MeV [Exp. 137(A)] (LASL, Univ. of Illinois)

One short test run was completed this quarter for the experiment to observe the weak interaction contribution in p-p scattering at 15 MeV. The objective of this run and other work in recent months is to prepare for a production run this fall, which should reduce systematic and statistical errors on the parity violation to the level of 3×10^{-8}.

Search for Parity Violation in P-Nucleus Scattering at 6 GeV/c [(Exp. 137(B)] (LASL, Univ. of Illinois, Univ. of Chicago)

In our second data run, our stated goal was to measure the helicity dependence of the p-water total scattering cross section at 6 GeV/c to an accuracy of one part in 10^6. The data analysis is essentially complete. We have observed a parity-violating (PV) effect of $\sigma^+ - \sigma^-/\sigma^+ + \sigma^- = (15 \pm 2) \times 10^{-6}$. After completing this run we considered the possibility of a PV background associated with the weak decay of hyperons produced in the target. We have estimated that this effect might be as large as one part in 10^5, although an accurate calculation is impossible.

The hyperon PV background comes about as follows. A polarized proton strikes a nuclear target and produces a Λ, for example. In general there will be a transfer of longitudinal polarization to the Λ. The longitudinally polarized Λ then decays weakly. Parity is violated; the proton is preferentially emitted parallel to the Λ spin and the π^- antiparallel. Thus the laboratory angular distribution for protons coming from Λs of positive helicity is more forward peaked than that of protons coming from Λs of negative helicity. The opposite is true for the laboratory angular distribution of the π^-. This effect causes the number of charged particles striking the transmission detector T to depend on the helicity of the incident proton (see Fig. X-17). The transmission of incident protons is taken as the ratio of signals in the T and I detectors. Since the signal in the T detector depends on the helicity of the incident proton beams, so will the transmission.

The longitudinal polarization transfer parameter is known for inclusive Λ production in p-p scattering. A Monte Carlo calculation for the PV background in this case gives $(+0.6 \pm 2) \times 10^{-5}$. The large error reflects primarily the uncertainty in the polarization transfer parameter. Since the polarization transfer parameters are not known for Σ hyperons or for inclusive Λ or Σ production from oxygen, which is the major constituent of the target, a complete calculation is impossible. The PV effect is dominated by charged pions resulting from hyperon decay. Typically these pions have a laboratory momentum of ~1 GeV/c.

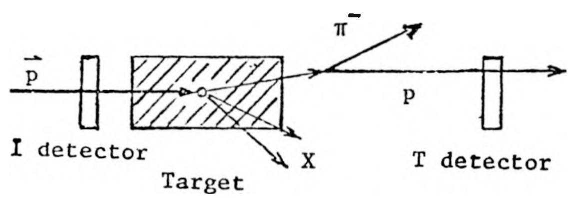


Fig. X-17.
The hyperon effect.

The apparatus employed in our second data run was a refinement of that used in the first data run. The proton spin was aligned to be parallel by bending the 6-GeV/c beam down by 7.75°. The beam was then scattered by a thick-water target. Water was chosen so as to have a homogeneous target. The thickness inhomogeneity was less than two parts in 10^5. The incident and transmitted proton intensities were redundantly measured by ionization chambers and scintillation detectors. Integral counting techniques were used. The component of polarization parallel to the momentum at the position of the target was measured by an eleastic-scattering polarimeter located upstream of the vertical bending magnet. The transverse components of polarization at the target were measured by scintillation detectors (Y detectors on Fig. X-18) located downstream of the target. In order to minimize the effects of drifts, the direction of polarization was reversed on alternate pulses.

Various other properties were measured by an array of scintillation detectors shown in Fig. X-18. The horizontal and vertical centroids of the beam were measured near the T detector and near the I detector by the wedge-shaped scintillation detectors labeled P and S. The horizontal and vertical RMS sizes of the beam were measured by parabolic detectors labeled A. In addition, the intensity and time-averaged instantaneous intensity squared were recorded. As in our previous run, regression analysis

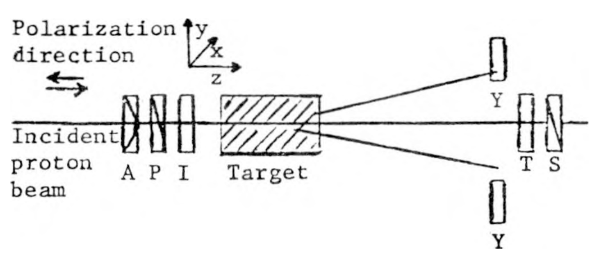


Fig. X-18.
Incident and transmitted proton intensities measured by ionization chambers and scintillation detectors. The longitudinally polarized beam enters from the left. Its x and y sizes are measured by the parabolic detectors A. Its x and y centroid is measured at two locations by wedge-shaped detectors labeled P and S. The transverse polarization of the beam is measured by the detectors labeled Y which detect scattered beam.

was applied to use the knowledge of the pulse-by-pulse behavior of the beam properties to reduce statistical errors in the measurement of transmission. The measurement of the beam properties allowed us to set limits on possible systematic errors associated with variations of beam properties correlated with polarization reversal. A summary of upper limits (90% confidence levels) on systematic errors associated with each beam property is given in Table X-I. There was no evidence for polarization-correlated changes.

A possible source of systematic error is the imperfect alignment of the proton spin with its momentum. A technique for controlling this effect was developed for our last run. The transmission Z has the form

$$Z = A + \beta p_z + \alpha_x p_x (y - y_0) + \alpha_y p_y (x - x_0)$$

where

A is a constant independent of polarization,

p_z is the polarization of the beam parallel to its momentum,

p_x and p_y are the components of transverse polarization,

β is a PV term we seek to measure,

x and y are the horizontal and vertical beam centroids near the T detector,

x_0 and y_0 are values of x and y at which the effects of transverse polarization vanish due to symmetry, and

α_x and α_y are constants characteristic of the analyzing power of the target and geometry.

The third and fourth terms of the above expression are parity allowed. We determine the values of p_x, p_y, p_z, x and y for each pulse. A solenoid magnet placed upstream of the vertical bending magnet allowed us to vary p_x and p_y, and x and y could be adjusted using bending magnets. We took data runs for various values of these quantities and made a least-squares fit for β, α_x, α_y, y_0, and x_0, combining these runs with the bulk of our data runs where the beam was longitudinally polarized and the beam was centered on the T detector. The value of β from this least-squares fit gives the PV asymmetry in the transmission. Values of β and other quantities for the scintillation detectors and ionization chamber are given in Table X-II. It is expected that the βs for the ion chambers and scintillators should be equal. Further, α_x should be equal to α_y for the scintillators and ion chambers, and we estimate that α ion chambers equal 0.6-α scintillators from geometry. These expectations are in good agreement with the data given in Table X-II. The uncertainty in the coefficients is ~10%. The change in transmission due to transverse polarization when the beam polarization is nominally longitudinal is a few parts in 10^6 and is determined to one part in 10^6.

