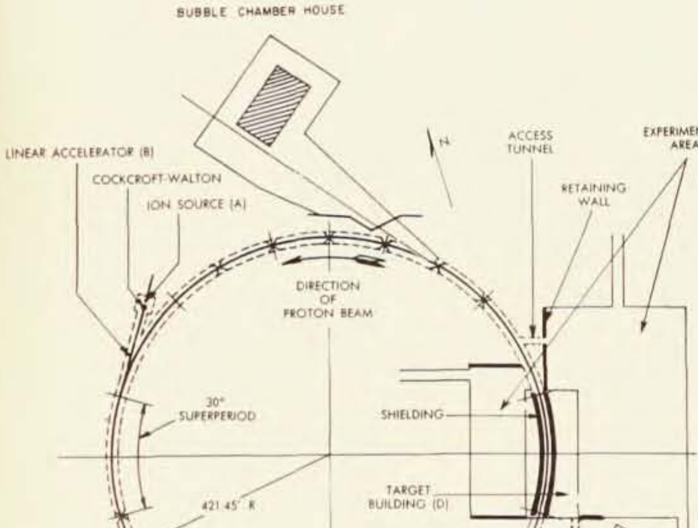
Aerial view of the Brookhaven Alternating Gradient Synchrotron. The half-mile circular tunnel housing the magnet ring is covered with an earthen dike as a shielding measure. At the lower left edge of the ring is the Linac Building, housing the injection system for the synchrotron. The large square structure astride the rear side of the ring is the Target Building, where high-energy experimental equipment will be installed; to its right is the laboratory and office area. (*Photos courtesy Brookhaven National Laboratory.*)



