STATUS OF THE MURA 200 MEV ELECTRON-POSITRON STORAGE RING*

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The design of the MURA 200 MeV electron-positron storage ring has been reported on previously.[1] There have been no substantial changes in the design as reported, therefore we will give only a very brief description of the machine and then describe in somewhat more detail those of its components which are of general interest. A plan view of the machine is given in Fig. 1. As can be seen, this machine is quite similar to the Orsay machine with the exception that the edges of the bending magnets of this machine take the place of defocusing elements of the quadrupole triplets of the Orsay machine. In this figure there may also be seen the many probes that have been incorporated in the vacuum chamber to facilitate beam observation. There are two types of these: movable probes that can be made to intercept the beam and electrostatic probes that can be used either to take signals from the beam or apply signals to the beam. There are also a number of synchrotron radiation viewing ports for both electrons and positrons.

The parameters of this machine are given in Table I. It may be noted that there have been some changes since the original report on the machine was given at Frascati. However, these are not significant. It will also be noted that the tune range of this machine covers the region $1.0 \leq \nu_x, \nu_y \leq 1.5$ that is now of some interest.[2]

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*Supported by the U. S. Atomic Energy Commission.

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The arrangement of the machine and beam transport system in relation to the MURA 50 MeV FFAG synchrotron is shown in Fig. 2.

The magnets and quadrupoles for this machine are laminated. The measured fields in the full size magnets agree well with those in the models made previously. Figure 3 shows a bending magnet mounted on the measuring system. Since the space between magnets and quadrupoles is quite small, the présence of a quadrupole affects the field of the magnet. Therefore, measurements of the bending magnet field are made with the quadrupole in position. Not only are the z fields measured in this system but also the R and θ fields. Thus we can also find the median plane of the bending magnets and correct deviations caused, for example, by improper placement of the magnet coils. After all eight bending magnets have been measured, a computer will determine the optimum arrangement of the magnets in the ring.

The magnetic fields are measured with rotating coils. In the case of the R-θ field, the coil is driven by an air turbine. The signal from this coil is passed through an integrator. Thus, the sensitivity of the R-θ measuring system is independent of the rotational speed of the coil. The R-θ field measuring system can detect transverse fields of the order of 10^{-3} gauss in a vertical field of 10^3 gauss.

In Fig. 4 there is shown a quadrant of the vacuum chamber. With only a preliminary bakeout (four hours at 100°C), this quadrant achieved a pressure of 1×10^{-9} Torr. All parts of the vacuum system reach 10^{-10} Torr after a more rigorous bakeout. Since the magnets are constructed so that their back legs face the center of the machine, it will be possible to bake the vacuum chamber in position by pushing the magnets into the center of the machine. The vacuum chamber will be heated during bakeout by passing a current of several thousand amperes through it. The current will be applied at the rf gap. This simple method of heating the vacuum chamber for bakeout has been tried and found to be completely practical. An insulating blanket is wrapped around the vacuum chamber to minimize thermal gradients. The vacuum pumps must, of course, be heated separately.

The injection system presented a number of problems. The positron beam requires that the aperture of the inflector be 2.5 cm radially and 2 cm vertically. Since there are no other elements in the injection system after the inflector, the inflector cannot have a septum. If the inflector were an electrostatic device with this aperture, it would require nearly 300 kV to achieve the required deflection of the beam. If it were a conventional transmission-line device, it would require half this voltage, but the charge line would still have to operate at 300 kV. Handling pulse voltages of this magnitude presents some rather difficult problems. To reduce the required voltage, the inflector was loaded with 96 per cent alumina ceramic. The resulting structure has an impedance of 25 ohms and a propagation velocity of about 0.3 c. This propagation velocity results in a ninefold increase of the energy stored in the inflector and therefore a factor of 3 increase in the beam deflection for a given voltage. To realize the full benefits of this scheme the inflector must be operated with a short circuit at the end, otherwise one gets only one-half of the increase in deflection since the amount of energy stored in the electric field in the region of the beam is unchanged. The injection straight section together with a cross section of the inflector is shown in Fig. 5.

