the Bulletin Board

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BROOKHAVEN'S AGS BEGINS OPERATION

STATEMENT BY DIRECTOR OF THE LABORATORY

Dr. L.J. Haworth has issued this statement:

The achievement of the AGS in accelerating protons to essentially the full design energy last Friday demonstrated the success of one of the most important projects that has been undertaken at Brookhaven. The availability of this accelerator for high energy physics experiments in the relatively near future will enable the Laboratory to remain in the forefront of research in this highly important fundamental field. For many years to come only CERN (the international laboratory at Geneva, Switzerland) and ourselves will have particles at anything like this energy.

Ken Green, John Blewett, and the entire staff of the Accelerator Development Department have earned the congratulations of Brookhaven, of AUI, of

(cont'd on page 8)

STATEMENT BY ADD CHAIRMAN AND ASSOCIATE CHAIRMAN

Dr. G.K. Green and Dr. J.P. Blewett of the Accelerator Development Department made the following statement today:

Last Friday afternoon was a happy occasion for the ADD. Many of the group have worked nearly eight years on designing and building the machine. Although we knew the AGS would work as planned, it was satisfying to see the experimental verification.

The AGS is an extremely complex machine, and has required the development of many new techniques, ideas, and devices. That such a piece of equipment operates, and came into operation promptly, is the best indication of the caliber and originality of the ADD staff. We have spent considerable time over the last dozen years assembling this group, and we are very proud of it.

The Department must also express its thanks for help from many parts of BNL; shops, maintenance divisions, administrative divisions, and many others.

Although many people have been involved, the actual existence of the AGS has depended most strongly on the personal efforts of Leland Haworth.

(cont'd on page 8)

Main AGS Control Room on Friday, July 29, at approximately 4:00 p.m.

Brookhaven's alternating gradient synchrotron (AGS) operated at approximately its design energy for the first time on Friday, July 29. At 4:15 p.m. it produced a beam of protons at an energy of more than 30 billion electron volts (Bev), the highest energy yet attained by a particle accelerator. Although no attempt was made to maintain this level for more than a few minutes, the AGS had just completed operation for about an hour at 24 Bev.

The project has been under the direction of Dr. Leland J. Haworth, Director of the Laboratory, and of Dr. G.K. Green, Chairman of the Accelerator Development Department, and Dr. John P. Blewett, Associate Chairman.

Commissioner John S. Graham, Acting Chairman of the Atomic Energy Commission, said, "The Commission is gratified that Brookhaven has successfully completed and operated the Alternating Gradient Synchrotron. It is appropriate," he noted, "that this fine new research tool is located at the Brookhaven National Laboratory, for it was there, in 1952, that the principle of strong focusing of the particle beams was discovered. If this discovery had not been made, the magnet for an accelerator capable of reaching the desired energy would have been prohibitively large and expensive."

Construction of the AGS, which includes 240 magnets placed in a ring-shaped 18 foot square tunnel one-half mile in circumference, was started in late 1955, following several years of preliminary design work. The total cost of this latest AEC research facility, including a 60,000 square foot service and laboratory building and an 85,000 square foot experimental building, is approximately $31,000,000.

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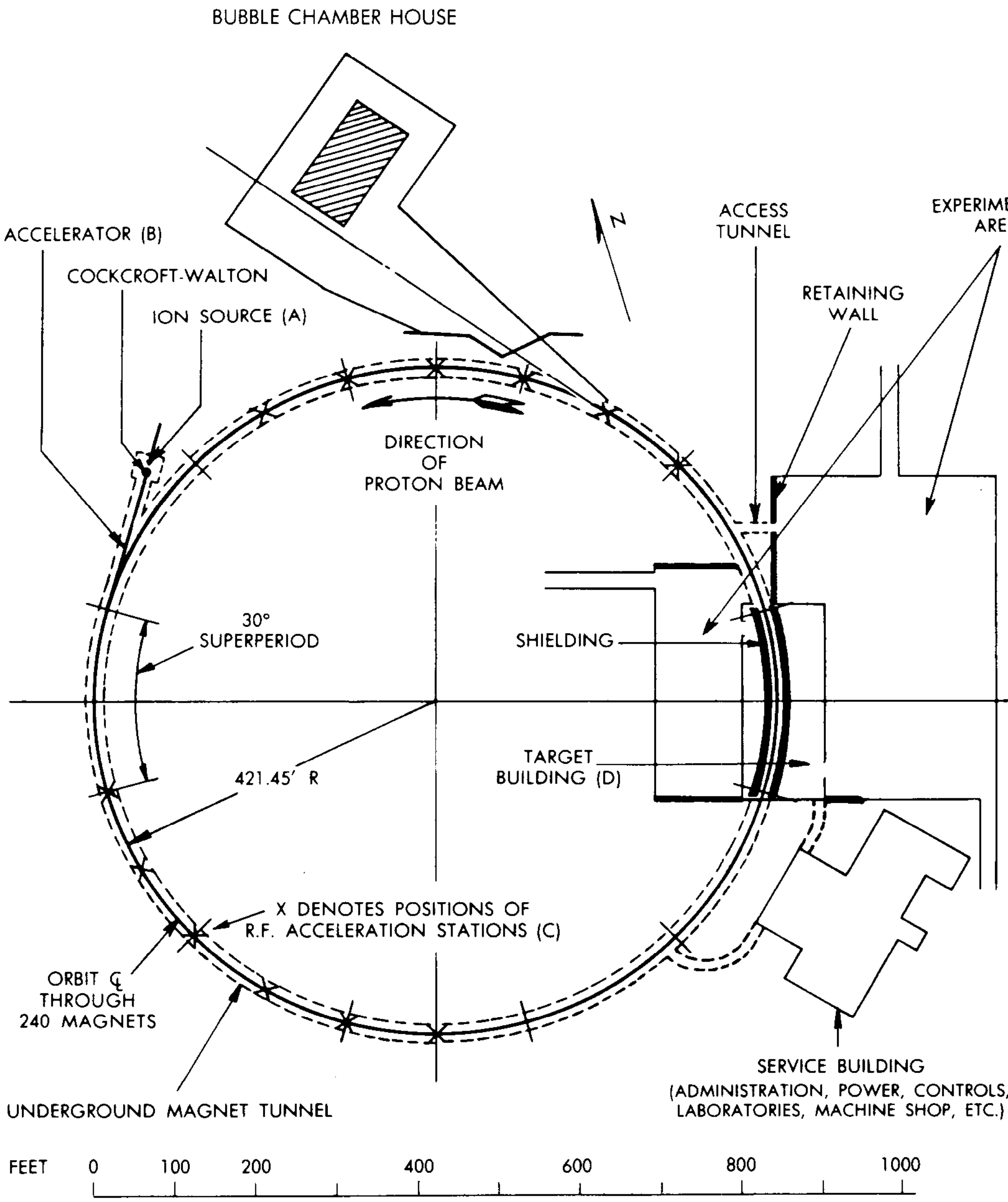
MAIN FEATURES OF THE AGS



