STATUS OF CORNELL 10 GEV ACCELERATOR FACILITY*

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Construction of the Cornell facility began in March, 1965 with the signing of a contract with the National Science Foundation for funding in amount of approximately 12 million dollars. The accelerator first operated usefully for experiments at an energy of 7 GeV about two and one half years later in November, 1967. By March, 1968 it was being used for experiments at an energy of 10 GeV. In the following October, the facility was dedicated and named the Wilson Synchrotron Laboratory in recognition of the leadership and inspiration which was provided by professor Robert Wilson during the twenty years he served as Director of the Laboratory of Nuclear Studies at Cornell. He directed the design of the Cornell accelerator and guided its construction until his departure in July, 1967, when he took leave to direct the construction of the 200 GeV accelerator laboratory at Batavia, Illinois.

Our laboratory currently operates under contract with the National Science Foundation. The fraction of the annual budget which is used only for operation of the accelerator is about 1.3 million dollars, and forty-five persons are employed for the operation, maintenance, and development programs of the accelerator. About 45 physicists use the machine. This number is equally divided between post Ph. D. and graduate students.

The basic parameters of the accelerator are given in the table. One unique characteristic of this machine is the relatively large radius. Because of this, the magnetic field at 10 GeV is only 3,300 gauss. This large radius plays a very important role in reducing the radio frequency power requirements due to radiation loss. It also leads to a considerable saving in the magnet excitation equipment and its power consumption.

The ring tunnel for the guide field magnets was constructed by using a boring machine entering from the side of a gorge, boring at a depth of 45 feet below the surface of the surrounding land. Figure 1

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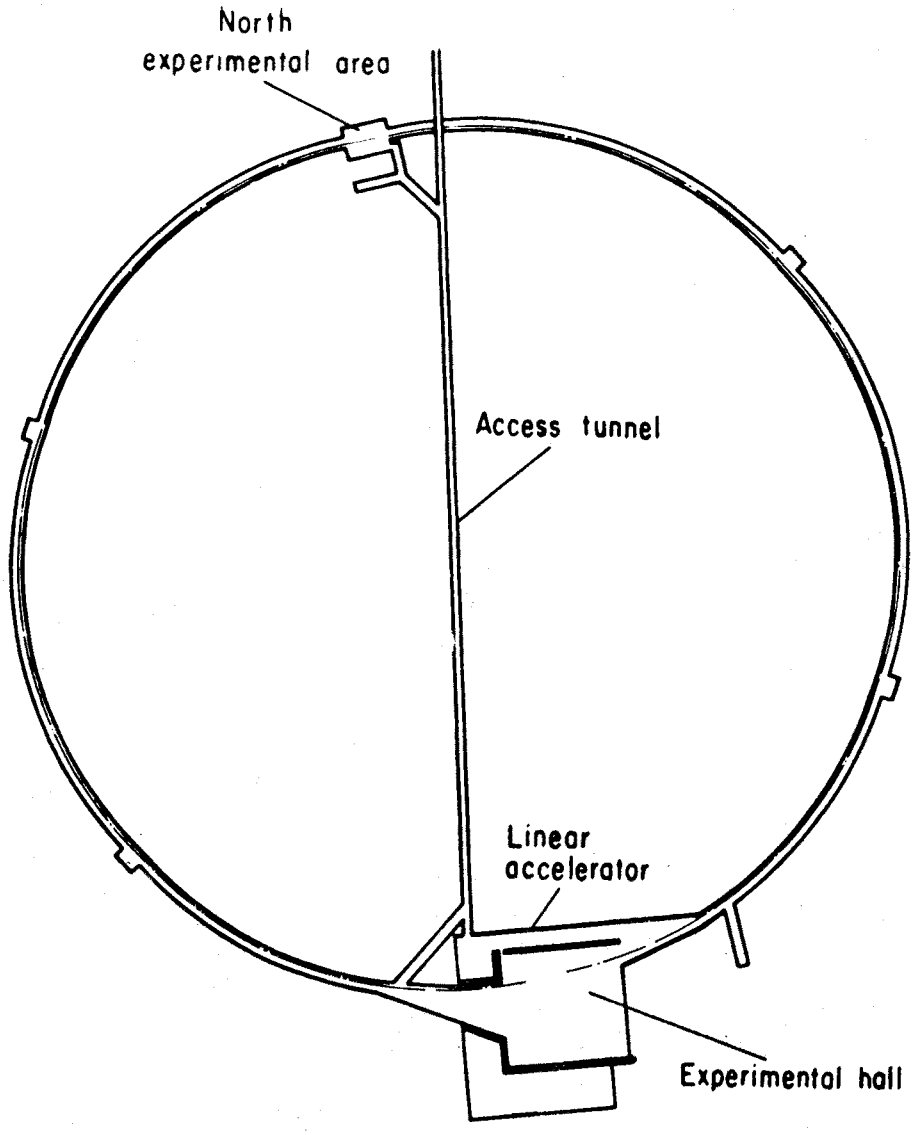


