# BROOKHAVEN ALTERNATING GRADIENT SYNCHROTRON

**Brookhaven National Laboratory, Upton, L.I., N.Y.**

*(presented by G. K. Green)*

## SYNCHROTRON DATA SHEET

Person in charge . . . . . . . . G. K. Green, J. P. Blewett

Person supplying data . . . . . . . . . . . . G. K. Green

### History and Status

| | |
|---|---|
| Design study | begun autumn, 1952 |
| Model tests | Electron Analogue, 1954 |
| Engineering design | begun 1954 |
| Construction started | trench digging—Jan., 1956 |
| Completion date | expected 1960 |
| Scheduled operation | eventually 120 hrs/wk |
| Magnet cost (overall) | $ 6 000 000 |
| Total cost | $ 29 600 000 |

### Design specifications

**Magnet**

| | |
|---|---|
| Focusing, type | alternating-gradient |
| Focusing, order | ½FO½F½DO½D |
| Field index, *n* | 357 equivalent |
| Orbit radius | 85.37 m, 280 ft |
| Mean radius | 128.5 m, 421.5 ft |
| Sectors, number | 240 |
| Field, at inj. | 121 G |
| Field, max | 13 000 G |
| Power input, max | 33 000 kW |
| Storage system | flywheel |
| Rise time | 1 s |
| Weight | Fe 4000; Cu 400 tons (U.S.) |

**Aperture**

| | |
|---|---|
| Width | 15 cm, 6 in. |
| Height | 7 cm, 2.7 in. |
| Shielding | earth, concrete |

**Design Goals**

| | |
|---|---|
| Particle accelerated | Protons |
| Energy | 30 GeV |
| Pulse rate | 20 /min |
| Output | ~$10^{10}$ part/pulse |

**Injector System**

| | |
|---|---|
| Type | Linear accelerator |
| Energy | 50 MeV |
| Injector output | ~1 mA |
| Injection period | 1 turn |
| Inflector type | pulsed electrostatic |

**Acceleration System**

| | |
|---|---|
| Frequency | 1.4 to 4.5 MHz |
| Accel. cavities | 12 double |
| Harmonic number | 12 |
| Orbit freq. final | 0.37 MHz |
| Gain, ave | 80 keV/turn |
| Input to RF, max | 500 kW |

### Unusual Features of Installation

Pulsed alternating gradient proton synchrotron with small aperture and large radius. This type of machine has been studied extensively but has not yet been operated. The Brookhaven AGS and the CERN Protron Synchrotron are similar in basic design.

### Published Articles Describing Machine

1. Blewett, J. P. The proton synchrotron. Rep. Progr. Phys., *19*, p. 37-79, 1956.
2. Green, G. K. and Courant, E. D. The proton synchrotron. In Handbuch der Physik. Berlin. Springer, 1959. *44*, p. 218-340.

## STATUS REPORT

The Brookhaven AGS is still under construction. It is hoped that beam can be injected quite early in 1960. Although unknown contingencies make any accurate schedule prediction impossible, it is reasonable to expect that particle beams of somewhat uncertain quality will be available during the summer of 1960, and that operation suitable for serious and sustained research will be obtained at the end of 1960.

Present buildings include the service building (with offices, laboratories, control rooms, pump room and power room), the ring, the linac house, the target building and a warehouse (see Fig. 1). These structures are already somewhat inadequate; additional offices are being added, and plans are being proposed for addition of laboratory and assembly area space.

The magnets are completely assembled on the ring and have been pulsed to some quarter of full power (see Fig. 2). Tests of the 240 magnet units showed uniformity, unit to unit, well within allowable tolerances. Moderate variations in remanence from unit to unit have been minimised by an arrangement on the ring which reduces the harmonics in the vicinity of $\nu = Q \sim 8.75$. Some of the quadrupole and sextupole correcting lenses have been received and measured: there are to be 24 and 36 of these, respectively. The magnet power supply is on test and shows the usual troubles with control circuits.

Surveying of the magnet ring is being done by establishing the figure of 24 " primary " monuments and then transferring from the primary monuments to the magnet units with a line-of-sight and precision length rods. Stability of the soil seems adequate, although definitive measurements are not yet available.

The main vacuum chamber units are installed in the magnets and most other vacuum parts are on hand, including some 75 titanium getter-ion pumps and special control cubicles.

The 750 kV Cockcroft-Walton pre-accelerator is operating with a modest beam ($\sim$1mA) for initial test work and clean-up. It is being evacuated by the titanium pumps on routine continuous duty. The linear accelerator proper is being assembled (Fig. 3). (About 90 of 124 drift tubes were hung in position by 1st September). The linac electrical systems are largely installed and are being tested and developed. Rather little of the system between the linac and ring is on hand, but most is on order.