PLAN OF BROOKHAVEN ALTERNATING GRADIENT SYNCHROTRON

At about the time Brookhaven's Cosmotron was completed, a new principle was discovered which promised to make the construction of large accelerators much less expensive than would have been possible by simply scaling up older designs. Discovered by E.D. Courant, M.S. Livingston and H.S. Snyder at Brookhaven, the "strong focusing" principle was published in 1952. It has since been found that a similar idea had been proposed two years earlier by Nicholas C. Christofilos in Greece, but had not been published. In 1953 the Accelerator Development Department was formed at BNL to design and construct a large proton synchrotron embodying the new principle. The Brookhaven 30 billion electron volt (30 Bev) Alternating Gradient Synchrotron, or AGS, is the result of this effort.

COCKCROFT-WALTON

The plan drawing illustrates the arrangement of the fundamental components of the AGS. The protons are accelerated in three stages. They are obtained from hydrogen gas by stripping the negatively charged electrons from the gas molecules, leaving bare positively charged protons in the ion source (A in the upper left of the diagram). A high constant voltage of 750,000 volts is maintained between the ion source and ground by means of a Cockcroft-Walton generator. This voltage imparts an initial impulse to the protons by accelerating them through an evacuated ceramic tube. As they emerge at a velocity equal to 4 per cent of the speed of light they are directed into the linear accelerator (B). (cont'd on page 3)

AGS MAIN FEATURES (cont'd)

LINEAR ACCELERATOR

This device, called the linac, is a long, cylindrical tank about 3 feet in diameter and 110 feet long containing 124 "drift tubes" along its axis. The second stage of acceleration takes place while the protons travel through these tubes. In each successive gap between adjacent drift tubes, the particles are accelerated by an electric field, which is set up by feeding high frequency (200 million cycles per second) power into the tank. The strength of the electric field is such that the protons emerge from the linear accelerator at a velocity of one third the speed of light and an energy of 50 million electron volts (Mev).

The proton beam is guided from the linac into the synchrotron proper through an elaborate injection system of debunching, deflecting, focusing, and monitoring equipment.

MAGNET

The circular orbit of the synchrotron, where the third stage of the acceleration is performed, is 842.9 feet in diameter (about one-half mile in circumference). The main magnet, which is divided into 240 units each weighing some 16 tons, must bend the protons into a path of just this diameter, and apply strong focusing forces which always tend to bring the protons back toward their orbit within the vacuum chamber whenever they tend to stray away from it. Thus, as the particles increase in energy the synchrotron's magnetic field must become stronger to hold the beam in the center of the vacuum chamber. The vacuum pipe is only 7 inches wide and 2¾ inches high, a small fraction of the ring's diameter. The vacuum chamber is maintained at a pressure of less than 10^{-5} millimeters of mercury or one part in 76 million of normal atmospheric pressure.

Besides providing a guide field, the synchrotron magnets perform another extremely important function, which embodies the alternating gradient feature of the machine. The pole pieces of each successive pair of magnets are shaped so that the magnetic field alternately increases and then decreases in the radial direction. This alternation of the magnetic field's gradient causes the circulating proton beam to alternately focus and defocus vertically and horizontally and after many traversals of the magnets, yields a tightly focused beam. Thus, the magnets in forming a series of alternately converging and diverging lenses present a beam path with much greater focusing power than the corresponding effect in a conventional "constant gradient" machine.

As a consequence, the beam can be contained in a much smaller volume of space around the circumference of the accelerator. Hence, the magnets can be much smaller with an accompanying saving in the amount of steel and copper required. For instance, the total amount of steel in BNL's 30 Bev machine is roughly 4000 tons, compared to Russia's 10 Bev machine of conventional design whose magnet weighs some 36,000 tons.

The large magnetic gradients require that the individual magnets be very precisely built and aligned to avoid errors in the magnetic field that would cause the beam to stray from the desired path and strike the walls of the narrow vacuum chamber.

