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Experimental planning and support - CY 67

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Introduction

Research groups from universities throughout the United States, and resident Brookhaven groups used the AGS for high energy physics research during the year. The research was done using bubble chamber or electronic counters as detectors. The bubble chamber program utilized three chambers and over five million pictures were taken for forty groups with these chambers. In addition fourteen counter experiments collected research data during the year. This research is supported by goods and services supplied by technical groups within the Experimental Planning and Support Division. These groups design, construct, and operate the equipment used in the particle beams at the AGS. Some highlights of the past year's accomplishments follow.

Experimental Facilities and Program

The three bubble chambers are served by four separated beams. These beams span the particle momentum region from less than 1 GeV/c up to 30 GeV/c. The lowest energy beam supplies particles to the 30-in. bubble chamber. The beam is capable of purifying a beam of K mesons to 900 MeV/c, and by a suitable use of material in the beam the energy of the particles can be degraded such that they stop in the chamber.

This low energy separated beam and the 30-in. bubble chamber continued operation throughout the year. Approximately 1.5 million pictures were taken for experiments done with a variety of incident particles and chamber fillings. Low momentum and stopping beams of π^-, $K^\pm$, and $\bar{p}$ were utilized in conjuction with liquid hydrogen and deuterium fillings. The longest run of 0.5 million pictures was made for Princeton University, with shorter runs of 25 to 220 thousand pictures for groups from Stanford, Vanderbilt, Yale, Brandeis, Syracuse and Tufts Universities, Illinois Institute of Technology, the Universities of Rome, Melbourne, California, Massachusetts, Florida and Brookhaven National Laboratory. A run was also performed for University College, London with K^- mesons stopping in emulsions.

Medium energy separated particle beams were obtained from Beam 1A for use in the 31-in. bubble chamber. During the past year experiments have been done with this beam and chamber by groups from the Lawrence Radiation Laboratory, the University of Kansas, Iowa State University, Syracuse University, the Atomic Energy Commission of Argentina, and Brookhaven National Laboratory. About 1.7 million pictures will have been taken in this year employing π^-, K^- and $\bar{p}$ beams in liquid hydrogen and, for one long run, in a liquid hydrogen-neon mixture.

The rate at which satisfactory pictures can be obtained in this latter beam has been improved recently by the installation of a "shutter" magnet, which is a device that can be pulsed to terminate the particle beam after a preset number of particles have entered the chamber. The instrumentation for tuning and monitoring this beam has been improved by the installation of a remotely programmed and operated scanning device at the second mass slit.

Since the last annual report the AGS North Area and the 80-in. bubble chamber has provided exposures for 11 experiments with a total of 1.3 million pictures. About one million of these were taken in the electrostatically separated beams #3, with the chamber filled with liquid deuterium. These include exposures with K^- mesons at 5.0 GeV/c and near 3.8 GeV/c (101 K and 284 K pictures) with protons, π^- mesons, anti-proton and protons at 7.0 GeV/c momentum (87 K, 96 K and 97 K pictures respectively). In the radiofrequency separated beam (Beam #4) the chamber, filled with a hydrogen neon mixture, was exposed to K^- mesons at a momentum of 12.8 GeV/c, and to protons of 28.5 GeV/c momentum (242K and 67K pictures respectively). After being shut down all winter for extensive modifications the 80-in. bubble chamber was filled with hydrogen and resumed experiments in Beam #4 with a K^+ meson exposure at 7.4 GeV/c for a total 137 pictures. In early fall the radiofrequency separators broke down from arcing damage and the deflectors were repolished. An extensive program of about 18 experiments for a total of about 1.8 million pictures is planned for the 80-in. bubble chamber using Beam #4 in the coming year.

Two target areas are used to produce secondary beams for counter experiments. Most of the experiments are accommodated at the G10 area. Three beams radiate from the target within the G10 target box. Each beam is split into two branches out on the experimental floor. In this manner some experiments can be set up while others are running. This increases the efficiency of operation, and smooths out the workload associated with changing experiments. Fig. 1 illustrates the beams to be set-up during the summer of 1968.

On the inside of the AGS ring the beam from G10 is split into a neutral beam and a charged particle beam. The latter beam was used by a large number of groups for testing their apparatus before their experimental equipment was installed in the final location. At any time the test beam had two or three groups using the particles.

The bending magnet that directed particles down the test beam channel swept all charged particles from the straight-ahead neutral channel. This was then used by Columbia Group for a total of 1228 hours. They were studying certain decay characteristics of K_2^o mesons. This was followed by a similar experiment for Harvard University. After 300 hours of data taking, they finished another aspect of K decay. The beam area is now being rebuilt for additional and more sophisticated experiments on K_2^o decay.