Since the inflector has no septum and since there are no other elements in the injection system after the inflector, the inflector field must be off when the injected beam goes through the inflector again after from two to four revolutions in the machine. This requires that the rise and decay times of the pulse be a few nanoseconds only. Furthermore, there must be no ringing after the pulse is over. A spark gap and delay-line system has been developed that will drive the short-circuited inflector with good rise time and no reflections after the pulse. A schematic diagram of the system is shown in Fig. 6. This configuration has another very useful property. Since the function of the spark gap is to ground one side of the energy storage line, it is possible to use one spark gap to switch several storage line-load circuits with little or no interaction between them. Further, it is not necessary that the storage line-load systems be of the same impedance. Thus the sometimes difficult problem of the synchronization of several spark gaps may be competely eliminated. It is, of course, necessary that all the systems operate at the same voltage.

The spark gap is of the short-gap high-pressure type. By careful design it was possible to eliminate discontinuities in the line caused by the gap itself. The rise time of the output pulse is less than 4 nanoseconds and there are no reflections after the one caused by the short circuit at the end of the inflector. It is reasonable to expect that the rise time would be less if the impedance of the system was higher.

Since the extraction system for the injector synchrotron also utilizes a spark gap,[3] it is necessary to synchronize the inflector spark gap with this spark gap. These two spark gap-load systems operate at different voltages and at opposite polarities, and it was not possible for us to use the method of synchronization described above. Instead, the synchronization was accomplished by using about one-third of the energy of the output pulse of the extraction spark gap to trigger the inflector spark gap. This pulse has a very short rise time (<1 nsec) and is 40 kV in amplitude. The use of this very large trigger pulse reduced the jitter in the inflector gap to less than $\pm$ 1 nsec. There are, of course, long time constant drifts between the two spark gaps which must be compensated. This is done with a "trombone" in the trigger line between the two gaps.

The magnet power supply utilizes a pair of 250 V, 400 A amplidyne generators driven by a high slip induction motor. The control fields of the amplidynes are driven with vacuum tubes. The time constant of the amplidyne quadrature fields is less than 0.03 sec, thus the frequency response of the amplidynes themselves extends well past 10 cps. As a result, pulse operation of the magnet, which is necessary during positron injection,[1] with a 3 cps triangular field variation is readily achieved. Further, since the amplidyne is incorporated in a feedback loop, arbitrary field variation as a function of time requires only that a low level signal of the desired shape be fed into the system. These amplidynes operated in this fashion make rather good high fidelity amplifiers with response up to about 40 cps with a resistive load. With the inductive load represented by the magnet, the response will be good to about 12 cps.

The entire design of this machine has been dictated by one consideration. We wish to build a device that will give us the maximum opportunity to study the phenomena that continually arise to confound the builders of high energy accelerators and storage rings as they move towards higher and higher intensities. We not only hope to gain a better understanding of these phenomena but we would feel cheated if we did not discover new effects. As an example of some of the experiments planned for this machine, it will be possible to check without the complications of injection phenomena the validity of both the neutralized and unneutralized space-charge limit calculations.[4] This can be done by simply decelerating the beam until the limits are reached. Further, we hope to verify the predictions of Sessler and Courant[2] concerning the effects of the tune and harmonic number on the resistive wall instability. Finally, as an example of an unexpected use of the machine, we find that already people are standing in line to use the synchrotron radiation from the machine for spectroscopy in the far ultraviolet range.

In conclusion, it may be stated that the important technical problems connected with the construction of this machine have been solved. The date for the completion and operation of the machine now depends on the speed with which we can complete the construction of the rest of the components of the machine with our facilities. Once the machine is operating we look forward to a long and interesting period of machine experiments.