In summary, we have measured PV asymmetry of $(\sigma^+ - \sigma^-)/(\sigma^+ + \sigma^-) = 15 \pm 2 \times 10^{-6}$. This asymmetry results from an unknown combination of two effects: a PV interference between strong- and weak-scattering amplitudes, and the PV decay of polarized hyperons produced in the target. More experimental work is needed to resolve this question. We have developed and proved experimental techniques to make precise measurements of PV asymmetries and to eliminate several sources of systematic error which will prove invaluable in future investigations.

TABLE X-I

SUMMARY OF UPPER LIMITS ON SYSTEMATIC ERRORS

Beam Property	Maximum Change with Polarization Reversal (90% confidence)	Maximum Systematic Error (90% confidence)
Y position	< 2 μm	0.6×10^{-6}
X position	< 11 μm	2.8
Y angle	< 1.3 μrad	0.45
X angle	< 2.0 μrad	1.2
Y size	< 0.7 μm	0.4
X size	< 0.5 μm	0.2
Duty factor	$< 10^{-2}$%	0.01
Intensity	$< 6 \times 10^{-3}$%	1.1

Muonic X-Ray Measurements of Nuclear Charge Radii in the Mass-60 Region (Exp. 163) (LASL, MIT, Univ. of Mainz, Purdue Univ., Florida State Univ., Oregon State Univ.)

The muonic $2p_{3/2} \rightarrow 1s_{1/2}$ and $2p_{1/2} \rightarrow 1s_{1/2}$ transition energies for the 16 separated isotopes $^{54,56,57,58}Fe$, ^{59}Co, $^{58,60,61,62,64}Ni$, $^{63,65}Cu$, and

TABLE X-II

VALUE OF β AND OTHER QUANTITIES FOR THE IONIZATION CHAMBER AND SCINTILLATION DETECTORS

Quantity	Scintillator	Ion Chamber
β	$10.45 \pm 2.63 \times 10^{-6}$	$12.17 \pm 2.64 \times 10^{-6}$
α_x	-0.301 ± 0.039	-0.257 ± 0.041
α_y	-0.367 ± 0.029	-0.230 ± 0.036
x_0	0.0049 ± 0.0038	-0.0028 ± 0.0032
y_0	0.0115 ± 0.0024	$+0.0076 \pm 0.0028$
χ^2/N-M	77.7/73-5	78.66/73-5

$^{64,66,68,70}Zn$ have been measured in the stopped-muon channel of LAMPF. Subsets of three different nuclides were measured simultaneously to extract precise values of isotope and isotone shifts. Equivalent-charge-radii differences between isotopes were determined from the Ford-Wills radial moments $<r^{1.55}>$ with accuracies of $\sim \pm 10^{-3}$ F. Some details of the measurements, together with results for the even iron isotopes, have been published.[8] Isotope-shift data for all the nuclei studied are summarized in the lower half of Fig. X-19, in which values for the differences in charge radii ΔR_k, between isotopes differing by both $\Delta N = 1$ and $\Delta N = 2$, are plotted. The isotope-shift values are plotted below the isotope pairs (in the upper half of the figure) to which they correspond. Two effects are readily apparent:

1. The isotope shifts between even nuclei ($\Delta N = 2$) form an approximately linear sequence, strikingly independent of Z, as N increases from 28 to 40. The cause of this systematic behavior is not presently understood.
2. A pronounced even-odd staggering exists for the $\Delta N = 1$ shifts. This effect, which has been observed in other optical and muonic isotope-shift studies, is also evident in our isotone-shift data, which are shown in Fig. X-20.

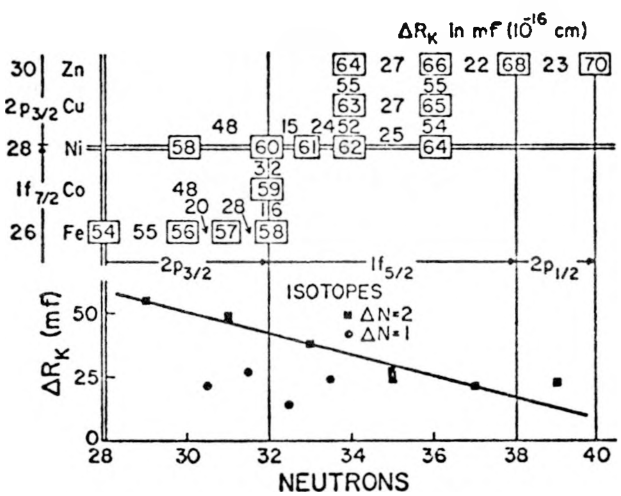


Fig. X-19.
Differences in equivalent charge radii ΔR_k between isotopes differing by $\Delta N = 1$ and $\Delta N = 2$.

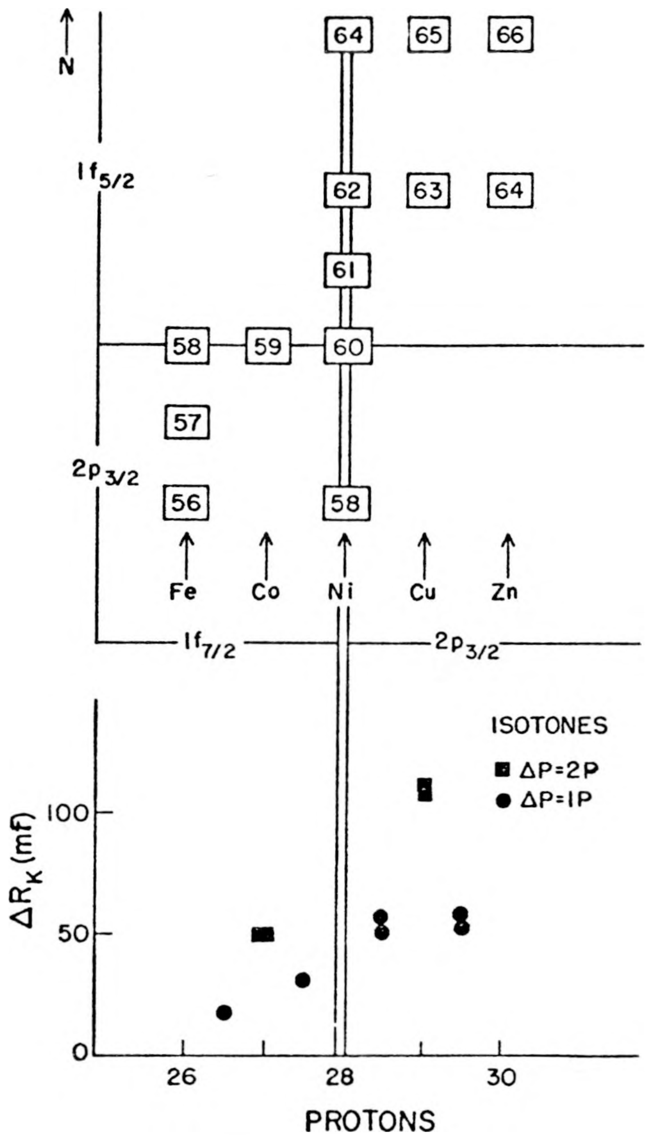


Fig. X-20.
Differences in equivalent charge radii ΔR_k between isotones differing by $\Delta Z = 1$ and $\Delta Z = 2$.