The 4.7^o degree beam from G10 on the outside of the ring provided muons for an extensive run by two groups from Harvard. They were both studying inelastic muon interactions and collected data for 1214 hours. Between the two muon runs the other branch of the beam was used for hours for an experimenton large angle scattering of pi meson by protons for a Cornell University group. Another experiment for a University of California group studied the scattering of K mesons on heavy nuclei. The 4.7^o beam is now being rebuilt to accommodate two new experimental setups. On one hand the University of California group returns to study another aspect of K meson decay while the other branch will be used by a group from the State University of New York at Stony Brook. The latter group will be studying the associated production of K and Σ particles by pi mesons.

The other beam from G10 is at 10 degrees on the outside. This beam is purified by the use of electrostatic separators. After a total of 953 hours the experiment of a BNL group measuring the magnetic moment of the cascade hyperon was completed. The other branch of the beam had two experiments in it. One for Columbia University was an experiment studying the production and decay characteristics of eta particles. They studied possible asymmetries in the spectrum of charged pions emitted in the decay. This experiment took 664 hours. Another experiment was able to use particles in this branch of the 10^{o} beam. A University of Rochester group collected data on the neutral decay of K^{o} mesons for 184 hours.

After the winter shutdown of the AGS experiments in both branches of the beam were changed. The short branch now contains an experiment measuring the large angle scattering of K meson in hydrogen for a group composed of physicists from Brookhaven, CERN and Rochester. In the other branch is a large magnetic spectrometer used by a MIT group to measure the energy of particles from the decay of K^{o} mesons.

The remaining target location for counter experiments is at F10. A long sequence of counter experiments has used a secondary beam from a target in that area. The area is now being rebuilt for use of the slow external proton beam. Before the rebuilding began, a large experiment on isobar production by pions and kaons was completed in 1074 hours. This experiment was undertaken by physicists from Brookhaven and Carnegie -Mellon University. At the end of this run, the use of internal targets at F10 was suspended and components for the new proton beam installed.

The massive shields to stop the full extracted proton beam were constructed in the East Experiment Area during this period. The cores of the backstops in which the residual beam will be degraded to a tolerable radiation level consumed some 3/4-ton of tungsten and 2 tons of depleted uranium on the beam analysis channel and 1 ton of tungsten and 4 tons of depleted uranium on the experimental channel. In addition some 1000 tons of steel were used in the shielding. The massive amount of shielding is dictated by the intensity and energy of the beam which creates muon shielding problems.

Construction is progressing on the Phase II backstop for the experimental channel. This is of steel some 18 ft. wide x 10 ft. high by 33 ft. along the beam direction having a re-entrant cavity some 13 ft. deep to contain the residual proton beam after targeting. The channels for extraction of experimental beams are provided at -5.36^{o} and 0^{o}.

The first experiments to utilize the SEPB are being installed. These have been chosen with a view to the physics interest and that their beam requirements. They can utilize the beam in the earliest stages before the optimal qualities of beam and spill are achieved.

Experimental Equipment

During the year there was an average of ten beams either in operation or construction in the East, West, and North Experimental Areas. The scheduling and use of these areas was arranged so that construction of new beams proceeded continuously. Thirty-six man years of effort was expended on new beam construction by personnel within the Experimental Division and from the Plant Engineering and Planning Division of the Laboratory.

A summary of the inventory and usage of major experimental service items is given below:

Item	Inventory	Usage
Magnets	211	86%
Beam Separators	12	83%
Power Supplies	185	79%
Shielding	90 tons	80%
Experimental Power	37 MVA	92%
Experimental Cooling Water	3550 gpm	96%

Miscellaneous Items

The Power Supply Group purchased 20-450 KW SCR controlled power supplies. The cost of SCR controlled units are now competitive with the mag-amp units. They have a higher over-all efficiency and require less maintenance. This group continues to work on power supply improvements with the major improvement this year in the current regulators. The new control units using field effect transistors rather than inverters and choppers have shown a much improved reliability record.

Approximately 8 MVA of new power will be made available along the outer wall of the East Experimental Area via 16 distrubution boxes. This power was provided by purchasing (1) 3750 KVA outdoor transformer (13.8V/480V) and relocating an additional transformer of the same capacity from the Cosmotron. The 13.8 KV power to these transformers will be provided by splicing into an existing feeder cable.