TABLE I. PARAMETERS FOR 200 MEV STORAGE RING

MAGNET	
Focusing Type	AG, Separated Function
Focusing Order	0/2, D, B, D, f, D, B, D, 0/2
Field Index in Bending Magnets	Variable, $-0.34 \leq n \leq 0.34$
Field Gradient in Quadrupoles	Variable, 1.6 kG cm^{-1} max
Field at Injection for e^-	2.36 kG
Field at Maximum Energy	12.3 kG
Bending Radius	0.635 meters
Average Radius	1.50 meters
Tune	Variable, $0.5 < \nu_x, \nu_y < 2.0$
INJECTION SYSTEM	
Type	50 MeV FFAG Electron Synchrotron
Injection Energy e^-	45 MeV
e^+	40 MeV
Injection Current e^- (per pulse)	0.5 amperes
e^+	25 μamperes
Injection Energy Spread e^- (total)	500 kV
e^+	2 MeV
Inflector	Delay Line, No Septum
RF SYSTEM	
Frequency	31.9 Mc
Harmonic Number	1
Number of Cavities	1
Maximum Volts per Turn	50 kV
Maximum Power Available to Cavity and Beam	20 kW

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1. E. M. Rowe, H. K. Meier, and J. E. O'Meara, Design of a 200 MeV Electron-Positron Storage Ring, Proceedings of International Conference on High Energy Accelerators, Frascati (1965, to be published).

2. E. D. Courant and A. M. Sessler, Transverse Coherent Resistive Instabilities of Azimuthally Bunched Beams in Particle Accelerators, UCRL-16751 (April 1, 1966).

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4. L. J. Laslett, On Intensity Limitations Imposed by Transverse Space-Charge Effects in Circular Particle Accelerators, Proceedings of the 1963 Summer Study Group on Storage Rings, Accelerators and Experimentation at Super High Energies (Brookhaven National Laboratory) p. 324.

FIGURE CAPTIONS

Fig. 1. Storage Ring Plan View.

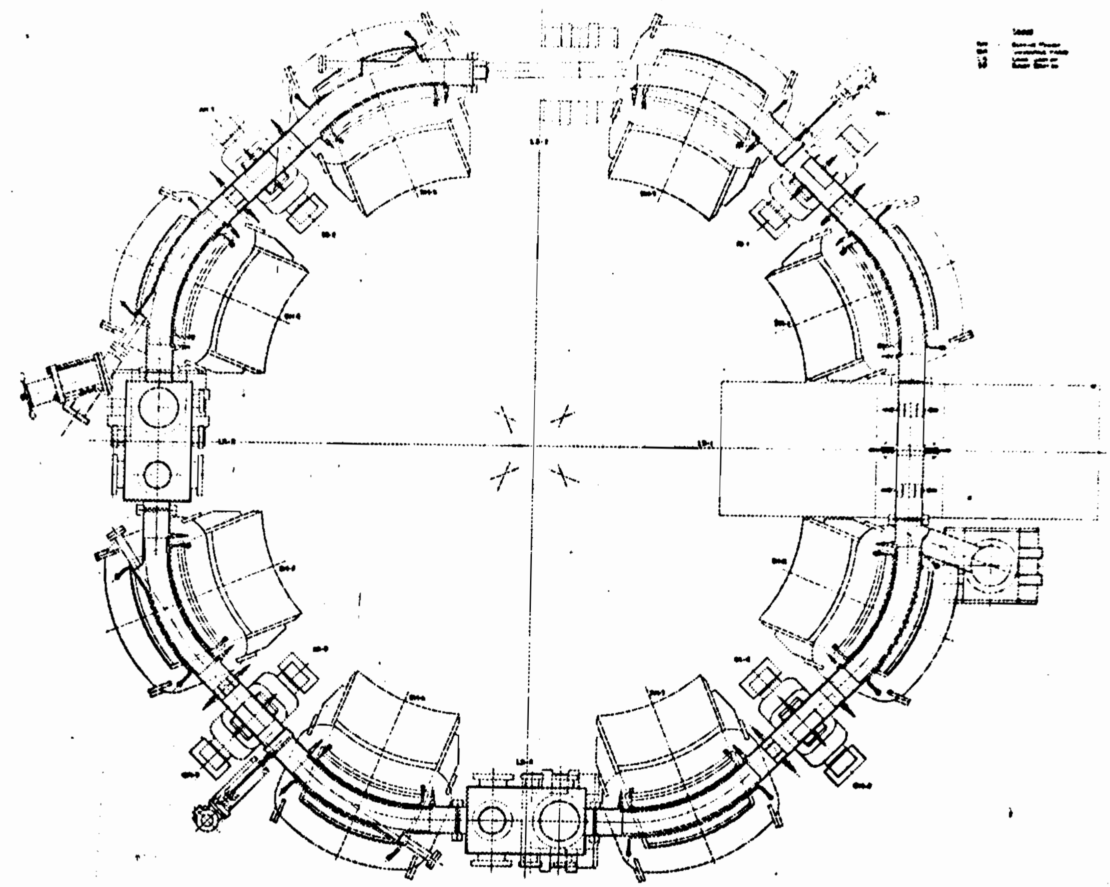
Fig. 2. Floor Plan of Storage Ring Facility.