ACCELERATION

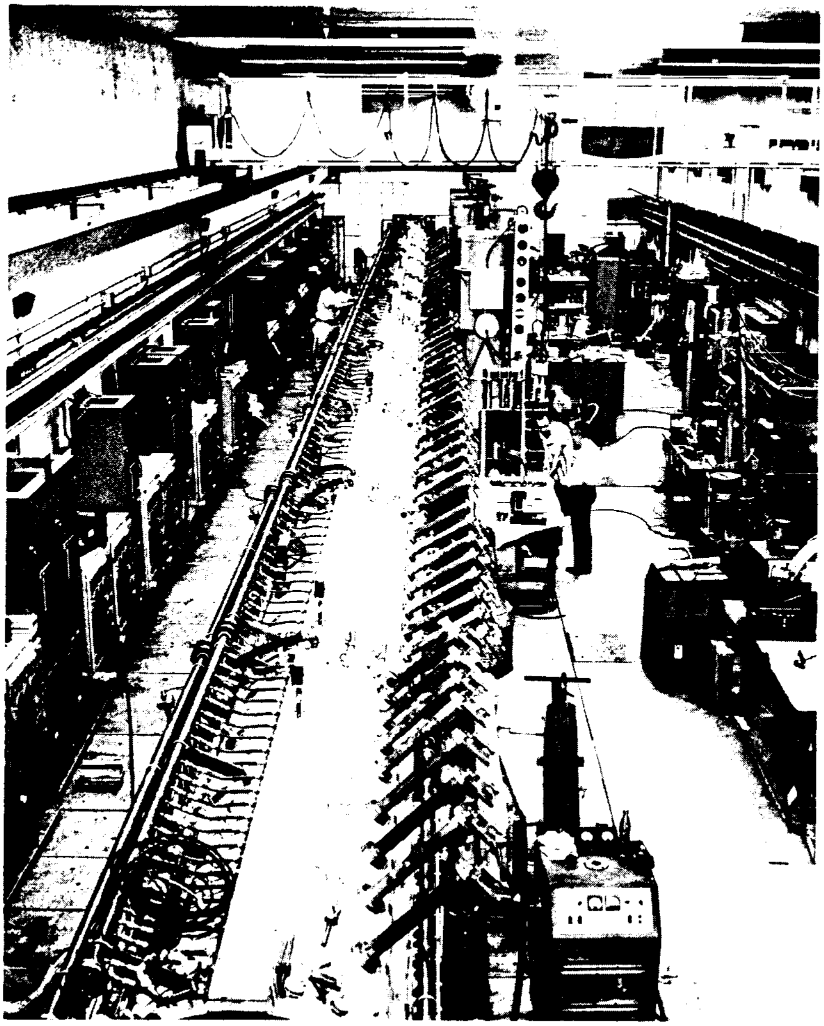
As the protons circulate around the ring, they are accelerated by electric fields produced in 12 radio-frequency acceleration stations (C). At these stations, a high frequency voltage is impressed across two gaps. Protons which cross the gaps when the electric field is in the forward direction are accelerated. If the applied frequency is correct, the same protons will always be accelerated at each gap. In this way, after many traversals very large energies can be acquired by relatively small increments. On the average each of the 12 stations accelerates the beam by about 7,500 volts each time it passes. Therefore, the protons gain about 90,000 electron volts of energy per revolution. To reach 30 billion electron volts, some 325,000 revolutions around the ring are required, a distance in the neighborhood of 160,000 miles. Toward the end of this one-second acceleration period, the protons are travelling at a velocity within less than one-tenth of one per cent of the speed of light, or over 186,000 miles per second. At this velocity, the mass of the protons has been increased more than 30 times, as predicted by the theory of relativity.

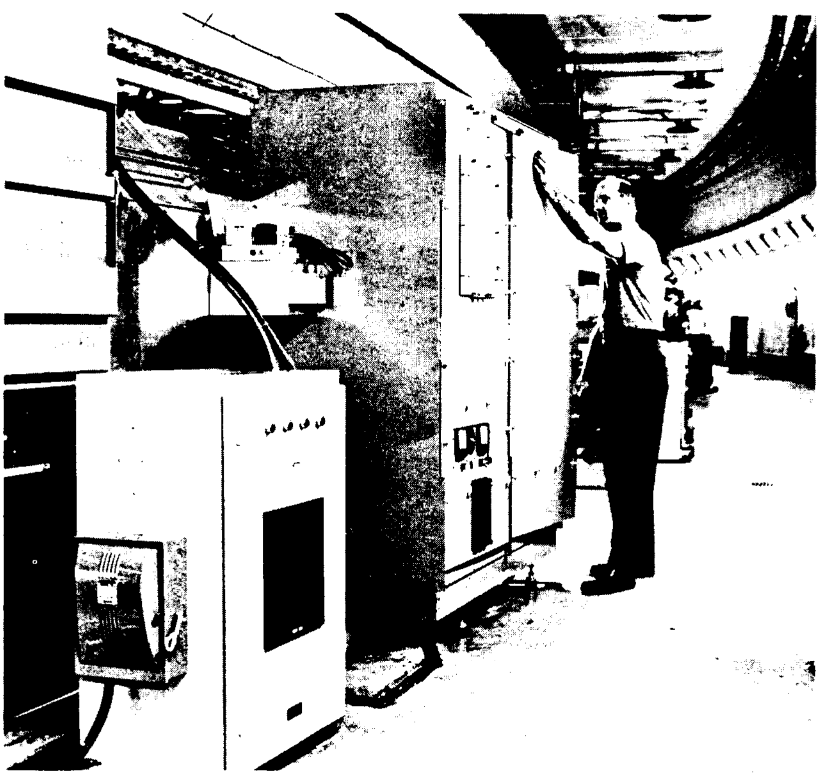
After a two second recovery period the synchrotron is ready to pulse again. 20 pulses of 30 Bev protons will be produced each minute of full operation.