An effort has been made to reduce the downtime on the machine due to magnet failure and to improve the radiation resistance of certain magnets in the G10 area. Eight of the closest magnets to the G10 target are provided with wooden skirts which deflect any water spray due to leaks away from adjacent components and down to water detectors which alarm to a central control room. In addition the coil jumper hoses have been fitted with quick-disconnect fittings to facilitate a regular replacement program with minimum radiation exposure to personnel. Plans are now being made to eventually replace these coil jumper hoses with ceramic spacers. In addition, all magnets in the G10 area (14) have been fitted with 1¼' bronze flexible water supply and return hose. These replaced the neoprene rubber hoses used previously.

Several new magnets were designed during the year. Two special types of C-magnets were designed for use with primary and secondary beams in the slow external proton beam facility. One design is for a large C magnet, designated 18C72 that will be used to direct the proton beam on to production targets. A small C magnet will be used to split off secondary particles produced on such a target from the unused proton.

A complete vacuum system for phase II of the slow external beam has been designed and should be available for installation in June of 1968. Indiun plated metal seals will be used throughout this beam due to the high radiation level caused by secondarys from the proton beam.

A large magnet transporting device, which is capable of lifting, moving and positioning a 100 ton spectrometer magnet within the necessary alignment tolerances has been designed and is now being fabricated. This device could possibly be used to transport and align other large magnets in the experimental area.

The efforts of the magnet study group were divided between research and development of magnet hardware and providing certain precision calibration services.

A harmonic coil was constructed for analysis of the new high gradient 3-in. diameter quadrupoles. An existing 12 in. harmonic coil has been modified for use in the analysis of the new 18-in. diameter quadrupoles. Harmonic aberrations and absolute calibration curves are provided for all types of magnets in use at the AGS.

A large number of Hall probes are routinely maintained and precisely calibrated for use by experimental groups. When modification of large solid angle magnet assemblies are proposed, design assistance as well as computer field studies are provided.

An effort of appreciable significance has been brought to completion in the description of the complex fields of the 120D36 and the 48D48 spectrometer magnets. Computer programs for precise momentum calculation are now available for experimental groups. A very simple method of momentum analysis which will produce precision momenta essentially instantaneously has been successfully applied to wide angle spectrometer spark chamber arrays. Fig 2 shows a magnet modified to provide an unusually large gap.

Magnet design both for beam handling and for accelerators has been pursued. Emphasis in beam transport has been shifting to septum type configuratonns for use in the critical areas where beams are split. Modeling and computations on both window frame and septum dipole iron magnets with high current density cryogenically cooled coils have been made. Fields approaching 40 kgauss appear practical in certain designs. A "yokeless" or "arrow" dipole model was tested with two section coils side by side between plane polefaces. If powered so the fields in each aperture are oppositely directed no field exists outside the two coils, and a return yoke is unnecessary.

The Beam Separator Group operated 12 electrostatic separators in four beams and the rf separated beam. In November six dc separators comprising two triplets were removed from the beam to the 80-in. bubble chamber in order to reduce the electrode spacing. Four separators have been installed in the same beam in the form of two doublets with the expectation that the two doublets will produce the same separation as the triplets. The remaining two separators will be installed later in the slow external proton beam facility.

Six 400 KV power supplies were purchased to replace obsolete units and to power separators in new beams. In addition, two turbine molecular vacuum pumps have been installed on separators in the G10+10^{o} beam with an improvement in over-all operation.

A series of tests conducted on the test separator this past year produced some interesting results. The most significant test was the addition of a grounded shield in the tank to decrease the electrical volume of the vacuum enclosure. The results showed that there was no longer an interaction between the electric and the magnetic fields, the separator operated longer between conditioning periods, and that a higher electric field might be feasible. The tests will continue and modifications based on the results of these tests will be made to beam-line separators as the separators become available.

The rf separators ran successfully until late Fall when internal arcing occurred in one of the deflectors. Inspection of both deflectors showed evidence of arcing with the result that both units had to be burnished and cleaned. It is believed that the cause of the arcing was due to organic contamination. A program was initiated to improve the deflector vacuum systems including the replacement of most of the organic seals with metallic seals.

The Cryogenic Group's major efforts have been directed towards the design, fabricatiom, and operation of liquid hydrogen or liquid deuterium targets. Seven targets were operated at the AGS and five targets were designed. These targets consist of a mylar flask surrounded by superinsulation and a vacuum vessel. Associated equipment includes a liquid hydrogen reservoir, a liquid level indicator for the reservoir and target, a vacuum jacketed transfer line, vapor vent lines, vacuum electronics, and an electrical power control chassis.