All RF cavities are on the ring (see Fig. 4). Power amplifiers are being received from the fabricator and most circuit parts are largely complete. A " starting oscillator " will be used for the first 2-5 milliseconds of acceleration, after which a full phase-lock feedback system will be switched on.

An extensive study of the experimental area has been conducted. We expect to expand into an area of some 200 by 450 feet for initial work in order to accommodate long particle beams. The initial order for focusing and bending magnets will be about 40 units. It has been decided to use solid-state rectifiers for all magnets, in cubicles to be placed adjacent to the magnets. An initial set of electrostatic beam separators is planned; but present techniques will probably not permit separation above momenta of the order of 3-4 GeV/c. Adequate overhead cranes will be installed to service the entire experimental area, especially for shielding, which will amount initially to some 6 000 tons. We are seriously considering a simple building shell to supplement the present target building and to cover the remainder of the experimental area.

Plans are being drawn for cutting a slot in the tunnel wall and developing a second target area for large bubble chambers and similar devices.

## DISCUSSION

MESCHERYAKOV: What is the accuracy of alignment of the magnet blocks in the AGS, and is there any automatic or manual means of alignment to put the blocks in the right place?

GREEN: I should mention that the magnet units are very nicely identical. We put an enormous amount of attention into the design and procurement of the magnet blocks and they show an extremely small scatter, except in the remanent field. Here the scatter is small but significant, and we have stacked it out. We have determined the effective position of a standard magnetic field strength in the gap and have transferred this to the survey points on top of the magnets. Our surveyors can then set a magnet with respect to our primary monuments to better than 1/10 mm. However, I am still uncertain as to

