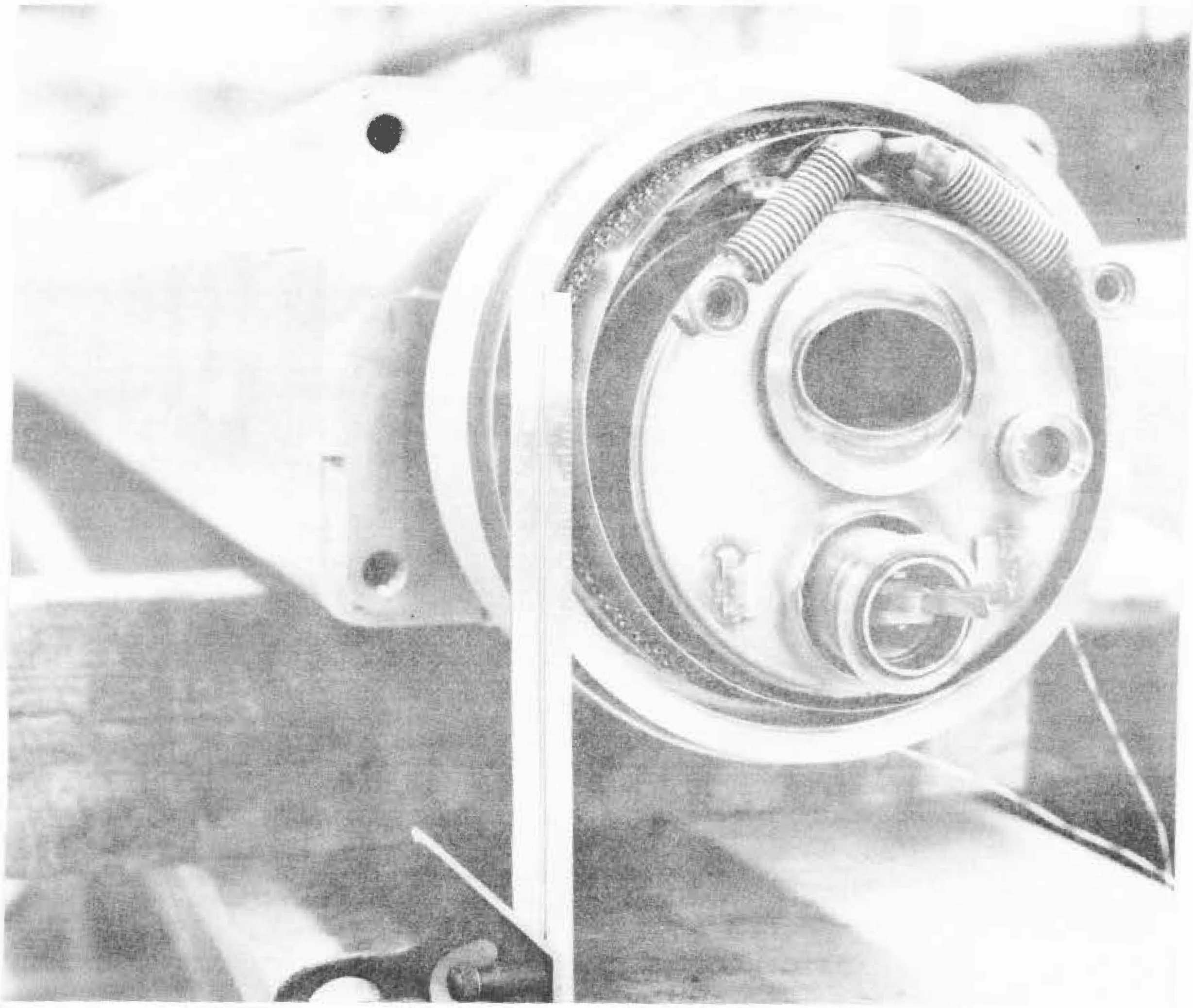
NALREP



Monthly Report of the Fermi National Accelerator Laboratory November 1976

Fermi National Accelerator Laboratory

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THE COVER: End view of Energy Doubler prototype magnet E22-7. The elliptical bore tube is on top, the two-phase helium return line at the right, the single-phase helium line with bus conductor showing at the bottom. One can also see the support system and the superinsulation outside.

CONTENTS

REPORT ON THE FERMILAB PROGRAM ADVISORY COMMITTEE MEETING

E. L. Goldwasser

The Fermilab Program Advisory Committee met for its annual autumn meeting on November 11-12. That meeting was preceded by a two-day Proposal Presentation Meeting which was held on October 14-15.