Fig. 1. Plan view of synchrotron tunnnel and experimental hall.

shows the lay-out of the magnet ring with the four straight sections for the radio frequency accelerating cavities, and the two diametrically opposite long straight sections which permit access to the circulating electron beam. One of these straight sections is located in the main experimental hall. Figure 2 shows a cross section view of one of the guide field magnets and its support system. As can be seen, the magnet is very small in cross section, being only 20 by 29 cm. This figure also shows how the entire magnet including both iron and copper are enclosed in a thin stainless steel vacuum jacket. Connections between the 192 individual magnets are made by all-metal high vacuum connectors. Figure 3 shows a photograph of the magnet ring in the tunnel.

The accelerator currently operates at energies up to 10 GeV with intensities of 3×10^{10} electrons per pulse at 60 cps, corresponding to 2×10^{12} electrons per second. Since the magnet is resonated at 60 cps, the magnetic field cycle is a sine wave, and the duty cycle is limited by the energy spread which may be tolerated in beam as it is being used. A one percent spread of energy will provide a gross duty cycle factor of 7 percent. Since single turn injection is used, the effective duty cycle is further reduced by the filling factor of the ring, which may be as

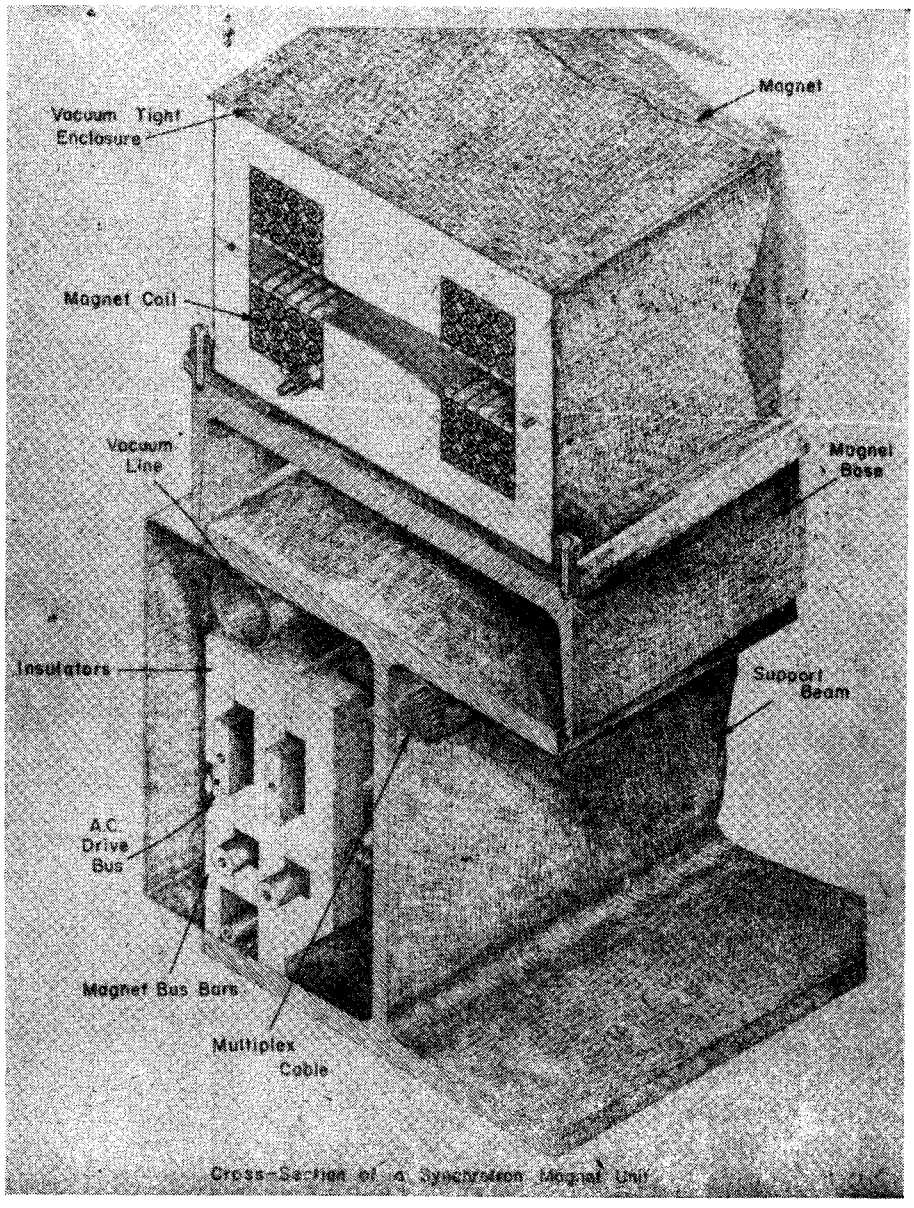


Fig. 2. Cross-section of synchrotron guide field magnet and support beam.