The solid hydrogen superconducting magnet system was certainly the most sophisticated of those systems operated. The system includes a closed cycle $4.2^{o}K$ helium refigerator, appropriate purification equipment, superconducting magnet dewar, and solid hydrogen target system. Certain problems were encountered with the magnet recharging techniques. However they were resolved as more experience was accumulated. The refrigerator performed well with over 1600 hours of operating.

Liquid hydrogen and liquid helium transfer lines were constructed and maintained for the various experimental set-ups. The associated equipment for targets which includes liquid reservoirs, liquid level indicator, gaseous vent lines, vacuum electronics, and electrical power control centers have been maintained by the Cryogenics Group.

The Hydrogen Storage Facility has distributed approximately 275,000 liters of liquid hydrogen. Both the 1000 and 175 liter liquid hydrogen transport dewar have been maintained by the Cryogenics Group.

The High Energy Electronic Equipment Pool known as (H.E.E.P.) is a section of the EP & S division. It supplies a large part of the electronic equipment used in counter experiments at AGS. H.E.E.P. has provided equipment for 28 experiments during the year. Equipment utilization has been about 85% due largely to H.E.E.P.'s policy of lending equipment to users outside of the high energy research groups on a "short-term" basis.

H.E.E.P. is running extensive tests to evaluate 200 mHz logic modules in an effort to provide the fastest and most reliable equipment for general use.

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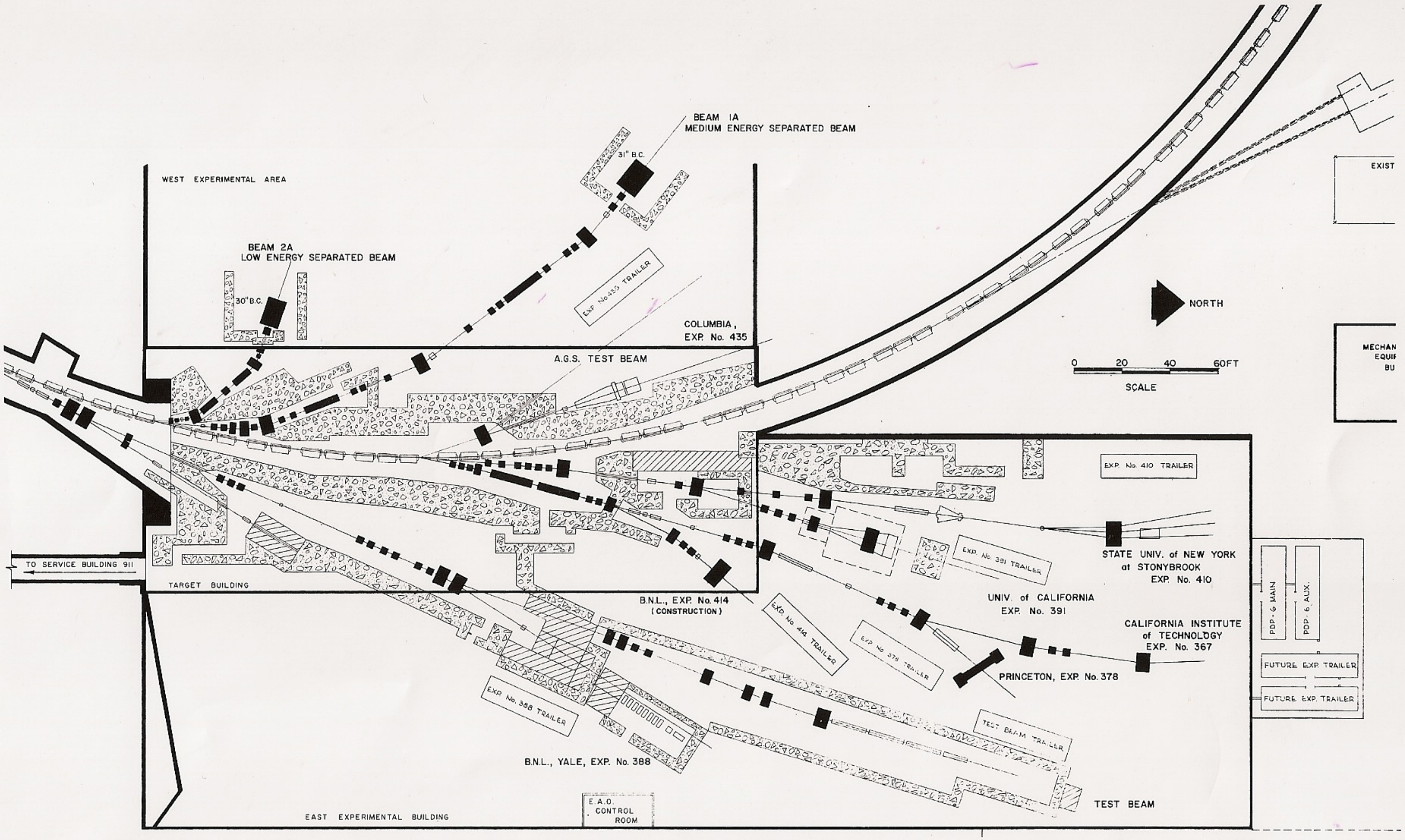