Experiments in Preparation

The Measurement of Differential Production Cross Sections of Multiply Charged Fragments (Exp. 179)

(LASL, California Inst. of Tech., Washington State Univ.)

Fragments from the bombardment of light elements carbon-iron by 800-MeV protons will be detected with a ΔE,E TOF telescope. Because of the short range of these fragments, $\sim$1 mg/cm^2, the elements of the telescope must be as thin as possible. We have built and are testing 10-μg carbon-foil time-pickoff units. So far we have obtained a time resolution of 400 ps, which is sufficiently small to allow us to carry out the experiment. We expect to improve upon this resolution. The time-pickoff units operate by detecting secondary emission electrons which are knocked out of the 10-μg carbon foils by heavy ions. The electrons are accelerated and isochronously transported to a channel-plate electron multiplier. The amplified pulses are then studied with conventional fast electronics.

We are also constructing two ionization chambers for the measurement of the ionization per unit path length of the fragments. One of these is a gridded parallel plate ionization chamber with the beam traversing the chamber parallel to the plates. Previous experience with these chambers indicates that this design should be sufficiently fast and linear in response, with adequate resolution for the present experiment. This system is in the engineering stage.

A prototype chamber of a different design is presently being constructed. The primary difference, as compared to the previous model, is that the beam traverses the chamber perpendicular to the plates rather than parallel to them. This defines the path length of the particles precisely. The disadvantage of this design is that the response of the chamber is somewhat slower and is a function of position. There is evidence that these problems can be minimized so that the effects are not significant. This prototype should be available for testing in approximately one and one-half months.

Measurement of the $\pi^- p \rightarrow \pi^0 n$ Angular Distributions and Calibration of the π^0 Spectrometer (Exp. 181) (Tel Aviv Univ., Case Western Reserve Univ., LASL)

During the last quarter we have continued to refine our design of the π^0 spectrometer. As discussed in the proposal and addendum, the π^0 spectrometer determines the energy of incident π^0 by measuring the opening angle and relative energy of the decay gammas. We have investigated the opening-angle resolution by means of a Monte Carlo program we have developed to simulate the evolution of electromagnetic showers in lead-glass Cerenkov detectors. We have improved the accuracy of this program by a better treatment of screening corrections in bremsstrahlung and pair production. A manuscript describing the Monte Carlo shower program is being prepared.

The choice of the optimum lead glass and photomultipliers for the Cerenkov detectors is under consideration. According to semiquantitative estimates, it appears that a light lead glass coupled to a S11 photocathode will give optimum energy resolution.

Proposal to Search for Direct Lepton Production at LAMPF (LASL-Temple Univ. Collaboration)

A proposal is being written for a LASL-Temple Univ. collaboration to search for direct lepton (specifically $e^{\pm}$) production at LAMPF. The experiment will have a sensitivity of 10^{-34} cm^2/sr for the production of electrons or positrons with large transverse momentum in p-p collisions at 800, 500, and 275 MeV.

It has been known for some time that leptons appear to be produced directly (i.e., not coming from the decays of known mesons and hyperons) in p-nucleus collisions at Fermi National Accelerator Laboratory (FNAL) and at the CERN intersecting storage ring facility (ISR) energies. A remarkable feature of these observations is that the ratio of leptons (e or μ) to pions is $\sim 10^{-4}$ independent of $P_{\perp}$, s, and A of the target. New, unpublished results from an experiment at BNL indicate that the ratio e/π is 10^{-4} down to $\sqrt{s}$ = 4 GeV. No satisfactory explanation of these results exists.

The experiment will be located in the downstream cave along EPB. The apparatus consists of a liquid hydrogen target, two threshold gas Cerenkov counters, a 12D24 bending magnet, two hodoscope banks, and a lead-glass shower counter. The Cerenkov counters and the shower counter give very good electron identification, while the hodoscopes and magnet are used to measure the momentum of particles traversing the spectrometer. The spectrometer is located at 60° to the beam direction.

We intend to be ready to take data on September 15 when beam turn-on is scheduled for Area B.

General Research Projects

Programming for Experiments

The off-line analysis program for the ZGS parity violation experiment [Exp. 137(B)] was transferred from the 360 to the 6600 computer, modularized, and the regression was generalized to use any number of independent variables. Routines for converting NOVA words to CDC words and for printing summary statistics were added. A separate regression program was written to do the final fitting and χ^2 computation using the accumulated punch from the analysis program on several data runs.

The HISTMK and SCATMK subroutines for plotting histograms and two-dimensional scatterplots were modified for use on the Tektronix graphics terminal. The plots produced by the new routines can be printed on a line printer or displayed on the 4013 using the KRONOS text editor. These routines were tested in conjunction with the PIZERO Monte Carlo code.

Several short programs were written to test features of the PLOT-10 software for the 4013. Included were line drawing, scaling, ASCII I/O, and cursor input. A program to draw designs was converted to PLOT-10 for use in demonstrating interactive graphics.

The scheduling program, which compares equipment requests by experiments with withdrawals and inventories, was modified to print separate tables for the LEEP and MP pools. The MP-1 CABLE program was modified to run from a remote batch terminal. Several changes were made in 6600 TRANSPORT to correct for the loss of portions of the print file when generating film and to allow the user to suppress unwanted parts of the fit output with a 22 card.

Harp Fabrication Techniques

A solution was developed and tested for the problem of how to fabricate harps with carbon wires. The wire-winder, normally used to wind MWPCs, was modified as follows: 1) large-diameter aluminum cylinders were used to keep the carbon wires from making sharp corners; 2) the winding speed was slowed down to reduce velocity changes; and 3) the electronics were modified to permit four wires to be grouped together. Since epoxy could not be used to hold the wires in place, and since solder would not bond to the wire, they were electroplated locally. Then, to prevent the solder from dissolving the electroplate, the region was coated with a tinning solution before soldering.

Line-A Guard Rings

Construction of the 11 quadrant secondary emission monitors (QSEM) which will be installed in Line A has been completed. Two samples were taken to Space Radiation Effects Laboratory for testing with beam. The following conclusions were drawn: 1) the gain is $\simeq 20\%$ for an aluminum QSEM with two signal plates and three hv plates; the gain for an inconel QSEM was about one-half the gain for aluminum, 2) quadrant-to-quadrant pickup is $< 1\%$, and 3) sensitivity to shift in beam centroid is ~ 1 mm. Heat-cycling tests were conducted in which an inconel QSEM held together with no apparent damage or warping of its plates to a test temperature of 600°C. However, the resistance from signal plates to ground dropped as a function of temperature to ~ 15 MΩ at 600°C. This test will be repeated in a vacuum furnace to understand if this resistance drop was related to the oxidation which was observed.

Beam-Profile Monitor

Four MkII versions of this device are under construction. The first is complete.

Beam-on-Target Monitor

The prototype ion chamber was tested in the external proton beam at the Space Radiation Effects Laboratory during June. We have acquired efficiency vs bias curves for proton beams of average intensity up to 50 μA, both pulsed with ~ 50-μs pulse length and nearly continuous. Under the worst of these conditions, about 2 kV is required to reach the plateau.