It remains our general plan, with regard to advice on the Laboratory's research program, to work out the main features of the program during an extended annual summer meeting with our Program Advisory Committee. Additional meetings, which are held during the remainder of the year, are principally for the purpose of tieing up loose ends remaining after the summer meeting and for the purpose of considering timely problems which may appear on a short term basis.

At the recent meeting about 15 individual new proposals were given some consideration. As a result of our discussions, approvals were given for 4 experiments, 4 proposals were rejected, and consideration of 7 additional proposals was further deferred.

One major problem to which we turned our attention was the program of neutrino experiments. As a result of our discussions, E-310, an experiment of the Fermilab-Harvard-Pennsylvania-Rutgers-Wisconsin group, which had previously been approved only for operation with the double focusing horns, was approved for a run during the month of December with the quadrupole triplet and a 1-millisecond spill of protons on the neutrino target. The use of the quadrupole triplet suppresses the low energy events which predominate in the data obtained with electronic detection equipment when it is used with the focusing horns. Thus this new run should give a great deal of valuable information on high-energy neutrino interactions, presumably involving a large number of dimuon events and presumably also containing valuable new data in the region of the suspected high-y anomaly.

The scheduling of the quadrupole triplet for a neutrino run will delay the previously scheduled neutrino and antineutrino bombardments of the 15-ft bubble chamber by a corresponding interval. Following the completion of that run we expect to turn to those experiments.

With the scheduling of E-310 to run with a neutrino beam generated by the quadrupole triplet, it also becomes possible to run the 15-ft bubble chamber simultaneously with the quadrupole triplet beam. No approvals had as yet been given for bubble chamber runs with the quadrupole triplet, but two proposals had been submitted: one, P-460, using a heavy neon mix, and another, P-520, using a light neon mix. A careful study of the logistics of the liquid neon supply indicated that it would not be possible to run a light neon mix just prior to the runs with a heavy neon mix. We have therefore focused our attention on P-460, the proposal for use of the heavy neon mix with the quadrupole triplet beam. That proposal also involves the rearrangement of the EMI so as to give deep coverage in a narrow forward cone and less broad coverage at wider angles. The deep central coverage means a much more positive muon identification in that region, using a double layered EMI with additional hadron absorber. We are now working to prepare for the rearrangement of the EMI so that E-460 can be run simultaneously with E-310. The main purpose of E-460 will be to study, using the techniques available with the bubble chamber and a highly selective EMI, the dimuon interactions which have previously been observed to occur in the data obtained in the experiments which preceded E-310.

In another discussion at the recent meeting it was noted that the first hadron jet experiments that were scheduled during a hadron jet workshop in 1973 are now in an advanced stage of development and operation. It was also noted that a number of new proposals are beginning to surface, designed to explore in some detail the production dynamics and the structure of hadron jets. It seems appropriate before reaching any decisions on new hadron jet proposals to survey the information that should be forthcoming from the present generation of experiments and to take a broad look at all of the new proposals designed to look more deeply into hadron jet phenomena. We therefore intend to schedule a workshop on hadron jets sometime in 1977. It is our tentative plan to hold such a workshop in the month of April or May. All experimenters who feel they may be interested in new jet experiments should collect their thoughts and their proposals on a time scale corresponding to that kind of a workshop schedule.

Another workshop which we are tentatively planning to schedule this spring would be concerned with major new neutrino experiments. During the recent presentation of E-310 the proponents re-emphasized their agreement with the Laboratory's policy that the equipment they have put together for that experiment is available as a Laboratory facility. Several new groups have indicated an interest in undertaking studies of neutrino interactions. Some of those studies would require large detectors, and several ideas have been proposed for detectors which would be entirely different from those which exist today. Plans of this kind are usually discussed at the summer meeting of the Program Advisory Committee. The workshop on neutrino experiments would be held preparatory to the summer PAC meeting in 1977. At that workshop we shall invite presentations of proposals addressed to new neutrino experiments and facilities.

A completely different type of subject was discussed at the recent PAC meeting. Some questions were raised about the difference in procedures that apply to proposals which are presented at our special proposal presentation meetings, such as the one we had in October, and the procedures which are used for proposals which are sometimes presented for the first time before meetings of our full Program Advisory Committee. We have now decided to try to normalize those two sets of procedures, insofar as possible.