Fig. 1 Experimental setup in the West and East Experimental Areas of the A.G.S., Summer 1968

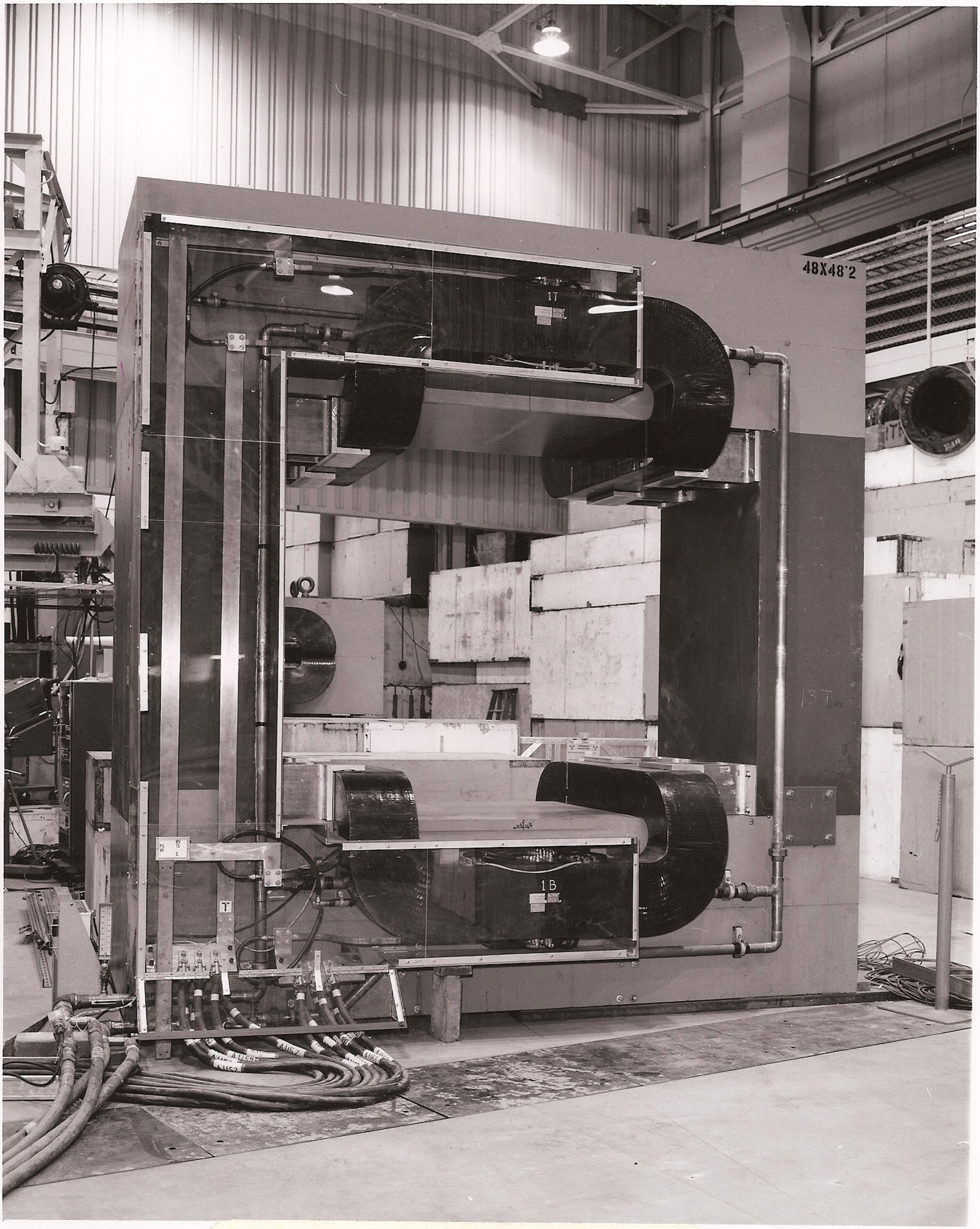

Fig. 2 Spectrometer magnet modified to provide an unusually large gap.