Leakage currents caused considerable difficulty. These had been virtually eliminated, before departure for Los Alamos, by a cleaning and pumping process. The increased humidity seems to have had an effect on the insulating properties of the aluminum spacers. The next two chambers, now under construction, will be made with an eye to keeping the insulators uncontaminated during brazing and other handling. Leads will be welded rather than soldered to the structure. Two chamber housings, of the design intended for the target cells, are also under construction.

Theory

Pion Elastic Scattering

The elastic-scattering angular distribution[9] for 51-MeV π^+ incident on ^4He is shown in Fig. X-21. The curves marked K and LL are optical-model calculations performed with the Kisslinger and local-Laplacian models, using potential parameters derived from free π-nucleon phase shifts. One striking difference between the theory and the data is the location of the minimum. The inward displacement given by the data is characteristic of several light targets at low energies for both π^+ and π^- projectiles.

At 51 MeV, the π-helium scattering is dominated by s- and p-wave nuclear phase shifts. With this observation, it is possible to see that a stronger s-wave π-nucleus interaction is needed than was predicted by the free π-nucleon phase shifts in order to put the minimum in the correct location.

Figure X-21 also shows a best-fit solution using a K model which treats the parameters as adjustable.

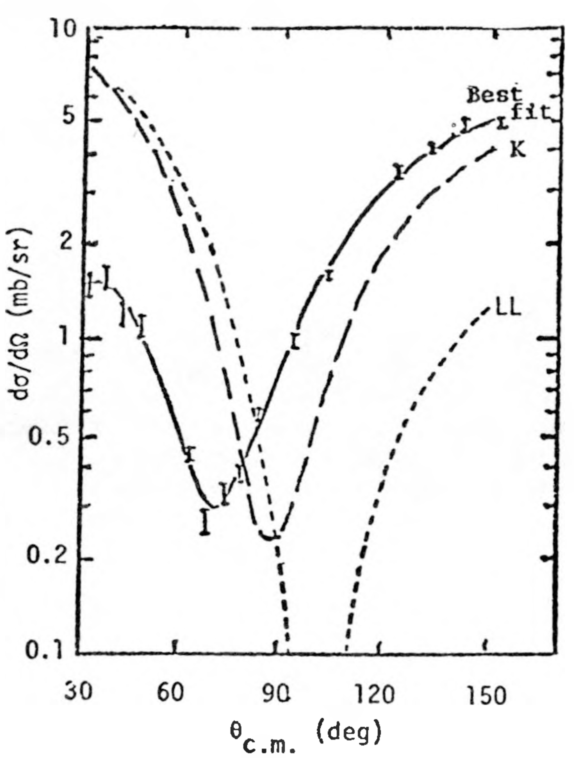


Fig. X-21.
Elastic-scattering angular distribution for 51-MeV π^+ incident on ^4He.

This fit suffers from the fact that in one partial wave the phase shifts are not unitary. The nonunitary defect is common to both the K and LL models for both ^4He and ^{12}C over a range of low energies.

In an attempt to understand the origin of the difficulties, the first Born term of the scattering matrix was examined. First, it was observed that the minimum in the angular distribution was due to an interference of the s- and p-wave pieces of the potential and was not a diffractive effect. Second, the location and depth of the minimum placed restrictions on the parameters. The restrictions did not rule out a unitary solution, but indicated that the unitarity requirement might be very hard to satisfy unless the model was considerably different from the ones discussed or not dominated by the Born term.

It was concluded that more complete theories and better experiments should do much to mitigate the difficulties discussed.

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XI. PRACTICAL APPLICATIONS OF LAMPF

(Summarizes work being performed under the auspices of USERDA Division of Research, USERDA Division of Biomedical and Environmental Research, National Cancer Institute, and USERDA Division of Military Application.)

Biomedical Research Facility

A large number of instrumentation and control projects received attention during the last quarter. A dose-integrator system for the 300-KVP x-ray machine was designed, constructed, and checked out. The transmission ionization chamber in the machine was also rebuilt.

The SHM isodose plotter was received and checked out. A circuit modification in the SHM motor-control circuit was made, and an electrometer preamp for use with ion chambers is under construction. CAMAC interfaces for the Tennelec PACE ADC and for the 30 positioning scanners are undergoing check-out.

The new power-supply controllers based on digital-to-analog converters are nearing completion, and several have been checked out. The five-digit computer-readable digital voltmeter for measuring magnet currents and the associated relay multiplexer installation are nearly completed. Wiring and motor drivers for all slits were installed. (Cable terminations at the slit end are all that remain, and will not be done until the slits are installed.)

Design work is near completion on the gas-bottle farm and associated computer-readable pressure-transducer system. This is to provide control and delivery of MWPC gases and helium for the beam-transport system.

A computer-controlled analog-function generator was designed and fabricated to allow exercising the oil-piston assembly being built by MP-9 for tailoring the momentum distribution. This will be useful in determining the momentum distribution necessary to obtain nearly uniform biological response as a function of depth in radiobiology experiments.

A surplus color TV monitor was reconditioned and modified for separated RGB input for use with the color character-display-scope system. Hardware for a second color character-display-scope system was installed, but considerable software effort will be required to make it usable.

The large DIVA disc system (20 megawords per drive) ordered last quarter was received, and a second drive was ordered.

Software projects included further work on PIPLAN, magnet-control software to allow use of the new digital-voltmeter systems and controllers, software for the 30-positioning scanner, a CAMAC exerciser code for general check-out use, completion of the channel table editor, development of a line-by-line channel-display system, work on a graphics-spooling package, and work on software for knobs and buttons on the console. Conversion to the new RSX-110 operating system release and to FORTRAN IV-Plus was started and is over half completed. Documentation was improved, and regular supplements to the Biomed Users Software Manual were issued.

Biomedical Pion Channel Development

Detailed field mapping of bending magnets BM-01,-02 was undertaken during this quarter. These wedge magnets in the Biomedical channel form a momentum-dispersed focal plane. The objective is to find the effective boundaries of the magnetic fields, and to thereby improve the TRANSPORT representation of these fields. The new matrix elements will then be used to make predictions of channel performance that can be compared with experiment. Midplane field maps and Hall probe scans of fringe fields were made. This shutdown period was the first available opportunity to make such field measurements. Analysis of the magnetic field data is in progress.

The construction of helium tanks for the first part of the Biomedical channel is complete. This project was undertaken to reduce the adverse effects of multiple scattering due to the air in this section of the channel. A compromise design was reached in which the slit assembly between the entrance triplet and the first bending magnet remains in air as originally designed. One foot of air plus four 0.0013-mm Kapton windows are allowed, two windows as dust covers for the slit and one window on each of the two separate helium tanks. This material does not markedly decrease the momentum resolution of the channel.

One tank of circular cross section fits inside the entrance triplet. The beam-entry end uses a standard, remotely serviceable flange with a thin-aluminum window. The downstream end has a special quick-change window assembly that can be handled with remote manipulators. The second tank is rectangular in cross section and is contoured to fit inside the bending-magnet assembly BM-01,02. Its upstream window flange is entirely contained inside the coils and uses a single nut for attachment.