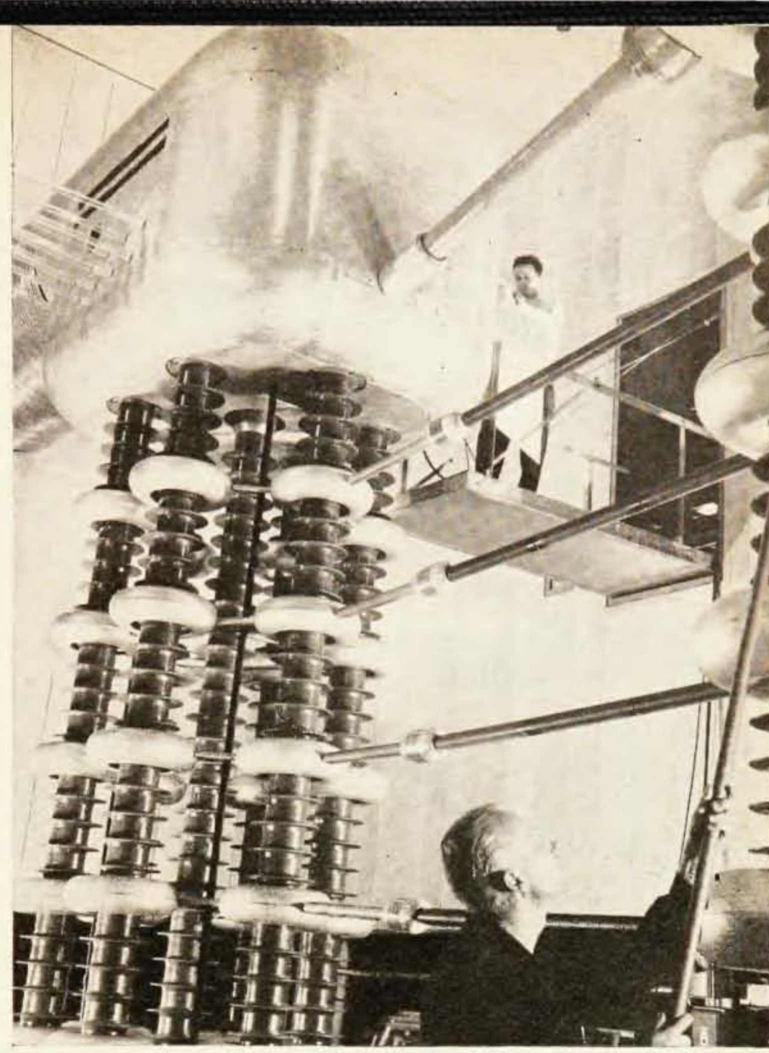
PLAN OF BROOKHAVEN ALTERNATING GRADIENT SYNCHROTRON

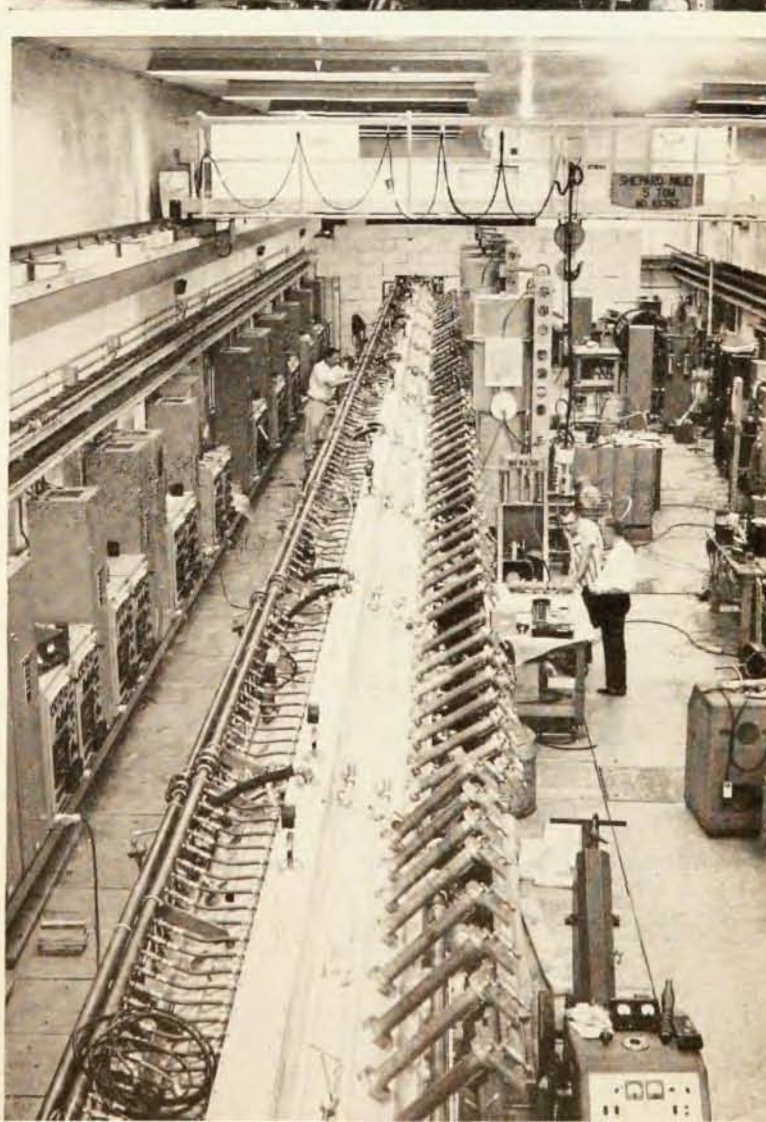
Brookhaven AGS in Operation

The first trial run of the newly constructed alternating gradient synchrotron at Brookhaven National Laboratory was completed successfully on July 29 when the accelerator produced a beam of 30-Bev protons after having operated for about an hour at 24 Bev. Having achieved a satisfactory accelerated beam, the 170 members of the AGS staff expect to devote most of their work during the next few months to perfecting the machine's performance and preparing it for the experimental programs to follow. This will involve efforts not only to increase the intensity of the beam and to determine its characteristics but also to deflect the protons out of the vacuum chamber in order to provide the experimental versatility which an external beam will offer. Most of the initial operation will involve acceleration to approximately 25 Bev. Consistent attainment of the maximum design energy of 32 Bev will require extensive adjustment of equipment for correcting the effects of magnetic saturation in the magnet iron.

