ORIC BEAM EXTRACTION SYSTEM

R.S. Lord, E.D. Hudson, F.M. Russell(*)
and R.J. Jones
Oak Ridge National Laboratory(**)
(Presented by R.J. Jones)

The ORIC extraction system utilizes both electrostatic and magnetic channels. The decision was made to extract the beam before the $\nu_r = 1$ region because of the possible beam deterioration and the difficulty of maintaining isochronism for 75 MeV protons. The use of an electrostatic channel alone, for these conditions, would have required very high potential gradients. The possibility of high potential gradients creating operating instability due to electrical breakdown led to the choice of a combination of electrostatic and magnetic channels.

Two magnetic channels have been developed to fulfil the demanding requirements of transporting variable-energy particles across the ORIC fringe field. One, a coaxial channel with a high-magnetic field gradient so as to accept the deflected beam from the electrostatic channel with only 2 cm separation from the circulating beam; the other, an electromagnetic compensated iron channel designed to provide a variable-magnetic field in the deflected beam region while providing field cancellation externally. The general arrangement of the extraction system is shown in Fig. 1.

The electrostatic channel shown adjacent to the dee is 77 cm long, or 56° in azimuth. The present system uses a water-cooled aluminum deflector electrode and a 0.8 mm thick graphite septum. Operating at 60 kV across a gap of 1 - 1.5 cm, design value for 75 MeV protons, the electrostatic deflector will provide a separation of about 2 cm between the circulating and deflected beams.

The second element, the coaxial magnetic channel, achieves a field reduction of 4 kG in a radial distance of 3 mm, over an azimuthal length of 22 cm. The basic configuration of the conductors is that of a coaxial transmission line. In the ideal coaxial conductor there is no leakage field outside the conductors (in the circulating beam region), and there is a strong circular magnetic field in the region between the conductors (in the deflected beam space). A modification of this basic design produces a region of nearly uniform field for the deflected beam with very little disturbance outside this region, regardless of magnet excitation or channel current. Fig. 2 shows the arrangement of the coaxial conductors. The drawing is a section through the channel. The inner and outer conductors are formed by 48 wedge-shaped

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(*) On leave from Rutherford High-Energy Laboratory.

(**) Operated for the USAEC by the Union Carbide Corporation.