Pion Dosimetry Program

Work has continued on converting the data-analysis programs and the data-plotting routines for both dosimetry and microdosimetry from the CDC computers to the biomed PDP-11/45. New software has also been written for the biomed computer to analyze these data more efficiently. Most of the programs have been converted from "batch jobs" to user-interactive programs.

Development of improved methods for doing microdosimetry experiments has also been continuing. The logarithmic amplifier has been tested and appears to be working properly. The mixer router (for use with the Canberra 8100 MCA) has been repaired and tested, and seems to be capable of handling pulses from both the log amp and a linear amp simultaneously. These improvements should reduce significantly the time required for microdosimetric measurements. A new miniaturized low-noise preamplifier has also been built and tested for use with the LET chambers. Circuit-board layouts have been fabricated to allow manufacture of the entire preamplifier assembly at LASL, thus reducing the cost of these units by a factor of 2.

Treatment–Planning Code

During the last quarter, work has begun on methods for incorporating the microdosimetry data into treatment-planning codes for pions. To the best of our knowledge, no existing treatment-planning code is capable of calculating isoeffect contours in three dimensions for a therapeutically useful pion beam. The microdosimetric data, along with other physical measurements, will be needed as input data to treatment-planning codes for this purpose. Modifications to existing computer programs (such as PIPLAN) are presently being considered to provide this information.

Some preliminary work has been done in this area. An experimentally determined depth-dose curve has been used as input to a computer program which then generated, by means of a range shifter, a depth-dose curve with constant dose over a depth interval of 5 cm.

The physical formulas describing energy-loss mechanisms in π^- radiotherapy are being developed for eventual inclusion in the treatment-planning code. Since this code is expected to be small and efficient, many approximations must be made while maintaining sufficient accuracy for clinical applications. Range straggling has been incorporated into the primary ionization loss. The star dose is divided into three separate parts: 1) heavy charged fragments, which deposit their energy locally; 2) protons, which deposit their energy throughout their longer range; and 3) neutrons, the dose distribution for which is modeled from previous calculations.[1] The star-proton dose distribution must be folded with the pion-stopping distribution before the various components of the calculation can be assembled into a working subroutine.

Practical Applications Experiments

Tissue Chemical Analysis with Mu-Mesic X-Rays (Exp. 100)

Data analysis was completed for two of the targets studied in Exp. 100. These targets are Shonka tissue-equivalent (TE) plastic and a tissue-equivalent liquid. Table XI-I outlines the results. The column labelled "Z-Law" is for predicted x-ray yields, assuming that no muons are captured by hydrogen and that all the rest are captured on the other elements present according to the Fermi-Teller Z-law. The column "Modified Z-Law" assumes that hydrogen present in the target also captures its share of muons according to the Z-law, but that the muons are immediately transferred to the atom to which the hydrogen is bound.

TABLE XI-I

DATA ANALYSIS FOR TWO TARGETS

Target Element	% Yields of X Rays		
	Predicted		Measured
	Z-Law	Modified Z-Law	
Shonka TE Plastic			
C	84.8 ± 0.4	86.9 ± 0.4	87.8 ± 1.8
N	3.7 ± 0.1	3.9 ± 0.1	3.9 ± 0.3
O	7.5 ± 0.7	6.1 ± 0.6	6.5 ± 0.4
F	1.9	1.5	1.0 ± 0.1
Ca	2.1	1.6	1.1 ± 0.5
TE Liquid			
C	13.9	14.7	15.1 ± 2.4
N	4.0	5.0	3.7 ± 0.6
O	82.2	80.3	81.3 ± 2.9

A Visualization Experiment on a Stopping π-Meson Beam Using Charged Particles (Exp. 196)

In this experiment, the projected position at which a π^+ stops is measured by determining the path of the e^+ produced by the $\pi^+ \rightarrow \mu^+ \rightarrow e^+$ decay.

Preliminary analysis of the data is complete. Figure XI-1 shows the density distribution of stopping positive pions in a 3-cm-thick slice of a Rando body phantom placed at a 45° angle to the biomed pion beam. The phantom slice is a cross section from the chest region. The pion-stopping distribution was obtained by viewing the slice with pairs of MWPCs looking at right angles to the pion beam. The paths of detected positrons were then projected back to the plane of the slice to obtain the pion-stopping distribution. Figure XI-1 also illustrates the relatively high pion-stopping density in the spinal region where the tissue density is high, and also shows the lower stopping density in the lung regions.

Analysis is continuing with the aim of correcting the data for the incident pion-beam flux distribution.

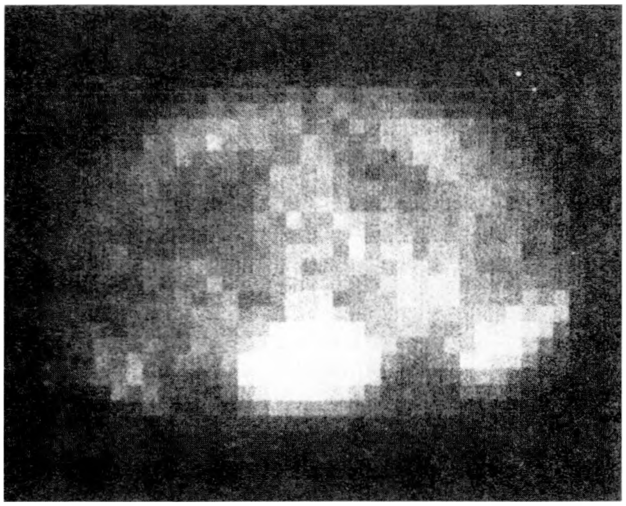

Fig. XI-1.
Density distribution of stopping positive pions in a 3-cm-thick slice of a Rando body phantom placed at a 45° angle to the biomed pion beam.

Technology Transfer

Localized Current Field Tumor Therapy

Thermal LCF treatment of spontaneous animal tumors continues in a collaborative program with the Univ. of New Mexico School of Medicine. Two human cases (squamous cell carcinoma of the tongue) were treated in July with LCF by the staff of the medical school and the Cancer Research and Treatment Center. Tumor regression and pain relief were seen in each case, but general deterioration in patient health ruled out further treatment.

Design is under way of a general temperature controller for use in LCF therapy. This unit can be used with a variety of commercial rf sources and amplifiers. This is being done so that a minimum amount of LASL equipment will be needed by those who might wish to use the LCF technique for heating tissue.

Bioelectric Potentials

Apparatus for the measurement of differential breast-skin potentials (for tumor-diagnostic purposes) is essentially complete. Initial data on one female subject, presumed healthy, indicate that normal variations in tissue potential are large enough to make tumor detection difficult. Work will continue to isolate the source of the variations, and eliminate the portion that is related to instrumentation or technique. Some of the potential variations seen appear to be related to gastric motility, which may have application in the diagnostics of certain gastric disorders.

Electrosurgery

Development efforts on the device for use in cutting and sealing small arteries is considered complete, as is the development of circuitry and techniques to reduce electrosurgery-noise interference with ECG monitors. No further work in these areas is planned at this time.