Thus, the next meeting of our Program Advisory Committee which will occur in March will be proceeded, as is now standard, by a proposal presentation meeting which is scheduled for February 10-11, 1977. That meeting, like its predecessors, will be an open meeting with all interested physicists encouraged to attend and to participate in the discussions. Furthermore, when we meet in March with our Program Advisory Committee, we will attempt to structure the meeting so that the first portion of the meeting will be held in the Curia II seminar room and will be open to all interested physicists. That interval of time will be devoted to the presentations of any proposals that, for one reason or another, could not be heard in February. Following the hearing of those presentations, the committee will go into the usual closed session.

PROGRESS REPORT ON THE ENERGY DOUBLER

The Energy Doubler Group

Introduction

Since September 1973, the time of the last progress report on the Energy Doubler in these pages, substantial progress has been made on this important development for Fermilab's future. The purpose of this article is to report on that progress.

The possibility of building a ring of superconducting magnets was discussed in 1967 when the basic design decisions for Fermilab were being hammered out in the Laboratory's first temporary quarters in Oak Brook. It was concluded that the technology of superconducting magnets was not advanced enough to commit Fermilab's future to them and the Main Ring was designed with conventional steel and copper magnets. Space was left in the main-ring tunnel for another future ring of magnets, either below the main-ring magnets or suspended from the ceiling.

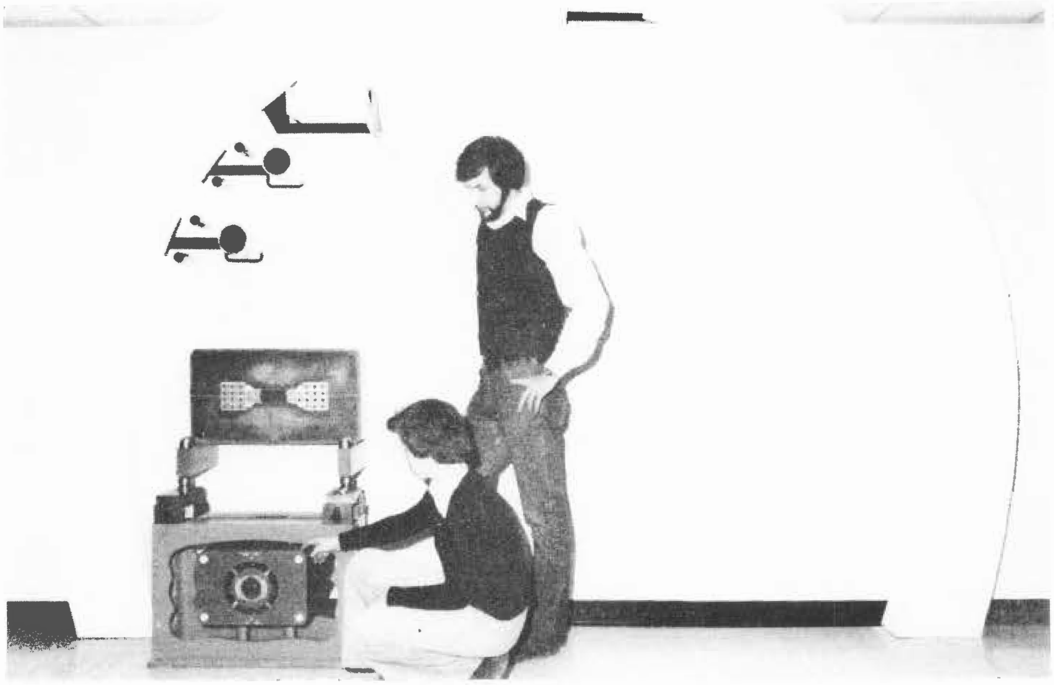
Almost no work was done here on a superconducting accelerator until 1972, after a 200-GeV beam was achieved and operation begun. A group then began exploring the design, fabrication, and use of superconducting magnets and accelerator systems, setting up shop in the former main-ring lab and houses in the Village. Superconducting magnets are fabricated and tested in the Industrial Buildings near the Main Ring.

The basic goal of the Energy Doubler is to provide a means of accelerating protons to 1000 GeV, twice the peak energy of the Main Ring and to achieve this goal with systems that can be installed in the present main-ring tunnel. Injection is to be from the Main Ring, at an energy of approximately 100 GeV. The present experimental areas can be upgraded for use at 1000 GeV.