TARGETS

The proton beam is then directed at appropriate target substances and the resulting reactions can be studied by means of the emitted radiations. It is expected that eventually the primary beam can be deflected out of the vacuum chamber and guided into the experimental area, where a number of separate experiments can be installed along the path of the beam and different portions used simultaneously. Most of the experiments will be conducted in the 25,000 square foot target building (D), which within a year will be extended to almost triple its current size.

Most of the elementary particles produced by the interaction of the high energy protons with the nuclei of the target atoms exist outside the atom for only a fraction of a millionth of a second before they decay into other particles or change their mass completely into energy. These brief lifetimes, however, are long enough to detect the particles by sensitive instruments - bubble chambers, counters, or photographic emulsions - and to determine their mass, electrical charge and other properties, or to observe the results when they impinge on secondary targets.





WORLD'S LARGES

Brookhaven's Alternating Gradient Synchrotron, or A energy of any existing particle accelerator. This huge m gering. Its design and construction required the effort a signers, technicians and others, and called upon the ser

When the AGS is in full operation, protons (cores of h through 750,000 volts into a 110 foot long linear accelera tons are accelerated to a velocity of one third the speed "Tuning" the linac is an extremely complicated process. which must be in exactly the right position to get the des

The protons are injected into the half mile ring by a protons from the straight course they have followed in th

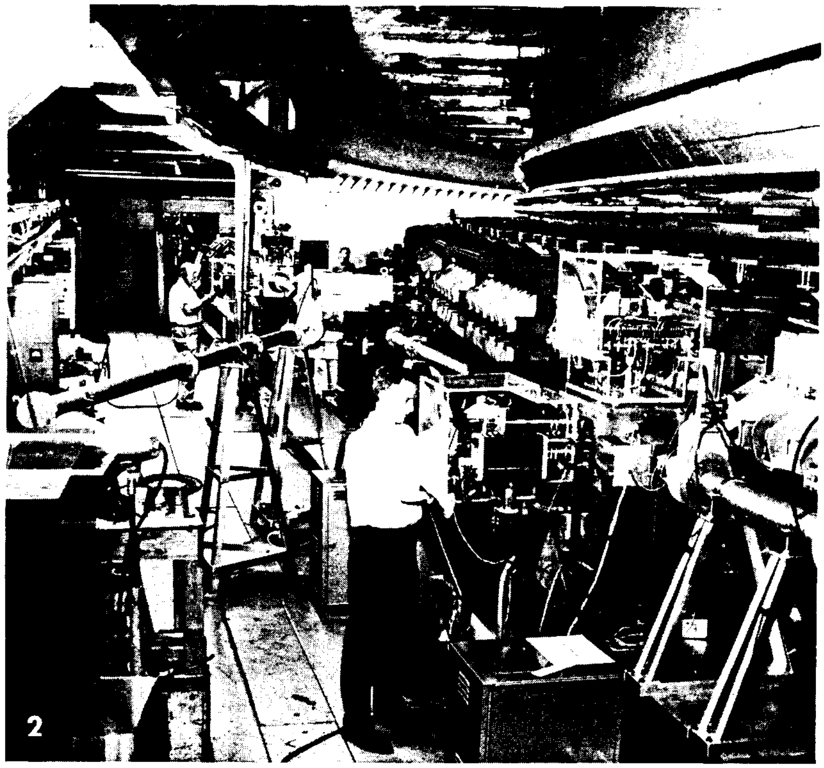
The main synchrotron ring is housed in an eighteen ring, the protons are accelerated by 12 radio frequency s electron volts (30 Bev). Two hundred forty magnets arou entire acceleration period takes one second. In this time ring, a distance equal to six trips around the world. They a over 186,000 miles per second. After a two second recov pulses of 30 Bev protons are produced each minute of op

The beam may then be bent so that it strikes a targ perimental area. 14,000 tons of heavy concrete shielding the target building.

When the protons strike a target, they interact with t such as mesons and hyperons, and also anti-particles of v some of which were discovered in the past several years research on the AGS. This new facility will give American with than ever before.

The high magnetic field gradients coupled with the ticles are accelerated, resulted in the necessity of exactr edented in a large construction project. The magnets, fo than twenty thousandths of an inch.

The completion of the AGS has given scientists in th the heart of the atom.