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XII. MANAGEMENT

Budget and Personnel Levels

For FY-75, operating costs were held to our budget authorization by deferring about $500k of expenditures to FY-76. Essentially all of our capital equipment authorization was obligated or costed. The work funded out of construction (Accelerator Improvement Project) associated with the upgrading of the facility for operation at high intensity is essentially completed. Work on the Polarized Ion Source is under way. An additional $115 000 of FY-76 construction funds is required to complete this project. This has been allocated. The values of the special process spares inventory was increased by about $518 000. The total current value of this inventory is $958 000.

The NCI contracts for continuing effort on Preclinical Studies for Pion Radiotherapy and Cancer Research and Treatment Center program have been signed and work is under way.

A proposal is being prepared for submittal to NCI for the design of a pion generator for medical applications. Hopefully, authorization for this project will be granted sometime late in this fiscal year.

The average number of employees—full-time equivalents (FTEs)—was 351, about 14% more than forecast for the year.

For the first month of FY-76, accrued operating costs were about 15% higher than forecast. This will present a serious problem if the JCAE authorization for LAMPF is not approved.

In-House Training

The maintenance and inspection technicians training classes were completed this quarter. This course, comprised of 24 class sessions with an average attendance of 40, was approximately equally divided between accelerator support and accelerator operations technicians.

Meetings and Tours

The VI International Conference on High Energy Physics and Nuclear Structure was hosted by LASL's MP-Division at St. John's College in Santa Fe and at the Laboratory during June 9-14, 1975. The conference was attended by about 500 participants from 23 countries. Thirty-six invited papers were presented. The sessions were held at St. John's, with a TV hookup at LAMPF for the Los Alamos-based participants. The presented papers (36) have been edited and compiled at LASL and are in the process of being published by the AIP. The logistics for the conference were handled by MP-Division personnel, with support from the Laboratory's Information Services Department

A summer Institute in Physics and Biophysics sponsored by AWU, ERDA, and by LASL under the Director's Academic Cooperation Program, was held at LASL during the period July 14-August 8, 1975. The courses were held at LAMPF and the Health Research Laboratory. Lectures in physics were conducted by T- and MP-Division personnel, and courses in biophysics were conducted by H-Division personnel. The students also participated in LASL's Summer Graduate Student orientation program.

Some of the LAMPF-related meetings that were held at LASL during this report period are:

5/9 – Biomedical Applications Subcomm. of PAC

6/8 – Biomedical Applications Subcomm. of PAC

6/14 – EPICS Working Group

6/23-25 – Briefing of National Cancer Inst. personnel by UNM Cancer Res. Center and LAMPF personnel

7/7 – Neutrino Working Group

Organized tours of the facility were held for the following organizations:

5/1 – El Dorado, NM High School special physics students

5/2 – National High School Educators

5/7 – Espanola, NM doctors and nurse-practitioners

5/7 – Albuquerque, NM Medical Explorer Post 200

5/7 – NM Highlands Univ. electronics technicians

5/10 – Rocky Mountain Quantum Chemists

5/17 – National Secretary Meeting

5/20 – Rotary Club (England)

5/20 – Adams State Coll. students

6/11 – VI Intern. Conf. on High Energy Physics and Nuclear Structure

6/12 – Intern. IEEE

7/11 – LASL Summer Graduate Students

7/16 – Aerospace personnel

7/17 – Alamosa Senior Citizens group

7/23 – Norwegian CAP Cadets

7/29 – Espanola, NM Tech. Vocational Inst. electronics students

Safety

Radiological Safety

Close control of the radiological safety aspects of work on the accelerator and in the experimental areas continued with the LAMPF health physics surveyors providing the direct field support. Individual personnel exposures as well as total man-rem exposures were kept to a satisfactory level considering the amount of radiation work that was done during this period. Sixteen "Game Plans" were used for work on radioactive accelerator and beam-line components and shielding. As a result, the total men-rem exposure for all LAMPF personnel and crafts was held to 16.6 man-rem for this quarter compared to 14.6 man-rem in the first quarter of this year. This exposure was divided among 153 people.

Safety Deficiencies

Design work has continued on various physical-safety deficiencies such as ladders, emergency lights, catwalks, and water systems. The hookup of trailer and counting-room fire-protection systems is nearly complete. Designs were completed on four additional fire-protection jobs involving enclosing the control cable trays in the Injector Building basement and installing smoke or heat detectors in the Beam Switchyard, the corridor between the Operations Building and Sector H and over the electronics racks in the master rf-signal Source Room. The contract for the installation of sprinklers in the Injector Building has been delayed. Installation was to have been completed prior to the start-up of the accelerator in July. The impact of having the contractor installing sprinkler piping adjacent to or over operating equipment will have to be carefully evaluated.

Training

A division-wide safety meeting was held covering special on-going safety items and two industrial health items: industrial ventilation and respirators. Various types of laboratory ventilation systems were discussed, the meaning of the term "use under proper ventilation" was clarified, and the methods of testing various types of hoods were summarized. The proper use of respirators was reviewed, and a 30-min film entitled "The Right to Breathe Safely" was shown.

Other safety training this quarter included a number of group and section meetings in which special safety topics were discussed.

Safety Program Activities

The committee of Group Safety Officers prepared a new and more definitive charter for their activities, responsibilities and authority. This was submitted to the LAMPF Safety Committee and approved at its July meeting.

Several safety representatives were appointed for each beam line to ensure the safety of work on the lines as well as in the conduct of experiments. These safety representatives, together with the members of the Experimental Areas Safety Committee and the staff of the LAMPF Safety Office, are readily available to assist personnel in the experimental areas, to provide day-to-day coordination in safety matters, and to take part in regular inspections of the areas. Particular emphasis is being placed on procedures and work habits, which constitute a more difficult and important aspect of any safety program than the more obvious physical-safety deficiencies.

Seven first-aid kits were fitted out and placed in various key locations throughout the site. These kits contain special materials (bandages, dressings, etc.) to provide emergency care of serious injuries. The kits, which are the size of a suitcase, have been sealed and placed in the hands of personnel who have received appropriate first-aid training. The kits supplement the 26 first-aid cabinets located throughout the site.

Accidents

During the quarter no serious accidents were reported, and the total number of accidents was about the same as in previous quarters. Eight sprains or strains were received, with only one resulting in lost time. Fifteen minor injuries were treated resulting from a variety of abrasions, lacerations, and from foreign bodies in the eye. None of these resulted in significant loss-of-work time.

Visitors Center

During this report period, 66 users were received at LAMPF and 27 have been checked out. Currently there are 94 users at LAMPF. In addition, there are 21 summer guests, and 19 guests on long-term assignments at LAMPF. A list of visitors and guests at LAMPF during this report period is presented in Appendix A.

The two secretaries in the reception area are receiving training in the use of the System-2000 data base. They have started entering the Visitors Center statistics as of January 1972 and have been entering all visitors who have arrived since the data base became operational.

Housing has been found for 52 LAMPF visitors (including users). The 20 kitchenette apartments reserved for LAMPF users have been fully occupied since June 1, 1975. With few exceptions, the 11 kitchenette apartments leased from the Los Alamos Medical Center have been filled since June 1, as well as the two Los Cerros Apartments and five Monte Vista apartments that are LASL-leased. Accommodations have been found for all the people wanting to visit LAMF for the summer as well as for some arriving in the fall and winter.