The Energy Doubler also has other uses. The cost of electric power has more than doubled since the first estimates of operating budgets were made. The superconducting magnets of the Energy Doubler operate with virtually no power loss, so we could save almost all the power now used by the Main Ring (most of our power use) by using the Energy Doubler even at our present operating energy of 400 GeV. With this use in mind, we sometimes use the name "Energy Doubler/Saver."

The Energy Doubler can also be used as a beam stretcher, to increase the length of time over which beam is spilled out to experiments, thus increasing the efficiency of experiments now limited by counting rates. Lengthening the present "flat top" for the conventional magnets in the Main Ring is almost prohibitive because of the cost of electricity.

The course of physics in the last few years has stimulated great interest in colliding beams at Fermilab and many plans have been proposed to achieve such collisions. The Main Ring and Doubler together can produce p-p collisions if beam is accelerated in the reverse direction in the Main Ring. Recent experimental results on achieving smaller, brighter beams by "electron cooling" give interest in accelerating and storing antiprotons for $\bar{p}$-p collisions, which can also make use of the Doubler. To make these collisions as easy as possible to achieve, the Energy Doubler is to be located just under the present main-ring magnets. This location is shown in the figure on the next page.

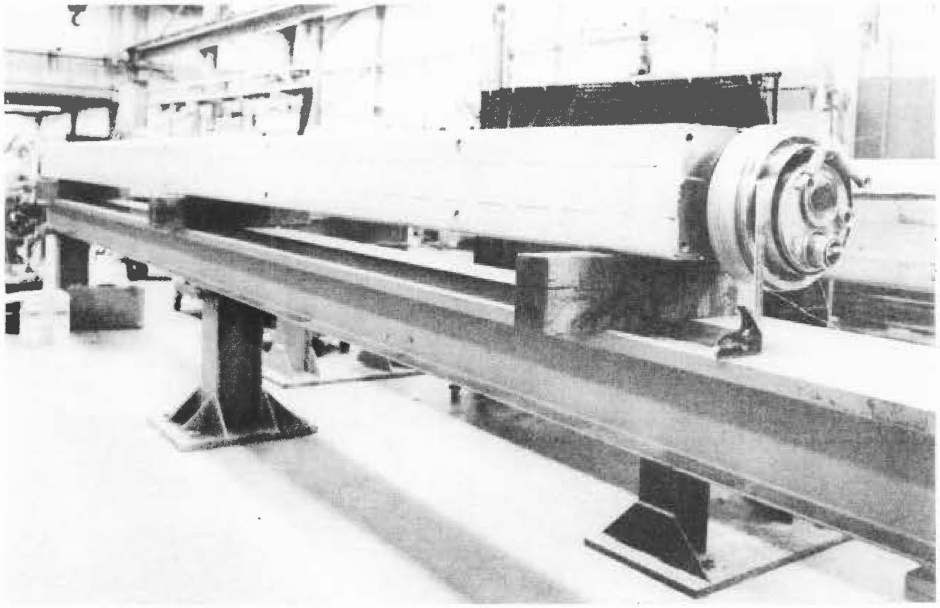


Louise Krafczyk points out the location of the Energy Doubler in the main-ring tunnel model to Wally Habrylewicz.

Most of the effort has been in developing good superconducting magnets and associated cooling systems, but other parts of the design of a complete accelerator have not been totally neglected. We shall review major elements of the design in the paragraphs below.

Magnet

It is entirely natural, since the Doubler must fit into the main-ring tunnel, to duplicate the separated-function main-ring lattice in the Doubler. It is also easier to build separated-function superconducting dipole and quadrupole magnets. A prototype dipole magnet is shown in the closeup on the cover and in toto in the photograph on the next page.



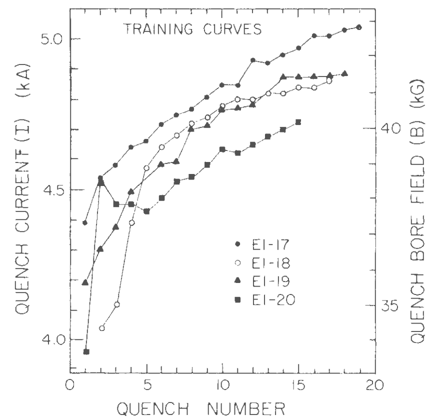
Magnet E22-7, the first full-length magnet constructed with keystone cable and elliptical bore tube.