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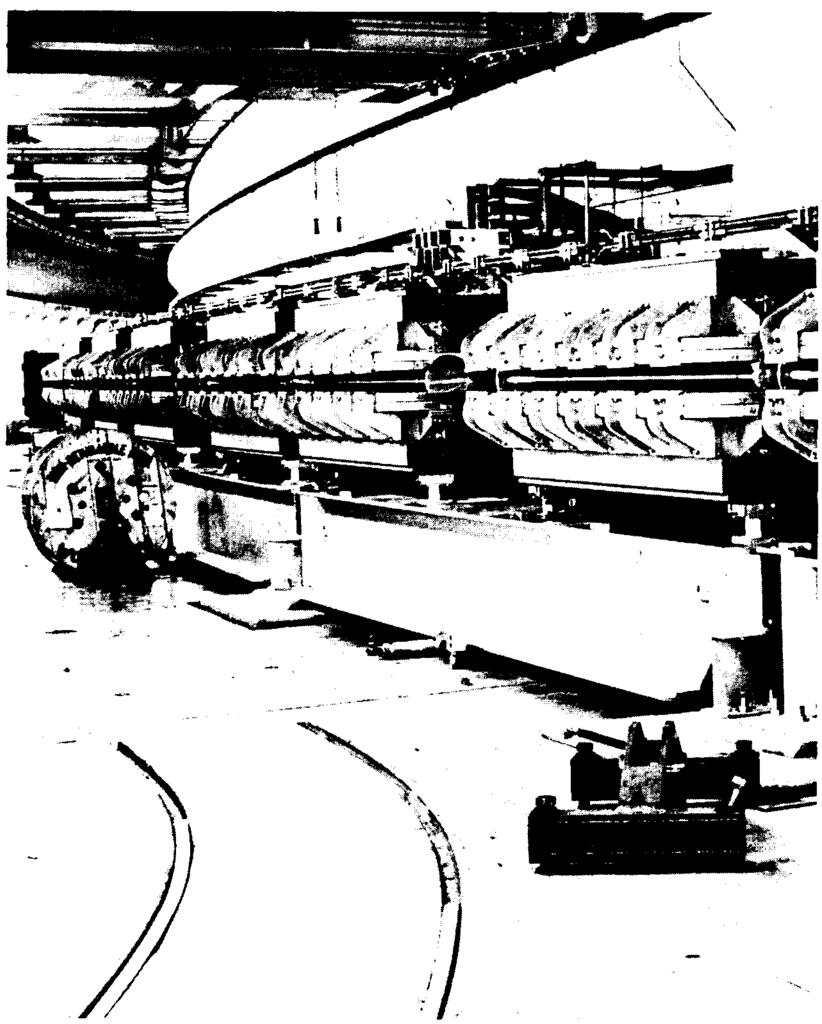
ATOM SMASHER

nder construction for five years, has the highest design
e works with speed and precision that is almost stag-
operation of a large team of engineers, physicists, de-
and talents of many people throughout the Laboratory.
;en atoms) are shot out of a Cockcroft-Walton generator
ee Figure 1). In the linear accelerator, or linac, the pro-
;ht and an energy of 50 million electron volts (Mev).
omparable to tuning a radio which has 64 knobs, all of
tation.
icate injection system (Figure 2), which must bend the
c into the start of a circular orbit of the synchrotron.
square tunnel covered by ten feet of earth. Once in the
is (Figure 3) located around the tunnel to thirty billion
ring (Figure 4) keep the beam in the correct orbit. The
otons have made some 300,000 revolutions around the
velling at a speed only slightly less than that of light, or
eriod the synchrotron is ready to pulse again. Hence, 20
n.
is deflected completely out of the chamber into the ex-
ks cover that portion of the magnet ring that intersects

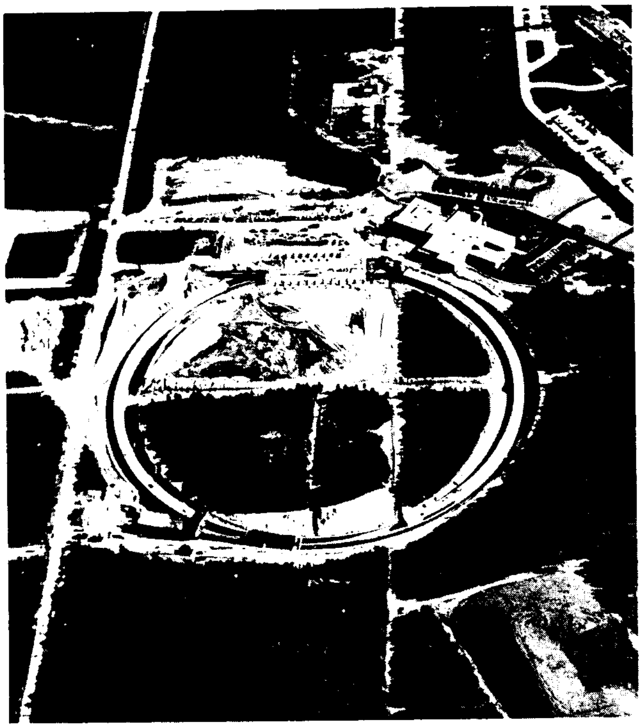
clei of the target atoms, producing subnuclear particles
kinds. Scientists are very curious about these particles,
possible that new particles will be discovered through
itists larger numbers of these strange particles to work

vely minute size of the chamber through which the par-
f surveying, measuring and engineering almost unprec-
nple, could not vary from their proper position by more

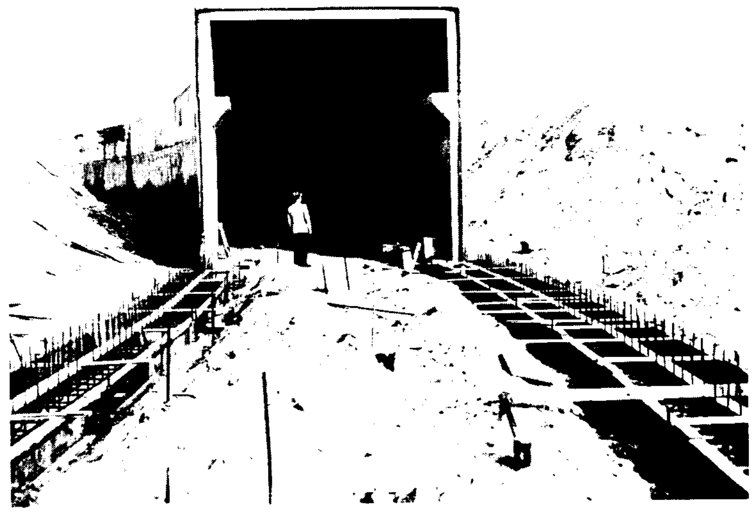
ted States an important new tool with which to examine