Work has not been started on the display case for the photos of LAMPF personnel and visitors. This work has been delayed in order to handle higher priority items.

Program Advisory Committee

On April 28, 1975, the Low-Energy Pion Channel Subcommittee met in Washington, DC to resolve the impasse caused by the serious oversubscription of beam time on that channel. In the time available, it was possible for the committee to suggest for scheduling only those experiments which required the low beam currents expected immediately following accelerator start-up. At a second meeting, held in Santa Fe, NM on June 8, 1975, the committee finalized its FY-1976 beam time recommendations for the remaining approved experiments. As a result of the final recommendations it will be necessary for many experimenters to request additional time to complete their experiments. Several experiments were postponed until FY-1977.

The Biomedical Applications Subcommittee met at Los Alamos on May 19, 1975. Six new proposals were heard and approved. Those proposals are:

212 "Comparative Effectiveness of Negative Pions vs Californium-252 in a Tumor-Animal System."
D. J. Mewissen and L. H. Lanzl, Spokesmen

215 "Visualization of Stopping Pion Distribution"
V. Perez-Mendez and J. Bradbury, Spokesmen

217 "π^- Production Cross Sections"
M. Paciotti, Spokesman

218 "Pion Dosimetry with Nuclear Emulsions and Alanine"
R. Katz, Spokesman

235 "Radiation Repair of Normal Mammalian Tissues"
E. L. Gillette, Spokesman

236 "Biological Effects of Negative Pions"
M. R. Raju, Spokesman

At the present time there are seventeen active biomedical proposals.

In its history, the PAC, or its subcommittees, have considered the scientific merit of 237 experimental proposals. Fifty-seven of those proposals have not been approved. Of the 180 approved proposals, 24 have received no recommendation for beam-time allocation. Eleven proposals have resulted in completed experiments.

LAMPF Users Group, Inc.

User Activities

An EPICS Working Group Meeting was held in Los Alamos on June 14, 1975, with Chairman R. J. Peterson (Univ. of Colorado) presiding. The following agenda items were featured: H. A. Thiessen (LASL) reported on the present status of the EPICS Channel; the status of the computer programming was described by James Amann (Carnegie-Mellon Univ.) and Joseph Bolger (Univ. of Texas); H. A. Thiessen discussed the status of the channel optics; Christopher Morris (Univ. of Virginia) described planned α-particle tests; a report on the work on the separator was given by Donald Slater (Univ. of Virginia); and the characteristics and status of the SUSI (SIN) system were presented by Jean-Pierre Egger (Univ. of Neuchâtel) and E. Boschitz (Univ. of Karlsruhe).

Various future plans involving EPICS and LAMPF were also discussed. It was decided that the next Working Group Meeting will be held in November in conjunction with the Ninth LAMPF Users Meeting. There were 23 attendees at the meeting. The complete minutes of this meeting will be published in the next LAMPF Users Group Newsletter, which will be mailed to members in September.

Nominating Committee

According to the By-Laws of the LAMPF Users Group, Inc., the annual election of members of the Board of Directors is to be held by written ballot mailed to the membership before October 6, 1975. The Nominating Committee, appointed by the

Board of Directors, consists of Mark J. Jakobson, Chairman, (Univ. of Montana); Hans Frauenfelder (Univ. of Illinois); Jon D. Shoop (Univ. of New Mexico); Richard R. Silbar (LASL); and Klaus O. Ziock (Univ. of Virginia). At its meeting on June 12, 1975, the Committee decided to select more than one candidate for each of the three vacancies on the Board for 1976. Herbert L. Anderson (Univ. of Chicago) will serve in the capacity of Past-chairman and David A. Lind (Univ. of Colorado) will become Chairman. The post of Chairman-elect is to be filled. There are two positions as members of the Board of Directors to be filled to replace outgoing members Robert E. Anderson, M.D. (Univ. of New Mexico School of Medicine) and Robert M. Eisberg (Univ. of California, Santa Barbara). Vernon W. Hughes (Yale Univ.) will complete his term of office as Past-chairman in December 1975.

The following slate of officers for 1976 was selected by the Nominating Committee:

Chairman-elect: Alfred S. Goldhaber (State Univ. of New York at Stony Brook)
Harvey B. Willard (Case Western Reserve Univ.)

Members: Bernard M. K. Nefkens (UCLA)
Rolf M. Steffen (Purdue Univ.)
Paul Todd (Pennsylvania State Univ.)

Liaison Office

The May issue of the LAMPF Users Group Newsletter was mailed to all members on May 20, 1975. Preparation of the September issue of the Newsletter has already begun.

Invitations to the EPICS Working Group Meeting were mailed on May 20, 1975. The "Notice of Annual Meeting: Call for Nominations and Amendment to the By-Laws" has been prepared and is being mailed to all members of the LAMPF Users Group, Inc., as of this writing. Currently, there are 1044 members of the LAMPF Users Group, Inc.

Chairman Anderson and Liaison Officers Donald R. F. Cochran and Hillard H. Howard have started to make plans for the Ninth LAMPF Users Meeting to be held in Los Alamos on November 10-11, 1975, followed by a Board of Directors Meeting and a Technical Advisory Panel Meeting on November 12. Work has started on the preparation of forms and other material concerning the meeting and election of officers that will be mailed to the entire membership the week of September 15, 1975.