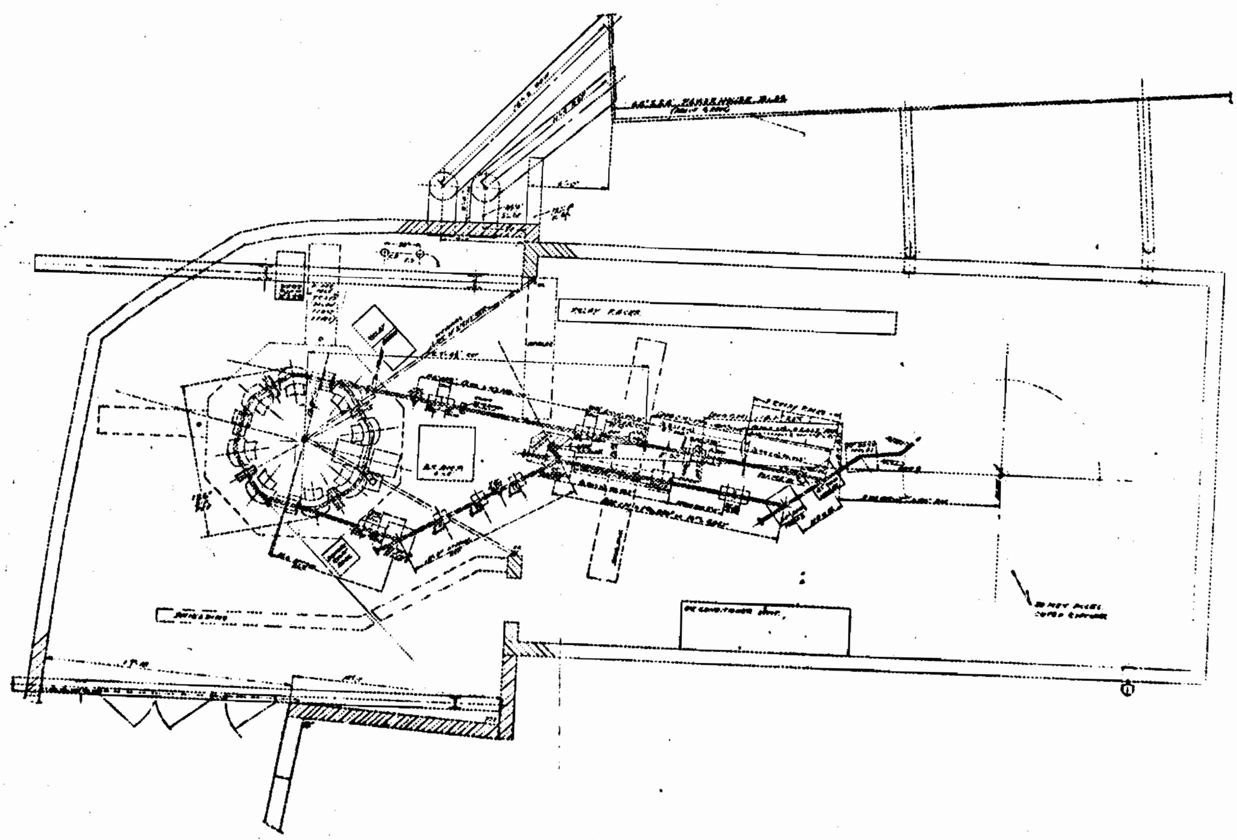
Fig. 3. Bending Magnet on Field Measuring System.