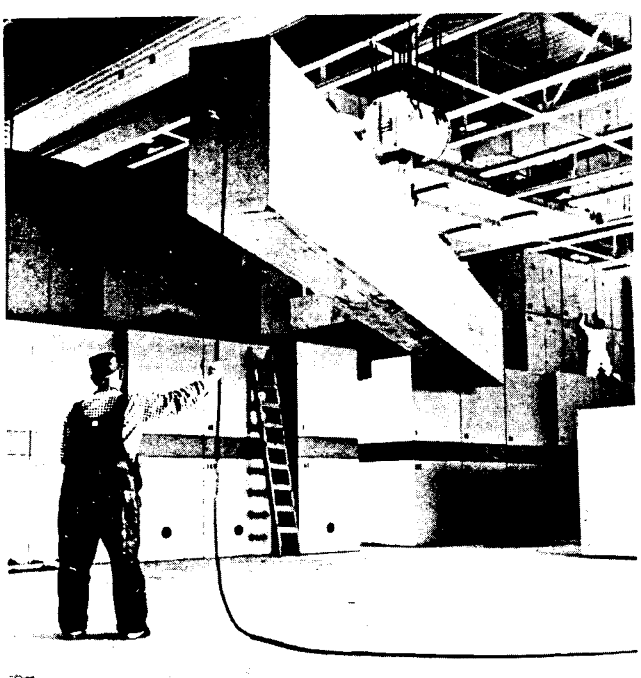
UNDER CONSTRUCTION THE AGS



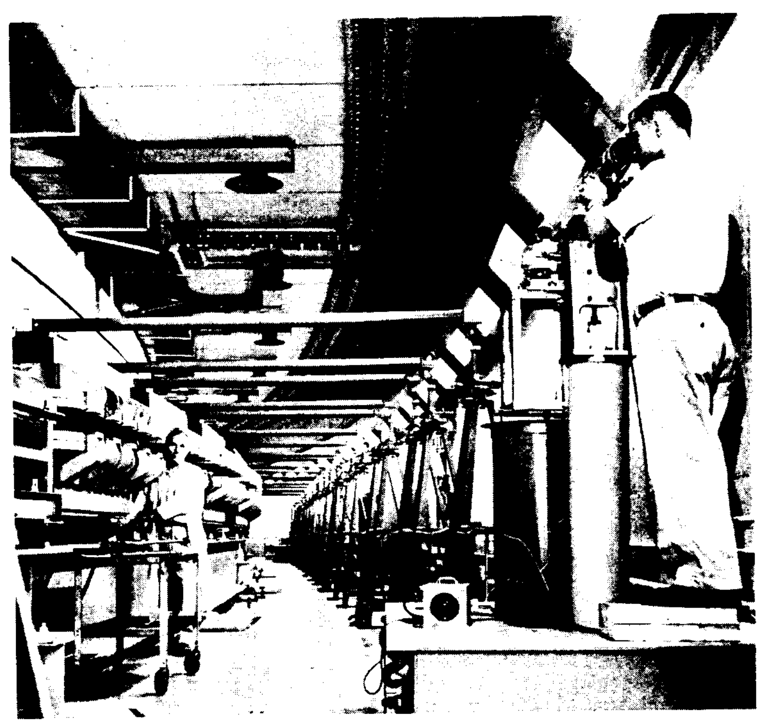
Construction of the AGS - photo taken in 1956.



Construction view in 1956 of concrete tunnel to house magnets for AGS.

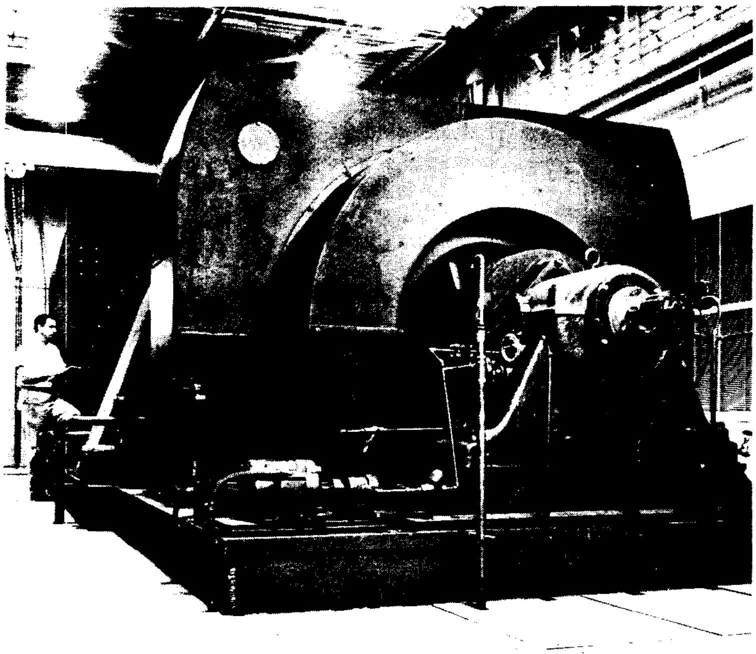


Moving Concrete Shielding Blocks into position in the AGS Target Building in 1958. These concrete blocks weigh 240 lbs. per cubic foot; some of the 1446 blocks weigh as much as 34 tons.