APPENDIX A

LAMPF VISITORS AND USERS PRESENT DURING THE SECOND QUARTER - 1975

John C. Allred — Univ. of Houston
Jonas Alster — Tel Aviv Univ.
James F. Amann — Carnegie-Mellon Univ.
Alan N. Anderson — Univ. of Idaho
Bryon D. Anderson — Case Western Reserve Univ.
Herbert Anderson — Univ. of Chicago
George W. Atkinson — UNM School of Medicine
Leonard B. Auerbach — Temple Univ.
Norman Austern — Univ. of Pittsburgh
Helmut W. Baer — Case Western Reserve Univ.
Thomas J. Baird — Rensselaer Poly. Inst.
Steven D. Baker — Rice Univ.
Howard I. Balshem — Temple Univ.
Edward E. Barnes — UNM School of Medicine
James H. Baum — Martin-Marietta Corp.
Fred E. Bertrand — ORNL
Hans A. Bethe — Cornell Univ.
Philip R. Bevinton — Case Western Reserve Univ.
Ed K. Biegert — Rice Univ.
Christopher W. Bjork — Univ. of Texas
Gary S. Blanpied — Univ. of Texas
Marvin Blecher — VPI/State Univ.
Felix Boehm — Norman Bridge Lab.
Joseph E. Bolger — Univ. of Texas
Jonathan S. Boswell — Univ. of Virginia
Kenneth Boyer — Univ. of Texas
Wilfred J. Braithwaite — Univ. of Texas
David W. Brock — Univ. of Colorado
Howard Bryant — Univ. of New Mexico
George Burleson — New Mexico State Univ.
Roger D. Carlini — Univ. of New Mexico
Donald E. Casperson — Yale Univ.
Constantine Cassapakis — Univ. of New Mexico
Joseph N. Craig — Carnegie-Mellon Univ.
Thomas W. Crane — Yale Univ.
Dorothy M. Crawford — UNM Cancer Center
Kenneth Crowe — LBL
Richard A. Cupp — Univ. of New Mexico
Frank H. Cverna — Case Western Reserve Univ.
H. Daniel — Univ. of Munchen
John P. Davidson — Univ. of Kansas
Arthur B. Denison — Univ. of Wyoming
Satish Dhawan — Yale Univ.
Byron Dieterle — Univ. of New Mexico
Joey B. Donahue — Univ. of New Mexico
Mohan Doss — Carnegie-Mellon Univ.
Thanasis E. Economou — Enrico Fermi Lab.
Robert A. Eisenstein — Carnegie-Mellon Univ.
Shalom Eliezer — Univ. of Massachusetts
Norbert Ensslin — Univ. of Colorado
Torleif E. O. Ericson — CERN
David Ernst — Case Western Reserve Univ.
Borge Espensen — BNL
Michael L. Evans — Texas A&M Univ.
W. Bruce Feller — Yale Univ.
Herman Feshbach — Massachusetts Inst. of Tech.
John C. Fong — UCLA
Hans Frauenfelder — Univ. of Illinois
James L. Friar — Brown Univ.
David R. Giebink — Univ. of Texas
Edward L. Gillette — Colorado State Univ.
George Glass — Texas A&M Univ.
Robert L. Gluckstern — Univ. of Massachusetts
Alfred Goldhaber — State Univ. of NY, Stony Brook
Kazuo Gotow — VPI/State Univ.
Pierre Grand — BNL
Steven J. Greene — Univ. of Colorado
P. C. Gugelot — Univ. of Virginia
Isaac Halpern — Univ. of Washington
William B. Harvey — New Mexico State Univ.
F. Joseph Hauser — Carnegie-Mellon Univ.
Walter Hensley — Univ. of Rochester
John C. Hiebert — Texas A&M Univ.
Virgil L. Highland — Temple Univ.
Gerald Hite — Universitat Kaiserlautern
Gerald Hoffmann — Univ. of Texas
Bo Hoistad — UCLA
David B. Holtkamp — Univ. of Texas
Charles S. Huff — Los Alamos
Vernon W. Hughes — Yale Univ.
Ed V. Hungerford — Univ. of Houston
George J. Igo — UCLA
Harvey Israel — Los Alamos
Steve Iversen — Northwestern Univ.
Mahavir Jain — Texas A&M Univ.
Mark J. Jakobson — Univ. of Montana
David A. Jenkins — VPI/State Univ.
Randolph H. Jeppesen — Univ. of Montana
Kenneth F. Johnson — New Mexico State Univ.
Kelley Kanizay — Univ. of Colorado
Arthur K. Kerman — Massachusetts Inst. of Tech.
Thomas R. King — Univ. of Wyoming
Harrold B. Knowles — Washington State Univ.
Lynn D. Knutson — Univ. of Washington

Thomas Kozlowski — BNL
Kenneth S. Krane — Oregon State Univ.
Raymond Kunselman — Univ. of Wyoming
Gary Kyle — Univ. of Minnesota
Wing Chee Lam — VPI/State Univ.
Lawrence L. Lanzl — Univ. of Chicago
Carl B. Larson — Univ. of Colorado
Chris P. Leavitt — Univ. of New Mexico
Tsung-Shung H. Lee — BRF
Marilyn M. Lieber — Univ. of New Mexico
Rodger P. Liljestrand — Univ. of Texas
Ronnie D. Lipschutz — Univ. of Texas
Stanley Livingston — Santa Fe
Earle L. Lomon — Massachusetts Inst. of Tech.
Daniel Lu — Yale Univ.
David G. Madland — Univ. of Minnesota
Donald J. Malbrough — Univ. of South Carolina
Vito Manzella — BNL
Fesseha Mariam — Yale Univ.
Thomas Marks — Univ. of South Carolina
Nina Marsh — UNM Cancer Center
Bill N. Mayes — Univ. of Houston
W. Kenneth McFarlane — Temple Univ.
John F. McIntyre — Univ. of Texas
Hans Otto Meyer — Univ. of Basel
C. Fred Moore — Univ. of Texas
Christopher Morris — Univ. of Virginia
Donald W. Mueller — Los Alamos
Leon Myrianthopoulos — Univ. of Chicago
Robert A. Naumann — Princeton Univ.
Peter Nemethy — Yale Univ.
Lee C. Northcliffe — Texas A&M Univ.
Andrew W. Obst — Univ. of Texas
Lewis T. Orrhanos — Univ. of Virginia
Herbert Orth — Univ. of Heidelberg
Alden Oyer — Univ. of Wyoming
Garrett A. Pelton — VPI/State Univ.
Roy J. Peterson — Univ. of Colorado
Gary W. Pfeufer — Rice Univ.
John M. Phillips — Univ. of Wyoming
William Powers — Washington Univ.
Barry M. Preedom — Univ. of South Carolina
Glen A. Rebka — Univ. of Wyoming
James J. Reidy — Univ. of Mississippi
Walter H. Reist — Univ. of Berne
Jeffrey D. Richman — Los Alamos
Martin Rickey — Univ. of Indiana
Robert J. Ridge — UCLA
Peter J. Riley — Univ. of Texas
Robert M. Rolfe — UCLA
Ted R. Rupp — Univ. of New Mexico
Marvin Sachs — Univ. of New Mexico
Darwin T. Scott — Univ. of New Mexico
Alpar Sevgen — Massachusetts Inst. of Tech.
Subhash C. Shah — Southern Univ.
Hasan Sharifian — Univ. of New Mexico
Joseph D. Sherman — Carnegie-Mellon Univ.
Ruby Sherr — Princeton Univ.
Donald Shirk — Texas A&M Univ.
Frank Shively — LBL
Philip J. Siemens — Niels Bohr Inst.
Donald Slater — Univ. of Virginia
Larry B. Sorensen — Univ. of Illinois
David M. Stupin — Oregon State Univ.
Richard J. Sutter — BNL
Richard Talaga — Univ. of Chicago
Fran L. Talley — Univ. of New Mexico
Raphael M. Thaler — Case Western Reserve Univ.
Willard Thomas — Univ. of New Mexico
Michael D. Thomason — Univ. of Virginia
Hossein Tootoonchi — Univ. of New Mexico
Carole Travis — Carnegie-Mellon Univ.
Anthony L. Turkevich — Univ. of Chicago
James Valentine — Temple Univ.
Philip Varghese — Univ. of Oregon
E. Alan Wadlinger — Univ. of Virginia
Louis Wagner — Univ. of Florida
John B. Walter — Univ. of Wyoming
Harvey Wegner — BNL
Richard M. Weiner — Indiana Univ.
Charles Whitten — UCLA
Harvey B. Willard — Case Western Reserve Univ.
Suzanna E. Willis — Yale Univ.
Stephany Wilson — UNM Cancer Center
David M. Wolfe — Univ. of New Mexico
Mary Ann Yates — Carnegie-Mellon Univ.
Mark Zaider — Tel Aviv Univ.
Alex Zehnder — Calif. Inst. of Tech.
Klaus O. H. Ziock — Univ. of Virginia

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