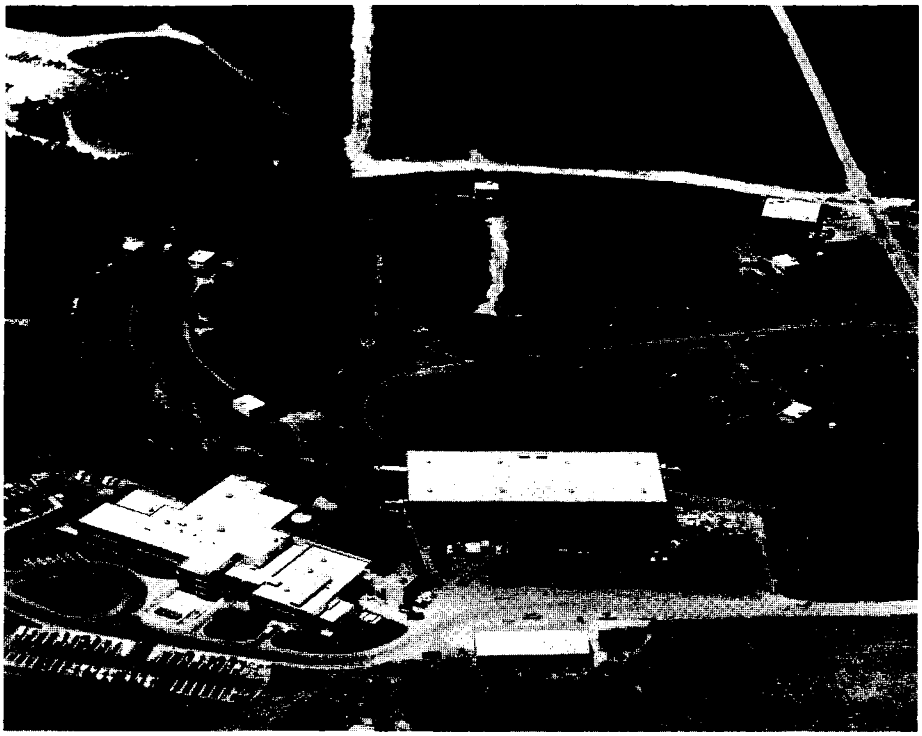

**Fig. 1** Aerial view of AGS ring and target building.

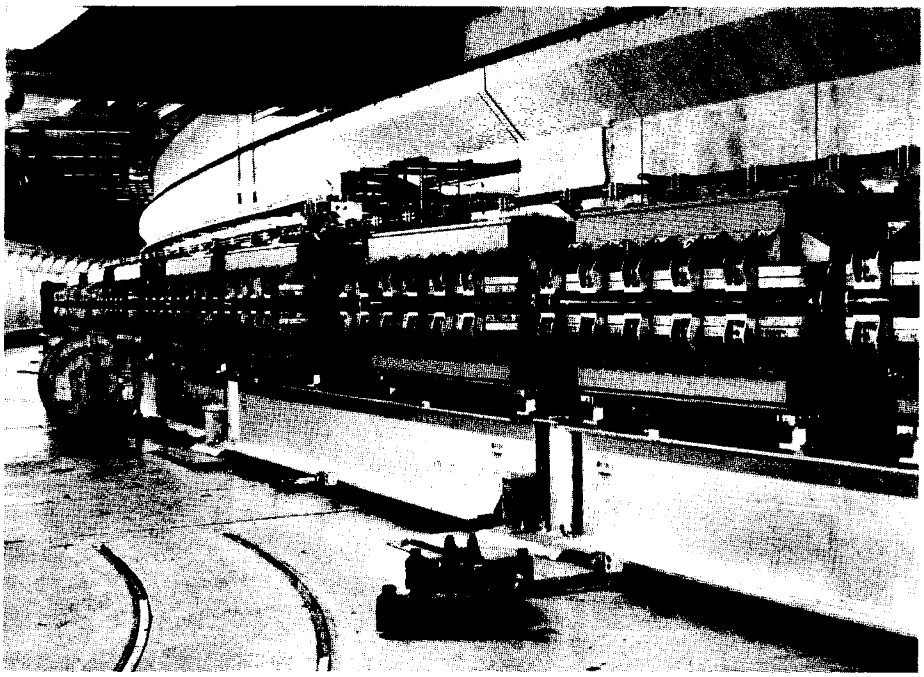

**Fig. 2** Magnet units and vacuum chamber, in the ring tunnel.

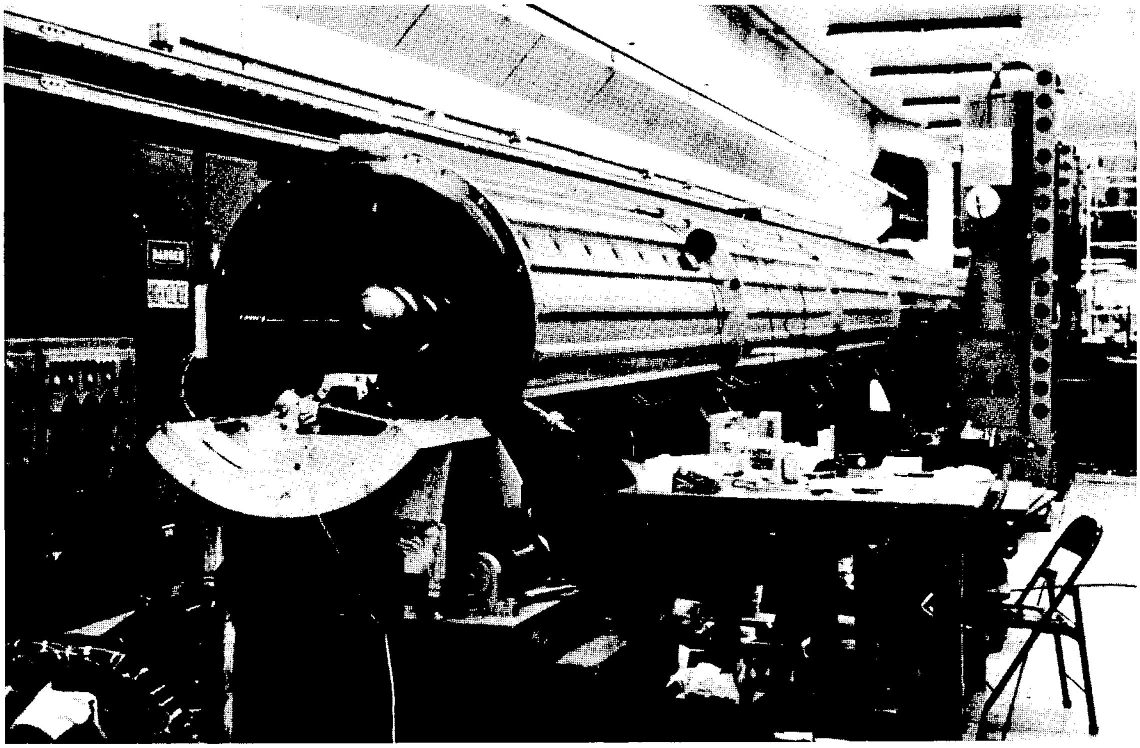

**Fig. 3** Linear accelerator. First section removed to show drift-tubes in position.

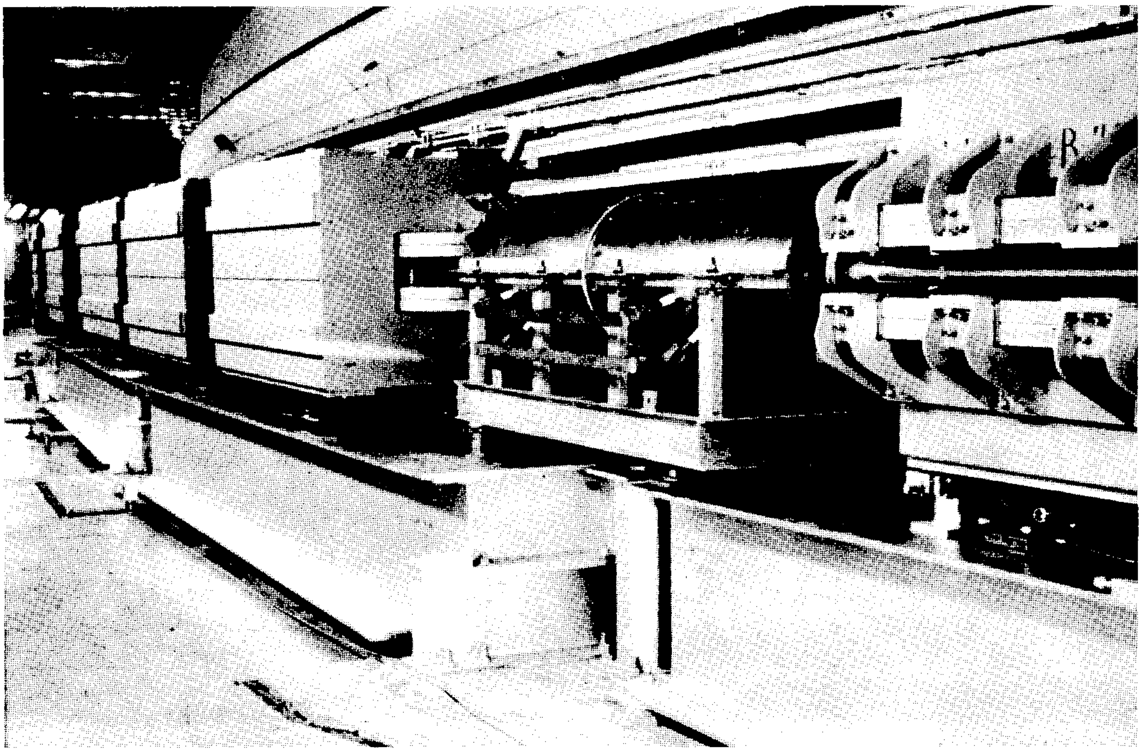

**Fig. 4** One of the twelve RF accelerating cavities.

how accurate the primary monuments themselves are. With respect to correcting position errors, we do not have any automatic movement of the magnets; one goes out with a little pump, pumps up the ball pads and moves the magnets.

HILDEBRANDT: What are the dimensions of the proposed target area?

GREEN: Our present target building is 100×250 feet, (30×75 m). We are proposing an additional extension at the side of it of 100×450 feet (30×140 m) and then we want to fill in over the forward beam by another piece of 75×200 feet (25×60 m).

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# STANFORD TWO-MILE LINEAR ELECTRON ACCELERATOR

## Stanford University, Stanford, Calif.

*(presented by R. B. Neal)*

## LINEAR ACCELERATOR DATA

Person in charge . . . . . . . . . . . . . . E. L. Ginzton

Person supplying data . . . . . . . . . . . . . R. B. Neal