After these preliminaries are over, the experimental program is expected to start in earnest with a beam at full energy of more than 10^{10} protons per pulse. Early research efforts will be devoted to the identification of nuclear particles generated when protons from the machine collide with the nuclei of target atoms, and to a thorough search for any hitherto undiscovered particles

AGS injection system includes 750-kev Cockcroft-Walton generator (shown at right) and 50-Mev linear accelerator (seen in over-all view below). To the right of the linac tank and towards the rear are the four "towers" of the high-power radiofrequency system. In background is a concrete shielding wall separating the linac from the main synchrotron magnet ring.



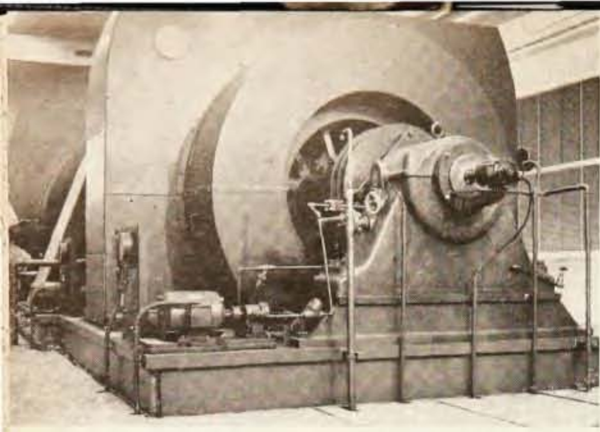


which might be produced at the very high energies made possible by the AGS. One of the primary incentives in designing bigger and better accelerators is the desire to produce an abundance of extremely energetic mesons and to observe their interaction with nucleons under the controlled conditions of the laboratory. The AGS is expected to meet the aims of its designers by proving to be an important and prolific source of high-energy mesons—and of hyperons and antiparticles as well.

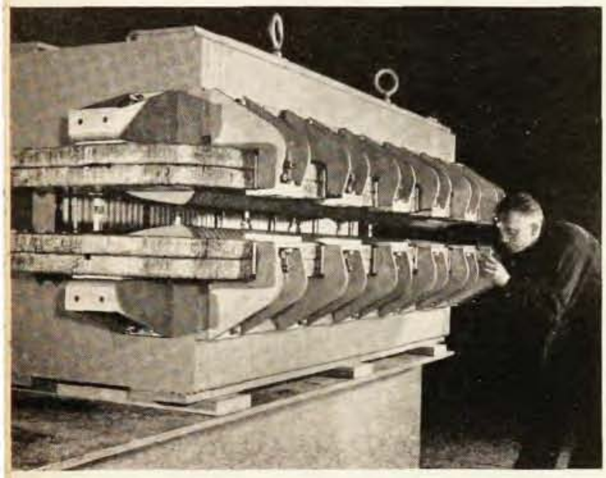
Apparatus for detecting the occurrence of such nuclear phenomena will include stacks of specially prepared photographic emulsions, large and complex arrays of counters of both the scintillation and Cerenkov type, and several of the big bubble chambers now in use at the 3-Bev Cosmotron. In addition, an eighty-inch hydrogen bubble chamber, expected to be the largest in the world, is now under construction at Brookhaven for use in the AGS experimental program.

The work of building the accelerator, which includes 240 magnets placed in a ring-shaped 18-foot square tunnel one-half mile in circumference, was started in late 1955 after several years had been spent working out the preliminary design. The total cost to the Atomic Energy Commission has been approximately $31 million. Major components of the AGS include an ion source for feeding protons into the accelerating tube of a 750-kev Cockcroft-Walton generator, which introduces them at that energy into a 50-Mev linear accelerator. The beam of 50-Mev protons is finally conducted from the linac into the vacuum chamber of the main synchrotron magnet ring through an elaborate injection system of debunching, deflecting, focusing, and monitoring equipment.