In both the dipole and quadrupole, the field shape is determined by the distribution of current around the bore of the magnet. The steel surrounding the magnet does not increase the magnetic field or affect its shape very much. Instead, it acts to contain the field, to correct a few selected multipoles and to provide mechanical support. The entire coil assembly, cooling channels, and vacuum tube are held in place inside by very light roller suspensions to reduce heat transfer from the room-temperature surroundings to the liquid-helium temperature coils. A current of 4343 amperes at 1000 GeV produces a field of 4.23 T in the dipoles and a gradient of 0.945 T/cm in the quadrupoles.

These fields represent a large amount of stored energy, approximately 0.5 MJ per dipole. A means must be provided to dump this energy outside coil-clamp system. Electrical insulation is provided by wrapped plastic and glass tapes and epoxy between inner coil and ground and between inner and outer coils.

Test Program. Magnets that meet the requirements of the accelerator have evolved through a strenuous test program designed to understand and control the magnetic and force characteristics of the coils during excitation. The program has included studies of aperture size, mechanical design, wire construction, insulation, cooling methods, and quenching.

Superconducting magnets exhibit "training." That is, they can be excited to successively higher current and field values before they quench. Examples of training behavior are shown in the graph at the right. The evidence indicates that magnets train because the wire moves slightly, largely at the magnet ends, and we now construct magnets that are fully trained after 10 to 15 quenches, a minor part of the test routine for magnets.



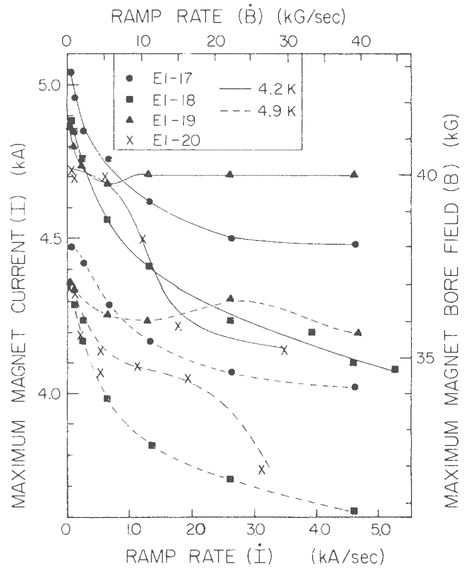
Training of four identically constructed magnets.

We have also studied the effects of ac losses in ramped magnets and have learned how to reduce the sensitivity of peak field to ramp rate. Some results are shown in the graph on the following page. It is clear that rf power and refrigeration, not the superconducting magnets, will be the limiting factor on Doubler ramp rate.

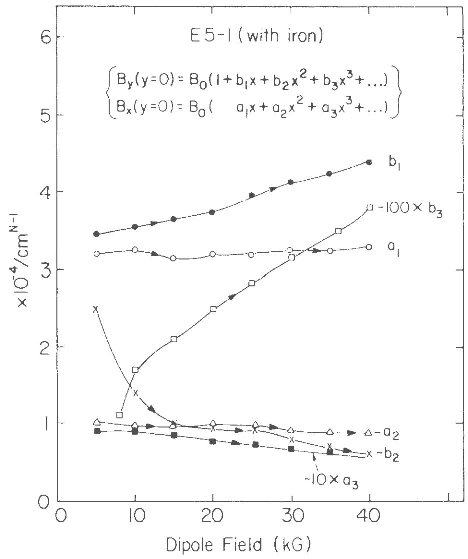
the magnets in the event of a quench, when, for example, the temperature rises above the critical temperature and the magnet "goes normal," that is, ceases to be superconducting. If this stored energy were to be dissipated inside the magnet, it could damage the coils. Electronic quench detectors provide signals to shunt the current through an external resistor by means of a thyristor.

Wire Development. A niobium-titanium alloy is chosen for its critical properties and fabricating convenience. A strand of the superconducting wire contains 2100 superconducting filaments embedded in a copper matrix that provides stability against the spreading of local quenches. A cable contains 23 twisted strands in a flat (0.3 in. by 0.05 in.) array of keystone shape. Originally, it was planned to utilize a monolithic strip, but alternating-current losses when the magnets are ramped dictate the use of twisted cable. The Laboratory has purchased substantial quantities of strands for superconducting wire for the Doubler. Cable is routinely produced by several industrial suppliers.