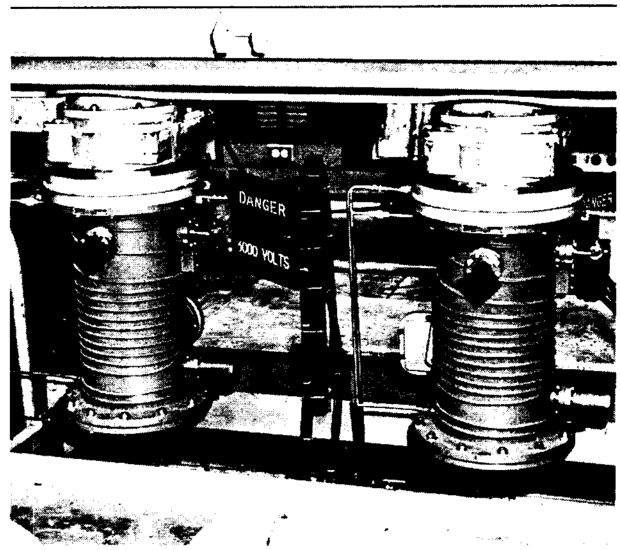


Positioning the Magnets in 1959 by means of precise surveying instruments. The line of sight in the AGS tunnel is being taken from the primary monuments that were installed by the U.S. Coast and Geodetic Survey.

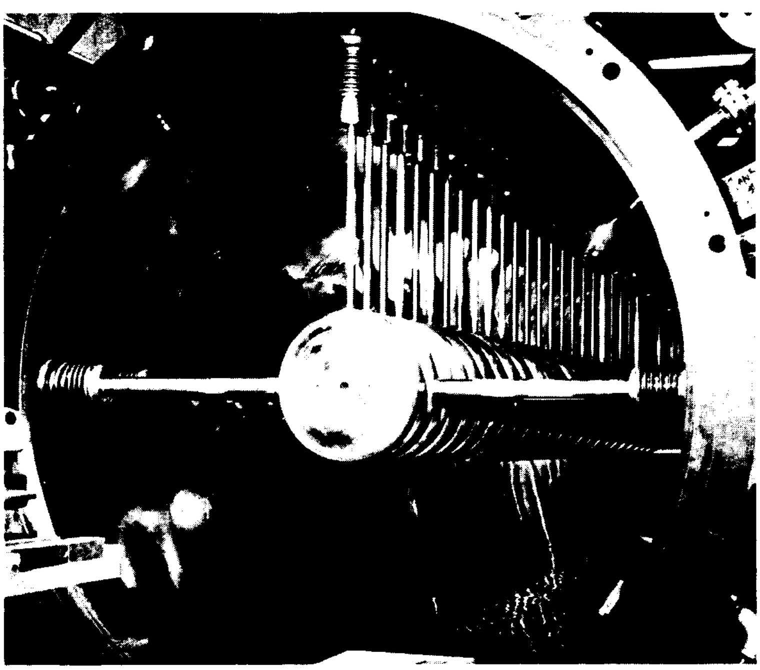
IN PICTURES READY TO GO



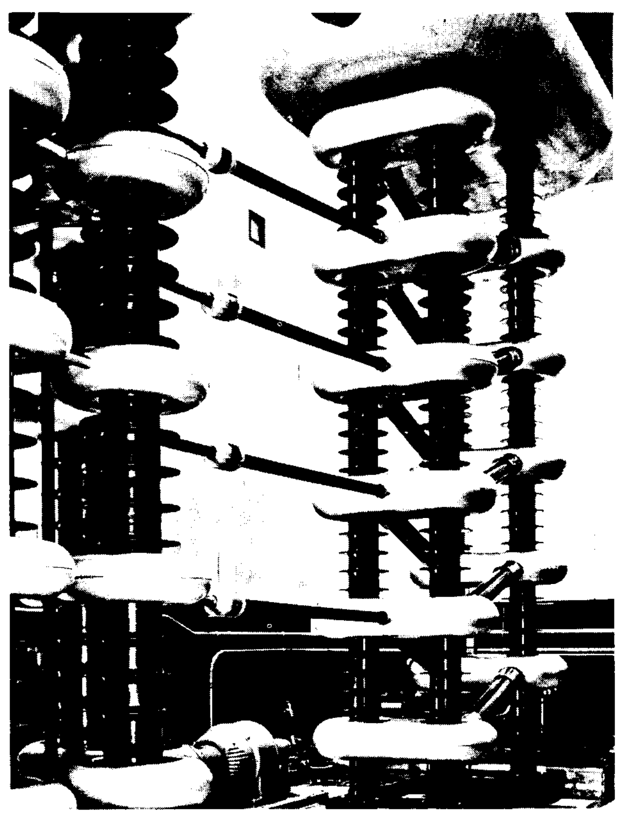
Motor Generator Set of the main magnet power supply of the AGS. With no load, the vol-age is 5,000 volts, and at full load it is 4,800 volts. A 47-ton flywheel serves to store energy from the 6,000 HP motor between pulses.



Linac Evapor-Ion Pumps in Position. These pumps produce a vacuum of about 2×10^{-6} millimeters. There are 20 of these pumps on the linac and 48 spaced around the main AGS ring.