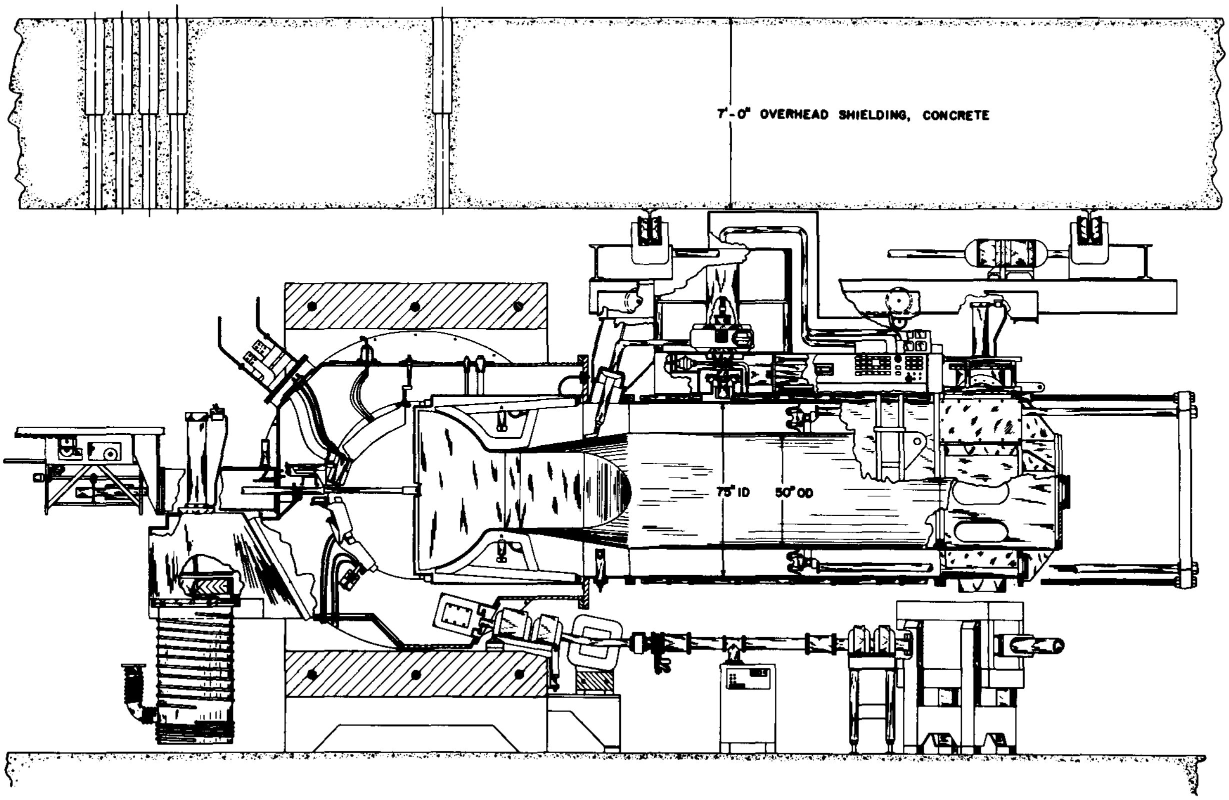

Fig. 1 A cross-section of the ORIC cyclotron showing the arrangement of the extraction system.

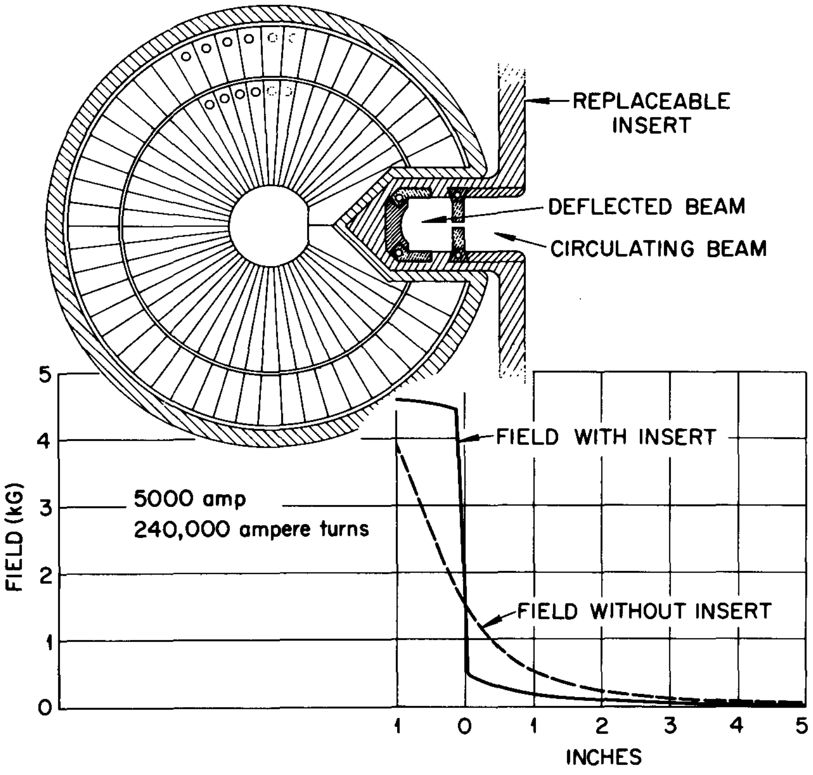

Fig. 2 A schematic cross-section of the coaxial channel with curves showing the magnetic field gradient without and with the insert.

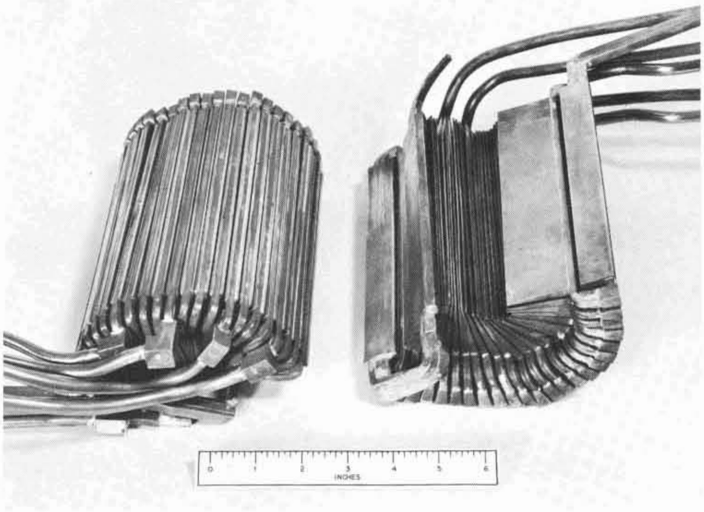

Fig. 3 Partial assembly of the 48 wedge-shaped coaxial conductors.