Coil Collars. Earlier in the Energy Doubler development, the coils were held in place by inner rings and outer spiral-wrapped bands. These bands gave rise to significant twisting distortions and coil deformation during excitation. In a conventional magnet, the good-field region is masked from the exciting coils by the steel poles, but in a superconducting magnet the coils are inside the steel. Coil movement and the accuracy of coil placement therefore have major effects on the field shape. The banded structure was therefore abandoned and replaced by a laminated



Ramp-rate sensitivity of four identically constructed magnets.



Multipole components of E5-1 magnet.

The ramp-rate studies, the coil-collar design discussed in the preceding section, and many other aspects of coil placement and field accuracy have been made possible by development of a field-measurement system for rapid and precise determinations of field values. A nuclear-magnetic resonance and signal-averaging system is used with an on-line data-acquisition system. The graph on the right above shows measurements of multipole field components of a test magnet. The measurements indicate that most higher multipoles are acceptably small, but that the sextupole component is still larger than the design value. This problem is still being investigated.

Cooling System

The Fermilab design is unusual in that the liquid-helium refrigerant is transported around the accelerator through the magnets, not through a separate transfer line. The helium is returned to the refrigerator in an outer counterflow channel that carries heat from the inner channel. A system of 24 satellite refrigerators will be located in main-ring service buildings, fed by a central liquifier. The compressor equipment for this central plant has been obtained as surplus from an Air Force liquid-oxygen plant in California. It will be installed in a building now being constructed for this purpose near the intersection of Roads D and B, near the Main Ring.

NOTES AND ANNOUNCEMENTS

MULTIPARTICLE SPECTROMETER WORKSHOP POSTPONED. . . .

Information from different segments of our Users' community has led us to conclude that our plans for a workshop on December 9-10 to determine a second generation program for the Multiparticle Spectrometer were premature. Accordingly, we have now decided to postpone this workshop until a later as yet unspecified date. Interested readers should watch for announcements pertaining to the rescheduling of this workshop in future issues of NALREP.

MEETINGS TO COME. . . .

A general schedule for PAC-related meetings to be held at Fermilab during the period January-June 1977 is currently in preparation and will appear in next month's issue of NALREP. In the meantime we call to the attention of our readers that Friday, January 28, 1977, is the deadline for receipt of new proposals in the Director's Office which are intended for PAC consideration at the spring meeting (March 10-11, 1977).

APPOINTMENTS. . . .

Richard A. Carrigan, who has served as Director of Personnel Services, will now move into the Directorate to serve a stint as Assistant Director. In addition to his new duties in support of the Directorate, he will retain his previous responsibilities for scientific and engineering personnel. He will also continue his responsibilities for scientific and technical information.

Charles F. Marofske will serve as Acting Director of Personnel Services. He will continue to carry out his responsibilities as Personnel Manager.

Dennis Theriot has succeeded Richard Lundy as head of the Neutrino Department, and Richard Lundy has become associate head of the Neutrino Department.

Drasko Jovanovic has been appointed associate head of the Research Division, having served as assistant head since 1975.

A. Lincoln Read is now head of Research Services.

RESEARCH ACTIVITIES DURING OCTOBER 1976

Halsey Allen

By October 1, there had already been good progress made on accelerator startup from the two-week budgetary shutdown during September. During the first weekend of the month, beam was delivered to the Proton-West Area at both 100 and 400 GeV to complete some absolute beam-intensity calibrations. Startup work continued smoothly with only minor difficulties and by Sunday evening, October 3, tuneup of the extracted 400-GeV beam was underway to all three external areas, using a 1-second flattop. Accelerated beam intensities were gradually improved during October from the 1.5×10^{13} protons/pulse level shortly after startup to an average of 1.8×10^{13} and a peak of over 1.9×10^{13} protons/pulse during the last weekend. After the first week of running, the flattop length was increased to 1.5 seconds. This operating cycle was then maintained through the rest of the month and enabled a match between the very high intensity and spill rate demands of the high-energy physics research program and the capabilities of the accelerator.

High-intensity slow-spilled beam was delivered to all three external experimental areas, in accordance with program requirements, and some 1-millisecond fast spill was also made available in the Neutrino Area. The tuneup and operation of the switchyard within reasonable loss limits under these conditions proved to be a difficult and delicate task, however, and it was often necessary to modify desired beam-splitting ratios. In spite of these difficulties, overall accelerator performance in October was good, with over 450 hours of beam time available for the HEP research program, an operating reliability of 72%. A total of 1.65×10^{18} protons were delivered at 400 GeV and there were several periods of extended running with minimal interruption. The major fraction of the downtime for repairs was split fairly evenly between the linac and main-ring magnet systems.