### History and Status (proposed)

| | |
|---|---|
| Design study | 1959-1960 |
| Model tests | 1960-1962 |
| Engineering design | 1961-1963 |
| Construction started | 1961 |
| Completion date | 1966 |
| Scheduled operation | 168 hrs/wk |
| Total cost | $ 105 000 000 |

### Design Specifications (tentative)

Injector System

| | |
|---|---|
| Type | Line type pulser |
| Energy | 80 keV |
| Output | 300 mA |

RF System

| | |
|---|---|
| Frequency | 2 856 MHz |
| Field mode | $TM_{01}$ (disk loaded) |
| RF power (peak) | 5 760 MW (Phase I)<br>23 040 MW (Phase II) |
| Power units | Klystrons |
| Equilib. phase | Wave crest |
| RF pulse duration | 2.5 $\mu s$ |
| Ions focused by | . . . |
| Multipactoring overcome by | . . . |

Beam Characteristics

| | |
|---|---|
| Particle accelerated | Electrons |
| Energy (maximum) | 10-20 GeV (Phase I)<br>20-45 GeV (Phase II) |
| Energy spread | ±0.5% |
| Output, average | 30 $\mu A$ (Phase I)<br>60 $\mu A$ (Phase II) |
| Beam pulse (maximum) | 1.7 $\mu s$ |
| Beam diameter | 1 cm |

Mechanical Details

| | |
|---|---|
| Tank length | 2 miles |
| Tank diameter | 3¼ in. |
| Drift tubes, number | . . . |
| Length 1st tube | . . . |
| Dia. 1st tube | . . . |
| Length 1st gap | . . . |
| Length last tube | . . . |
| Dia. last tube | . . . |
| Length last gap | . . . |