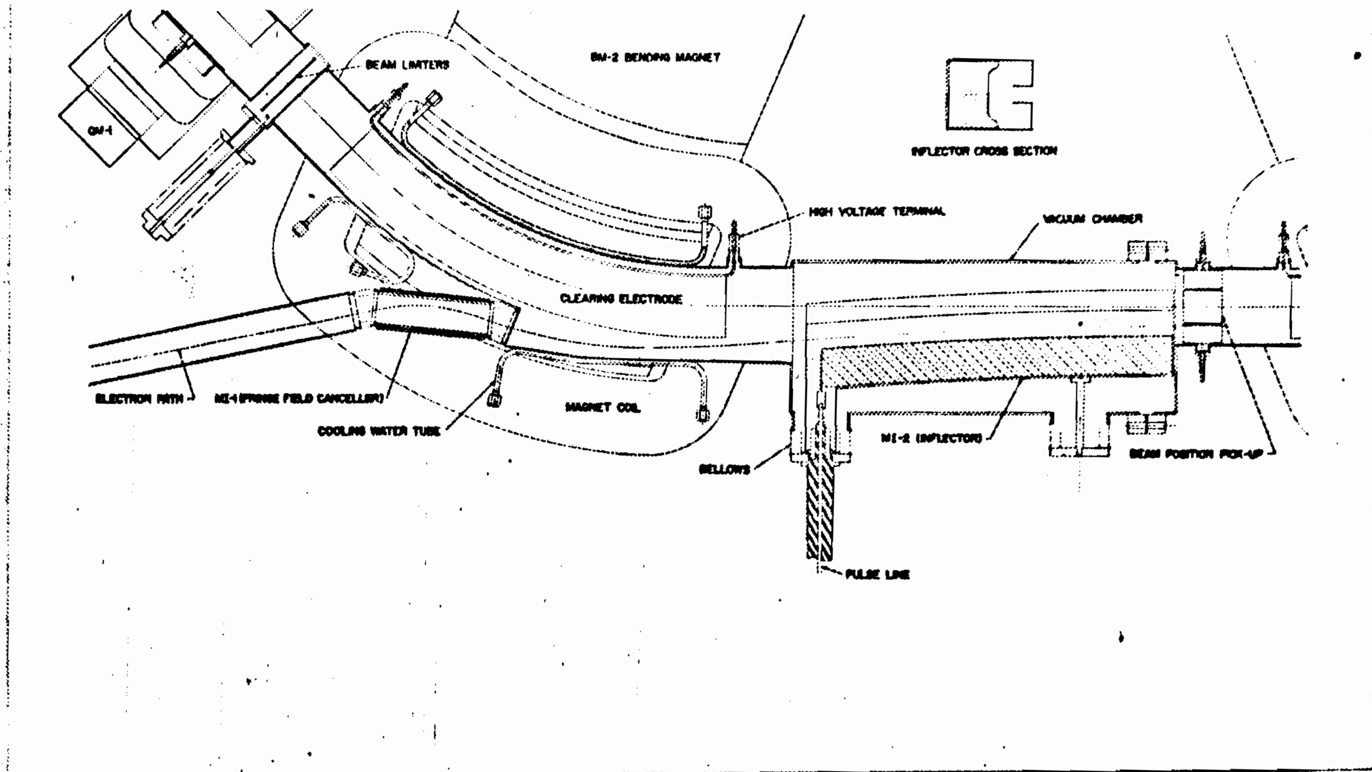
Fig. 4. Quadrant of Vacuum Chamber.