The historical origins of the alternating gradient synchrotron can be traced back three decades to E. O. Lawrence's first conception of the cyclotron: a circular-magnet machine for the synchronized radio-frequency acceleration of heavy particles in a spiral path. As cyclotrons grew in size, they began to approach a limit of 20 or 30 Mev imposed by the relativistic mass increase of the particles at high energies, accompanied by a corresponding decrease in revolution frequency. The next step occurred fifteen years ago with the introduction of the phase-stability principle for varying the interval between electrical impulses by frequency modulation to accommodate the rising energy and mass of the accelerated particles. The magnet size of the re-



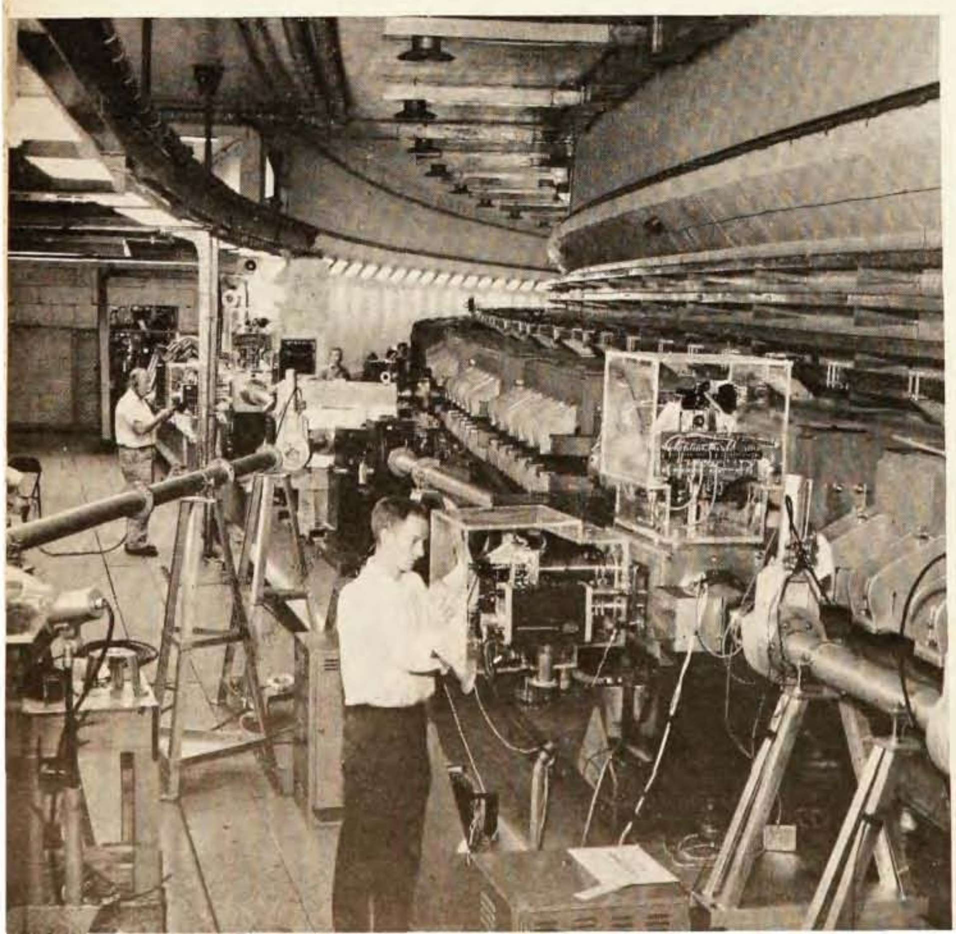
Motor-generator set of the main magnet power supply of the AGS. With no load, voltage is 5000 volts; at full load it is 4800 volts. A 47-ton flywheel serves to store energy from the 6000 hp motor between pulses.



One of the synchrotron's 240 magnet sections, with coils in place. Vacuum chamber for guiding the accelerated protons centers in the gap between the magnet poles. Each magnet section weighs about 16 tons.

sulting family of frequency-modulated cyclotrons was, however, found to have a practical limit in the energy range of one Bev. The sychrotron, devised a few years later by combining the synchronized radio-frequency acceleration of the cyclotron with the constant diameter acceleration of the betatron, resulted in a new family of machines capable of operating in the energy range between one and ten Bev. The first to exceed one Bev was the Brookhaven Cosmotron in 1952, followed in 1953 by the Birmingham one-Bev machine in England and in 1954 by the six-Bev Berkeley Bevatron. In 1957, the Soviet Synchrophasotron at Dubna, which is the largest conventional synchrotron now in operation, reached its full energy of ten Bev. The 36 000-ton magnet of the latter machine emphasized the practical difficulties of building still larger synchrotrons of that type.