Internal Arrangement of the Low Energy End of the Linac Tank. The drift tubes (accelerating electrodes) and their vertical and horizontal support stems are seen inside the tank. The proton beam passes through the small hole in the center of the 124 drift tubes. The spherical object in the upper right-hand section of the tank is a ball tuner, which serves to provide the correct resonant frequency of the tank.



Cockcroft-Walton Generator soon after installation in 1959. This machine provides the initial acceleration to the protons, after which they are injected into a linear accelerator before entering the orbit of the AGS.

AGS BEGINS OPERATION (cont'd)

The completion of the AGS represents an important step forward in USAEC-sponsored studies on nuclear forces and the properties of sub-nuclear particles. It will enable scientists in the United States to study nuclear interactions at energies about five times greater than ever before possible in this country. Another accelerator, quite similar in design and size to the AGS, has been completed at the European Organization for Nuclear Research (CERN) Laboratory, near Geneva, Switzerland. The CERN Proton Synchrotron first produced a beam of 24 Bev on November 24, 1959, and has since been run at 28 Bev.

Since 1954, the most powerful accelerator in this country has been the 6.2 Bev Bevatron at the University of California's Lawrence Radiation Laboratory. With a machine in the 30-Bev range, physicists at Brookhaven expect to learn more about the many kinds of particles, such as mesons and hyperons, and the various "anti-particles", that are produced in target nuclei by bombarding them with high energy protons.

Having successfully produced an accelerated beam in the AGS, the scientists and technicians operating the machine will devote most of their efforts within the next few months to perfecting its performance for experimental work. Attention will be concentrated on increasing the intensity of the beam, which was relatively low in the initial operation, and on determining the beam characteristics. Among other information, these early studies will determine the arrangement of the auxiliary equipment to be used for guiding particle beams into research devices.

DIRECTOR'S STATEMENT (cont'd)

the AEC and indeed of the scientific community and the public at large. They have worked diligently and effectively for many years to achieve this end. Special congratulations are also due Messrs. Courant, Snyder and Livingston whose brilliant concept of strong focusing has once more proved its great utility. Important contributions were also made by countless individuals in other departments and divisions of the Laboratory, whose unstinting assistance to the members of the Accelerator Development Department were vital to the success of the project.

We are deeply indebted to the Atomic Energy Commission whose wisdom and prompt action enabled us to initiate the project at an early date and whose continuing financial and other support were essential to its effective prosecution.

The successful operation of the AGS was a remarkable achievement. In the glow of success, however, we must not forget that the accelerator is a means to an end rather than an end in itself and that a successful research program is the ultimate objective. I am sure that all those who have already worked so hard and the many more who will join in the research program will bend every effort to make that program a highly significant one.

To all of those involved in our present success I extend the congratulations and thanks of the Laboratory, the Board of Trustees and myself.

AGS DESIGN SPECIFICATIONS

Type of particles........................Protons
Energy..........30+ billion electron volts
Pulse rate.........................20 per minute
Output............ ~10^{10} protons per pulse

MAGNET

Focusing type........Alternating gradient
Mean radius.............................421.5 ft.
Sectors, number..............................240
Field at injection....................121 gauss
Field, maximum................13,000 gauss
Power input,
maximum................33,000 kilowatts
Rise time..............................1.2 seconds
Weight........................Steel - 4000 tons; copper - 400 tons

APERTURE

Width.....................................6 inches
Height.................................2.7 inches

SHIELDING............Earth and concrete

INJECTION SYSTEM

Type........................Linear Accelerator
Energy.....................................50 Mev
Injector output................3 milliamperes

ACCELERATION SYSTEM

Frequency............1.4 to 4.5 megacycles per second
Accelerating cavities.........................12
Energy gain, average....90 Kev per turn
Input to radiofrequency,
maximum......................500 kilowatts

CHAIRMEN'S STATEMENT (cont'd)

He recognized, in '52 and '53, the favorable conjunction of ideas and circumstances, and moved immediately to obtain authorization and to begin construction. We have had his strong and constant backing. In addition, Dr. Haworth has quietly made numerous technical suggestions. Several of his ideas are built into the AGS.

We hope soon to be initiating an experimental program. Since this will take us into a little-explored energy range, we confidently expect that the results will repay the effort expended in building the AGS.

MILESTONES IN THE CONSTRUCTION OF THE AGS

SUMMER 1952	Concept of strong focusing principle.
AUGUST 1953	Proposal made to the U.S. Atomic Energy Commission.
JANUARY 1954	Authorization and funds allotted by Atomic Energy Commission.
LATE 1955	Construction of service building started.
DECEMBER 1955	Beam in electron analogue accelerated to 5 Mev.
JANUARY 1956	Digging started for circular trench to house magnet tunnel.
NOVEMBER 1956	Staff moved into new service building.
MARCH 1958	First magnets delivered.
NOVEMBER 1958	Motor generator set delivered.
MAY 1959	First beam accelerated by Cockcroft-Walton generator. Last magnets delivered.
APRIL 13, 1960	Linac proton beam accelerated to 50 Mev for first time.
MAY 17, 1960	50 Mev proton beam injected into synchrotron and successfully completed one turn around the ring.
MAY 26, 1960	Beam injected into synchrotron and successfully spiraled around ring approximately 100 times without r-f acceleration.
JULY 22, 1960	First attempt at appreciable acceleration resulted in occasional pulses to phase transition at a few Bev.
JULY 29, 1960	Beam consistently passed through phase transition and was accelerated to above 30 Bev.