high as 70 percent. Thus, for a one percent spread in the beam energy, a duty cycle of about 5 percent may be obtained.

The accelerator is currently scheduled for experimental use 86 percent of the time. This amounts on the average to 18 shifts of eight hours per shift. Of all scheduled time, the fraction of usable beam time is 85 percent. The machine is sufficiently stable and easy to operate such that only one operator is provided at all times.

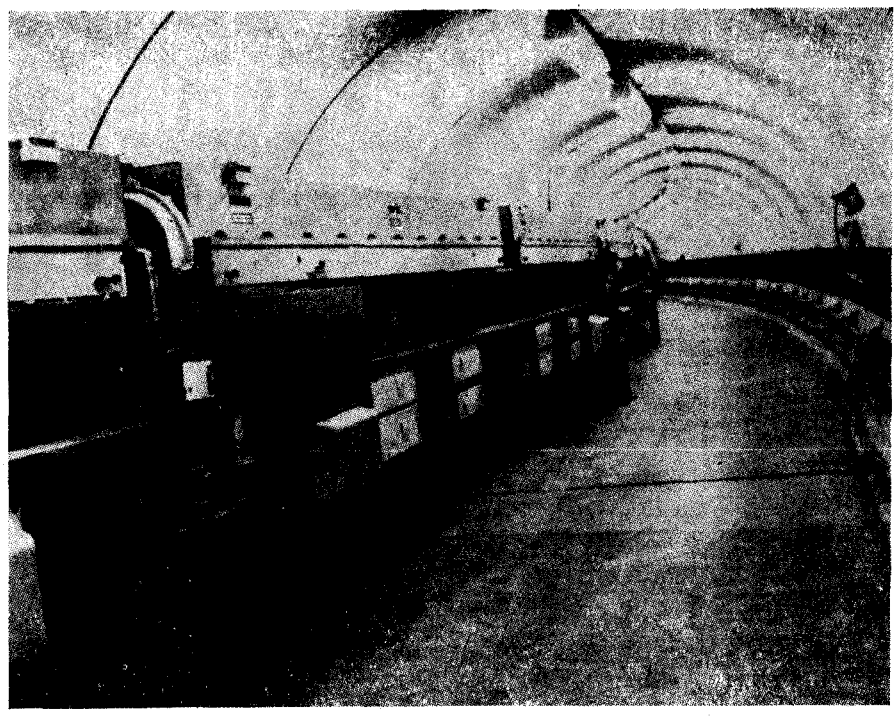


Fig. 3. View of assembled synchrotron in tunnel.

While one might have expected a number of difficulties to result from the design of the magnet, we are happy that to this date we have had no serious difficulty. Each magnet was formed by joining two halves in the median plane. These halves were made by epoxy potting the prefabricated vacuum impregnated coils in the stacked laminations. The two halves were then bonded together with epoxy, and enclosed in the vacuum jacket. Several difficulties might be anticipated.

One might fear that the coils wourd arc to the magnet laminations as a result of improper potting or an accident of poor vacuum in the ring while being excited. Since the resonant condensors are distributed around the ring, alternating with the magnets, the voltage to ground is maintained at less than 350 volts at any point. This of course reduces the hazard of arcing. One might also imagine that radiation damage to the epoxy impregnation material might lead to a physical