The concept underlying the AGS dates from 1952 when E. D. Courant, M. S. Livingston, and H. S. Snyder published their paper on the "strong-focusing" or "alternating-gradient" principle, permitting the use of ring magnets of great diameter but small cross section. The design of the AGS is based on calculations of orbit theory by Dr. Courant. It has since been found that a similar idea of strong focusing had been proposed two years earlier by N. C. Christofilos in Greece, but had not been published. In the conventional synchrotron, the forces necessary to restore a particle to its orbit had been built into the magnet by the introduction of a uniform field gradient. Simultaneous focusing in both vertical and radial directions could be achieved only with relatively weak gradients, and therefore weak forces. In consequence, the particles wandered considerable distances from their orbits and the



View at left shows interior of AGS tunnel at conjunction of linac and main magnet enclosure. Proton beam leaves linac (behind the shielding wall at left rear) and travels along pipe to lower right through a series of focusing lenses and steering magnets into orbit of magnet ring. Extending across aisle to left is exit pipe from analyzer magnet which bends proton beam through 25° for determination of proton energy spread. Above man in foreground is a set of steering magnets for horizontal and vertical deflections. Lucite-covered viewing box in foreground has adjustable slits used in aligning proton beam and examining its spatial and angular distribution for correct focusing adjustments. It also contains a quartz plate which can be rotated into beam for visual observations of beam position and dimensions; protons impinging upon quartz produce light, which is observed by means of TV camera in foreground. Man at rear, wearing interphone set for communicating with control room and other points, stands by another such viewing box.

magnetic field had to be provided over a considerable volume—hence the enormous size of the magnet required for the Russian machine. Much stronger restoring forces can be introduced by the use of high field gradients, if the gradients are reversed periodically around the ring. In such a configuration, the beam is strongly focused in one plane and simultaneously strongly defocused in the other plane. The sequence of focusing and defocusing fields yields a net strong focusing force, and has reduced the necessary magnet cross section to the point where only 4000 tons of steel are required for the AGS, even though its diameter is 843 feet and its circumference one-half mile.

Alternating gradient machines of various sizes are now under construction in a number of laboratories. Next largest in size to the AGS is the proton synchrotron at the CERN Laboratory near Geneva, Switzerland, which first produced a 24-Bev beam in November, 1959, and has since been operated at 28 Bev. From the very start, there has been close cooperation between scientists from CERN and Brookhaven, including joint meetings to discuss detailed design problems, and the interchange for short periods of key personnel.

Oceanographic Commission Proposed

Representatives of the governments of 33 nations, meeting in Copenhagen under the auspices of the United Nations Educational, Scientific, and Cultural Organization, agreed in July that international cooperation in oceanography should be placed on a firm and permanent basis by the creation of an intergovernmental oceanographic commission. The recommendation was approved unanimously and will be submitted for final adoption by UNESCO's General Conference in Paris in November.

The purpose of the commission would be to promote scientific investigation of the oceans through concerted action of the participating states in cooperation with international organizations. It would be established within the framework of UNESCO and would be open to all member states of that agency, as well as of the agencies of the United Nations participating in oceanographic programs.

The commission would recommend international programs to be carried out with the aid of resources of participating member states. It would also be responsible for organizing the exchange of oceanographic data through specialized centers and by other means, and it would serve in an advisory capacity in recommending to UNESCO and other specialized agencies certain activities relating to the training of oceanographers, assistance to the less developed countries, the exchange of information, and the unification and standardization of research methods.

The conference recognized that one of the main obstacles to oceanographic research is the lack of qualified oceanographers and recommended that the number of fellowships financed by UNESCO be appreciably increased. UNESCO was also asked to organize a