Work on the muon research program in the Neutrino Area received the greatest emphasis in October, with the Muon #398 experiment starting up and quickly getting into a data-taking mode at the Muon Lab. Their running has all been done with the N1 beam tuned at 225 GeV/c. Elsewhere in the Neutrino Area, Particle Search #379 used slow spill in the N5 beam line in Lab E to complete some trigger and rate studies during the first half of the month in preparation for future extended running. Following those tests, pinged beam was set up in the N3 line to the hydrogen-filled 30-inch bubble chamber, and after several days of tuneup, a run was begun for 30-in. $\bar{p}$-p @ 50 GeV #344, for which a total of over 137K pictures were exposed by the end of the month. The Neutrino #310 group also ran through most of October, making use of a relatively low intensity 1-millisecond spill pulse on the triplet target train at the end of flattop to test their apparatus and begin taking preliminary data. Two emulsion experiments, E-424 and E-510, each exposed stacks parasitically in the 225 GeV/c muon beam.

The Proton Area program also received a major emphasis this month, particularly in Proton-East, where the Total Cross Section #25A experiment continued their data-collecting effort using tagged photons from electron energies of 40, 60, and 90 GeV incident on hydrogen and nuclear targets. This work did not begin until October 8, however, as the first four days of P-East running were scheduled for emulsion exposures and cosmic-ray transition-radiation detector tests in the electron beam at the Tagged Photon Laboratory. Three emulsions/electrons experiments (E-340, E-399, and E-510) and the detector test were completed in this period. The exposures were made at 50, 100, 200, and 300 GeV within 44 hours of running. Photoproduction #152B then used the photon beam for a little over a day of testing before E-25A resumed running. During early October, p-p Elastic Scattering #177A continued to do installation and survey work in P-West. The group has been running since then, tuning up equipment, studying trigger rates, and taking preliminary data. In Proton-Center, the Di-Hadron #494 experiment resumed data-taking activities during October following a few days of startup and tuneup work.

One experiment was completed in the Meson Area this month, five other experiments were engaged in data-taking work, and one group was doing setup, tuning, and testing for their upcoming data run. In addition, a single irradiation was carried out by Nuclear Chemistry #81A. In the M1-West line, Inclusive Scattering #324 completed data-collection for this phase of their experiment after three weeks of running which began in September. The beam was then turned over to Form Factor #456 for setup, initial tuneup, and equipment testing during the fourth week of October. Particle Production #415 in the M2 line also used the beam for three weeks to tune up, test, and collect data at + and -200 GeV in a run which completed the experiment. Particle Search #472 then assumed control of the beam and was quickly taking data. Neutron Elastic Scattering #248 in M3 and K^o Regeneration #226/#486 in M4 were also primarily involved in data-collecting activities. Inclusive Scattering #118A, using the single-arm spectrometer in M6 East, collected data with the incident beam tuned at + and -175 and at -100 GeV/c.

Four groups were involved in the October program at the Internal Target Area. p-N Scattering #381 took data at 50, 150, 250, and 350 GeV with both hydrogen and deuterium, using the cold gas jet, during the first week of October. Nuclear Fragments #442 ran parasitically during this time but due to computer trouble collected only a limited amount of data. p-N Scattering #198A then took data for almost a week using the superconducting spectrometer before turning control of the device over to p-p Polarization #313 at mid-month. The latter group ran during the rest of October, but their data-collecting effort was limited to something less than half of the available beam time because of the inability of the helium liquification system to keep up with the operating demand rate. They were further frustrated by a failure of the liquifier that took some five days to repair. Their data were taken over an energy range of 20 to 400 GeV. The Nuclear Fragments #442 group was also able to take some data parasitically during part of the E-313 running time.