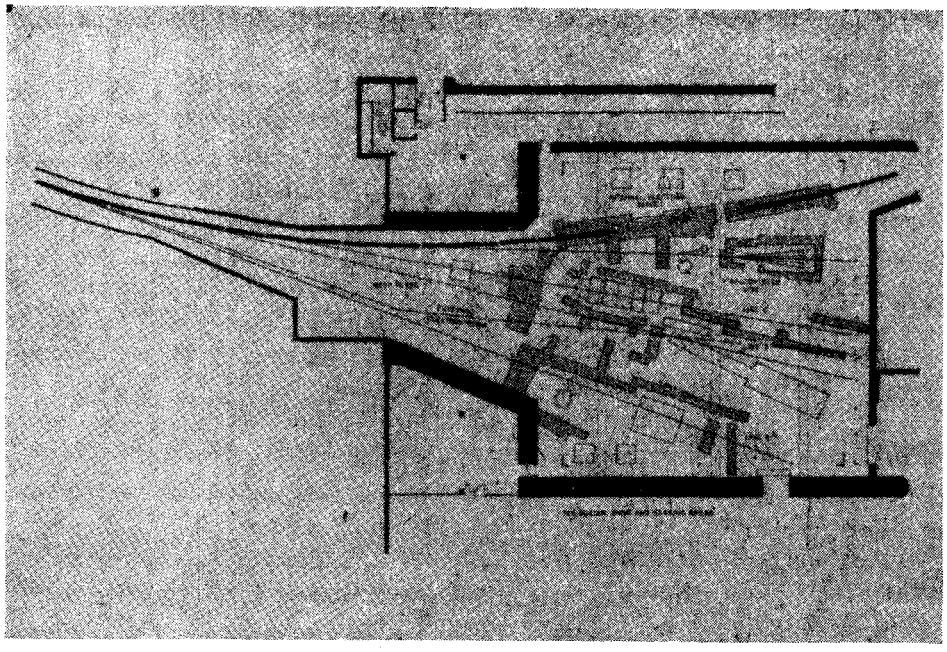


Fig. 4 Layout of synchrotron experimental floor.

break down of the coils with resultant arcing. Similarly radiation damage to the epoxy bond between the two halves of the magnet might lead to failure of the bond.

We have had no failure of the magnets due to these effects. Though there has been some discoloration of the epoxy of the coils, there is no evidence of change in physical or dimensional properties of the epoxy. The vacuum in the ring continues to be very good, measuring 3×10^{-6} torr at the end of the magnets nearest the pumps, and measuring less than 10^{-5} torr in the unpumped coupling between two adjacent magnets. One of the easiest maintenance jobs on the machine has been the vacuum system. It has been remarkably trouble free.

We have completed nearly two years of operation of the machine without failure of the sort described above. Because of this record, and since radiation effects cannot be expected to be uniformly distributed around the ring, we are now confident that whatever difficulty we may have in the future due to radiation damage, it will not occur at such a rate that we will have difficulty in providing replacement units when and if they are required.

As frequently occurs in accelerators, one of our major maintenance problems has been the RF system. Initial difficulties with over heating of the joints in the coaxial drive lines were overcome. The floating deck modulators for the klystrons have caused us much trouble, and a recent redesign of the system promises to relieve this difficulty. After a year of operation, we started to have trouble with

multipactoring of the cavities. We believe this was due to deposition of contaminants from the oil pumps and vapors from the epoxy in the magnets. We have now provided cold traps and the multipactoring is no longer a serious problem. We are building a fifth accelarating unit which will provide redundance in the RF system and allow us to continue running at 10 GeV even with a failure of one of the units. Of course, the fifth RF unit will permit a small increase in the maximum attainable energy of the accelerator.

Next, I would like to discuss the various beam lines and facilities. In Figure 4 is shown the lay-out of the experimental apparatus. Currently we have 4 photon lines as shown, and the access to the circulating beam in the long straight section. In addition we are now constructing an external beam line which will come out along the line shown.

The various experimental arrangements are shown as they are now located on the experimental floor. These are: a magnetic pair spectrometer for study of vector meson production; a muon pair range spectrometer; a 10 GeV magnetic spectrometer of high resolution, together with a wide aperture magnetic analyzer on the opposite side of the target for studying photo-and electroproduction; a wide aperture magnetic spectrometer with wire spark chambers for study of backward pion photoproduction, and a similar system for study of omega and A_1 photoproduction.

By applying an orbit distortion to the circulating electron beam, it is forced to collide with a target for the production of the bremstrahlung beam. By electronic switching of the location of the orbit distortion between acceleration cycles, any programmed pattern of beam alternation between two targets may be produced. The intensity at the two targets may be controlled independently.

For carrying on two experiments simultaneously, this arrangement is not an optimum mode of sharing if the experiments are limited by duty cycle instead of intensity of the machine. We have found it possible to share each beam pulse smoothly between two targets and to control the relative intensity of the beams. This results in a higher utilization efficiency of the accelerator.