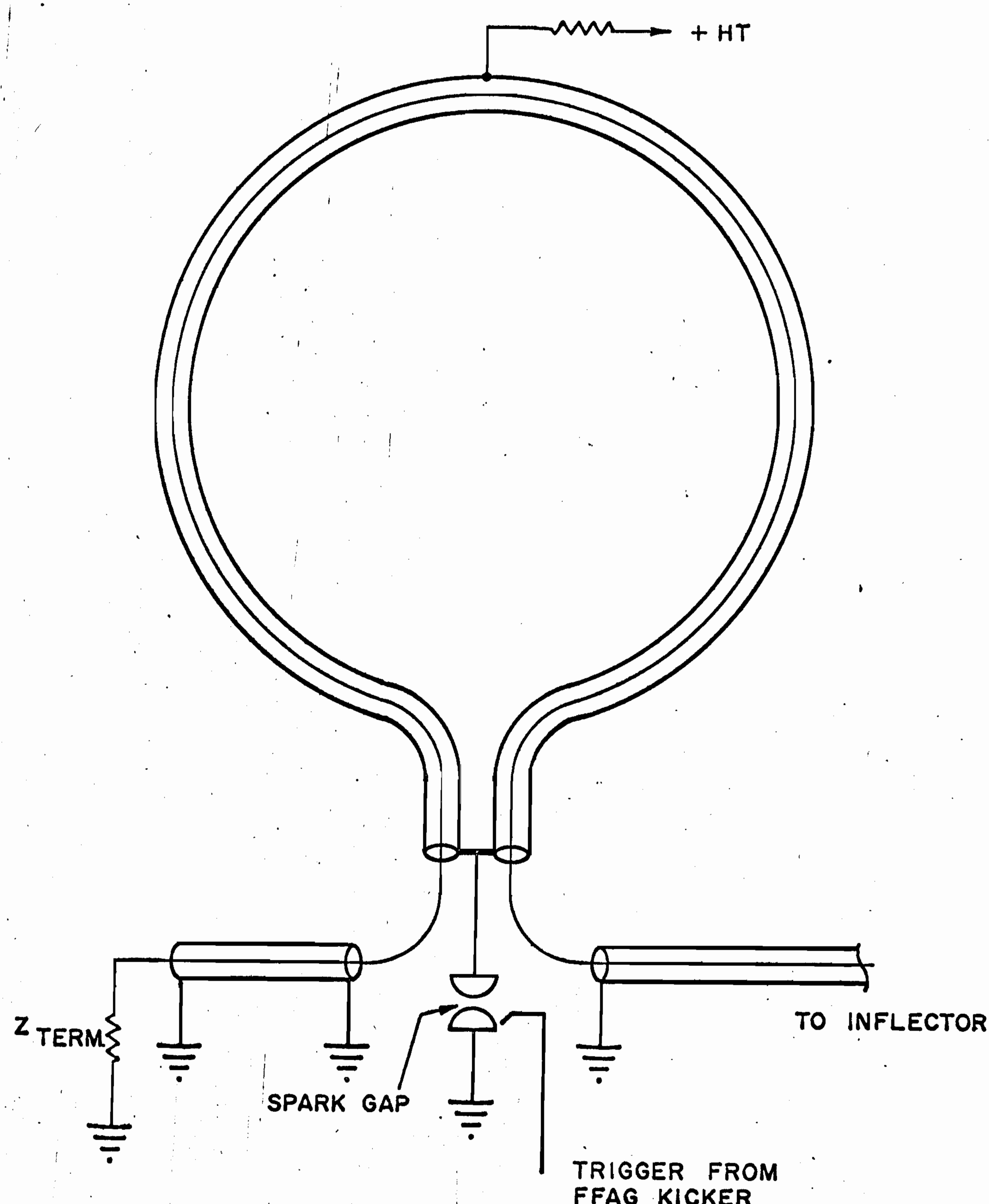
Fig. 5. Injection Straight Section.

Fig. 6. Schematic of Spark Gap and Storage Line Circuit.






BM-1
BEAM LIMITERS
BM-2 BENDING MAGNET
INFLECTOR CROSS SECTION
HIGH VOLTAGE TERMINAL
VACUUM CHAMBER
CLEARING ELECTRODE
ELECTRON PATH
MI-1 (FRINGE FIELD CANCELLER)
COOLING WATER TUBE
MAGNET COIL
MI-2 (INFLECTOR)
BEAM POSITION PICK-UP
BELLOWS
PULSE LINE



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