FACILITY UTILIZATION SUMMARY -- OCTOBER 1976

I. Summary of Accelerator Operations

		Hours	
A. Accelerator use for physics research			
Accelerator physics research		49.7	
High energy physics research		452.9	
Research during other use		(26.1)	
	Subtotal		502.6
B. Other activities			
Accelerator setup and tuning to experimental areas		18.3	
Program interruption		29.0	
Unscheduled interruption		195.1	
	Subtotal		242.4
C. Unmanned time			
	Total		745.0*

II. Summaries of High Energy Physics Research Use

	# of Expts.	Hours	Results
A. Counter experiments	18	3710.1	1 completed
B. Bubble chamber expts.	1	144.8	137.3K 30-in. pictures
C. Emulsion experiments	4	44.0	25 stacks, 3 exp. comp.
D. Special target expts.	2	-	2 target exposures
E. Test experiments	1	22.0	e^- test
F. Engineering studies & tests	-	2.2	$\overline{\nu}$ plug test
G. Other beam use	-	73.6	beam tuning in NA
	26	3996.7	

III. Number of Protons Accelerated and Delivered @ 400 GeV ($\times 10^{18}$)

A. Beam accelerated in Main Ring			1.88
B. Beam delivered to experimental areas			
Meson Area		.232	
Neutrino Area			
	Slow Spill	.956	
	Fast Spill	.231	
Proton Area		.232	
	Total		1.65

*Change to Central Standard Time, 0200, October 31.

IV. Beam Utilization by Experiment

	Hours	Results
A. Meson Area		
Nuclear Chemistry #81A	-	1 target irradiation
Inclusive Scattering #118A	366.0	Data
K^0 Regeneration #226/#486	378.3	Data
n Elastic Scattering #248	373.0	Data
Inclusive Scattering #324	263.8	Data
Particle Production #415	190.4	Data; complete
Form Factor #456	45.5	Setup and testing
Particle Search #472	173.1	Data
B. Neutrino Area		
Neutrino #310	292.8	Testing and trigger and background study
30" $\bar{p}$-p @ 50 GeV #344	144.8	137K pictures
Particle Search #379	127.9	Test data
Muon #398	373.4	Data
Emulsions/Muons @ 200 GeV #424	-	1 emulsion stack
Emulsions/Electrons #510	-	2 emulsion stacks
C. Proton Area		
Photon Total Cross Section #25A	274.4	Data
Photoproduction #152B	22.0	Tests
p-p Elastic Scattering #177A	196.7	Data
Particle Production #284	8.9	SEM calibration
Electrons/Emulsion #340	20.0	10 emulsion stacks
Electrons/Emulsion @ 100 GeV #399	12.0	6 emulsion stacks
Nuclear Fragments #466	-	1 irradiation (in progress)
Di-Hadron #494	285.7	Data
Electrons/Emulsion #510	12.0	6 emulsion stacks
D. Internal Target Area		
p-N Scattering #198A	51.4	Data
p-p Polarization #313	178.4	Data
p-N Scattering #381	74.8	Data
Nuclear Fragments #442	55.6	Setup and tests
Total	3920.9	

PROPOSALS RECEIVED DURING OCTOBER AND NOVEMBER 1976

No.	Title	Submitted By
508	Study of the Mechanism for Multiple Production of Particles at High Energies	W. Wolter
509	Search for the Large Angle Scattering of Muons	T. Shirai
510	Study of Cascade Showers Initiated by Electrons	K. Niu
511	Proposal to Study $\bar{p}$-d Interactions at 200 GeV/c with the 30-In. Hybrid Bubble Chamber	A. Fridman
512	The Inclusive Production of Charged Hyperons by Pions	P. F. Shepard
513	Semi-Inclusive Hadronic Interactions at High Energies	G. Brandenberg
514	Proton-Proton Deep Elastic Scattering	J. K. Walker
515	Proposal to Study Charmed Particles Produced in Hadronic Interactions	J. L. Rosen
516	A Study of Photoproduction Using a Magnetic Spectrometer at the Tagged Photon Lab	T. Nash
517	A Proposal to Study Neutrino-Induced Di-Lepton Events Using a Hybrid Emulsion Electronic Detector	A. L. Read
518	A Proposal to Measure Direct Electron Production in p-p Collisions from 100 to 400 GeV/c	F. E. Taylor
519	Proposal to Study High Momentum Transfer Phenomena and Search for New States	P. E. Schlein
520	Search for New Phenomena Associated with High Energy Neutrinos Using the Quadrupole Triplet Beam	W. F. Fry
521	Dilepton Production by Neutrinos in Deuterium	J. Vander Velde
522	A Study of Inclusive Proton Polarization	H. O. Ogren

DATES TO REMEMBER

January 28, 1977	Deadline for receipt of all new proposals to be considered at the March meeting of the Program Advisory Committee.
February 10-11, 1977	Proposal Presentation Meeting.
March 10-11, 1977	Spring meeting of the Fermilab Program Advisory Committee.