For the beam line which passes through the pair spectrometer, we have installed, as a target, a diamond crystal for production of coherent polarized bremstrahlung. This crystal may be rotated by 90 degrees to produce both directions of polarization and is currently being used in the study of rho and phi photoproduction.

In the beam line furthest from the machine, provision has recently been made to provide a tagged photon beam. This is accomplished by modifying one of the guide field magnets so that it is open on the inside of the ring Then those electrons which produce high energy photons in brehmstrahlung can be momentum analyzed in the guide ring magnet itself and be detected in coincidence with the reaction produced by the associated photon in the external experimental apparatus. This system has 16 channels which provide photons in the interval from 82 to 97 percent of the

circulating electron energy and with a resolution of about one percent. Preliminary tests of this system have been made and it is being used in an experiment on phi photoproduction.

The external electron beam line referred to above is just now being completed. We have used a resonant extraction process to remove the electrons. To this point, we have tested the extraction using components designed only to operate up to 2. 5 GeV. The beam has been extracted at that energy with an efficiency of more than 75 percent. Currently, final components are being built and installed to provide extraction at the full energy of the machine. It is anticipated that this work will be complete by the end of the year.

We have only limited computor facilities in the laboratory. An IBM 1800 is being used for a variety of functions. It serves to assist the machine operations by recording conditions and providing reset on command. We also have a program which use the computor to tune the correction coils of the accelerator for maximum beam intensity. This program produces a variable orbit bump and searches at each point around the ring in succession to optimize the beam intensity. This computor is shared with on-line experiments in an interrupt mode and is also available for off-line use. A smaller PDP 8 is being used directly in one of the experiments for data recording. We are hoping to add a new computor, larger than the 1800, in the near future. In addition to the computors which we have in the laboratory, we also have access to the central campus computing facility, an IBM 360/65.

The accelerating radio frequency is the fourth subharmonic of the linac frequency. We have recently added a "chopper" to the linac to knock out three of the four bunches of electrons so that the only electrons which are accelerated in the linac are the ones which can be accepted by the synchrotron RF system. This has the effect of reducing the radiation damage due to the injected beam currents in the linac. It is anticipated that the decrease of linac loading will increase the accelerated beam current to more than 6×10^{12}/sec. We have observed some signs of beam instabilities at the large currents and it is likely that some study of these effects will be necessary before reliable operation at the high currents will be possible.

During the coming few years we will be making a major effort to increase the energy of the accelerator. It appears quite reasonable to believe that we can increase the energy to 15 GeV. The field characteristics of the magnet at this energy are quite satisfactory, and only relatively minor changes are required to provide for the required magnet excitation. It may be necessary to provide some special magnets to damp the radiation induced betatron oscillations. However, by far the greatest difficulty is that of providing adequate RF voltage. Because of the fourth power law, five times the present voltage per turn will be required, that is 50 MeV per turn. This would require, if it were to be done in the same cavities, 25 times our current instantaneous power. It appears that the

voltage requirement could be met in a brute force approach by increasing the number of cavities, and the total power input. However, we hope that the requirement can be met in a more sophisticated manner utilizing a small number of super-conducting cavities. The development of super-conducting systems is proceeding rapidly in other laboratories and such devices appear to be a real possibility for us. We would hope that within the next three years we will have super-conducting cavities which will permit us to operate at 15 GeV.

SYNCHROTRON PARAMETERS

Electron Energy	10 GeV
Magnetic Radius	100 meters
Repetition rate	60 Hz
Nominal intensity	10^{11} electrons/pulse
Number of magnet units	192
Long sraight sections	2 of 12.2 meters
	4 of 6.1 meters
Gap Height, focus and defocus	2.54 and 3.80 cm
Gap width, good field	5.5 cm
Magnetic field, 10 GeV	3.3 kG
Betatron oscillations/turn $\nu_v = \nu_R$	10.75
Linac	150 MeV—2855 MHz
RF frequency	714 MHz
RF voltage/turn, 10 GeV	10.5 MeV

ДИСКУССИЯ

Есин: Ваш ускоритель имеет, кажется, дистанционное управление положением блоков электромагнита. Насколько эта система оказалась практически необходимой, как часто Вы проводите юстировку положения магнитов под пучком и каков выигрыш получаемый при этом?

McDaniel: We did prepare a fully automatic alignment system, but because we found the magnet foundations to be quite stable, the system has never been activated. All adjustments for movement have been done manually.

Schaffer: What is the total number of hours achieved with maximum beam intensity at 10 GeV?

McDaniel: Most of our operation has been at or near 10 GeV. However very few experiments have requested full beam intensity at this energy.