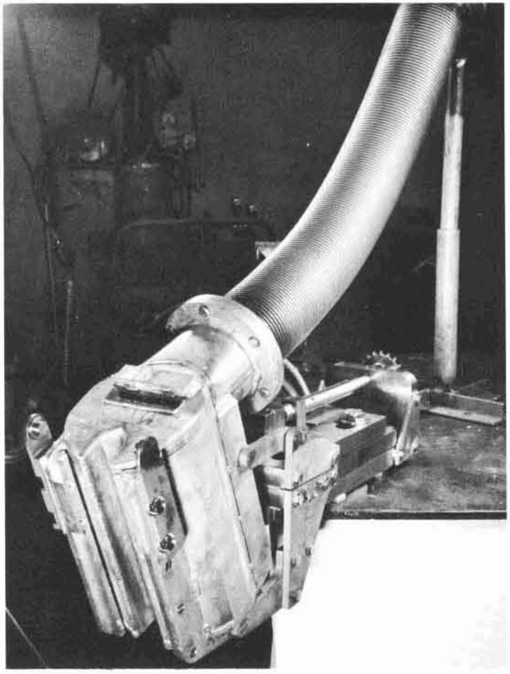

Fig. 4 Coaxial magnet in vacuum container with the vacuum bellows for the current leads.

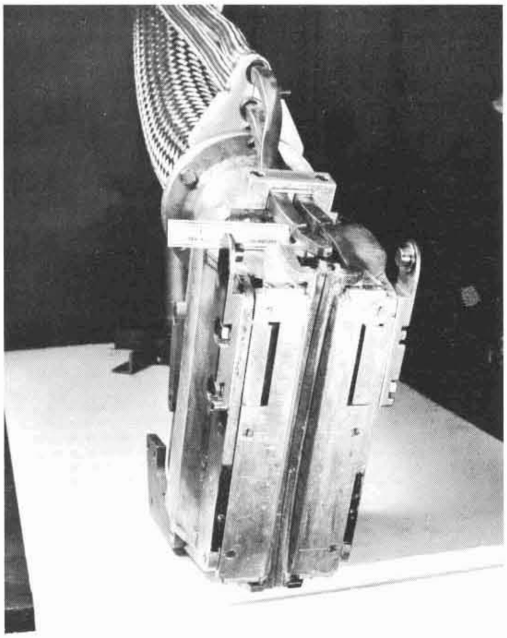

Fig. 5 Coaxial magnet in vacuum container with the insert installed.

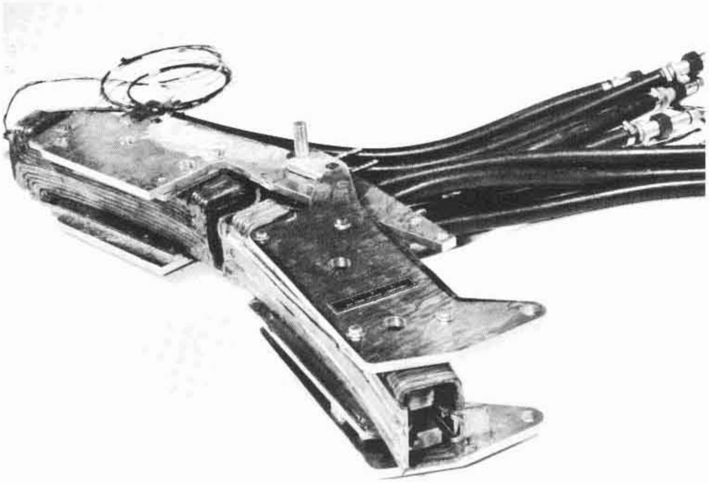

Fig. 6 Compensated iron channel.

copper elements connected in series so that the current makes multiple traversals, yielding about 220,000 ampere turns. If the inner and outer series of conductors were symmetrical in azimuth, the magnetic field outside the channel would be zero. However, it is necessary to provide an opening for the deflected beam. This was done by leaving out a sector of both the inner and outer conductors about 45°. This arrangement produces a field gradient as shown by the dashed line. The relatively large sector was removed to permit installation of an insert. This insert re-establishes most of the symmetry so that the entire channel produces a field gradient as shown by the solid line. The insert is expendable and can be removed in case of damage, or it can be shaped to provide radial-field gradient in either direction.

Fig. 3 shows the partially assembled concentric conductors. Fig. 4 shows the assembly inside a vacuum-tight aluminum container. The channel leads are brought through a bellows in order to maintain a vacuum seal. The channel with insert is shown in Fig. 5. The insert is not enclosed in the vacuum container.

The third element, a compensated iron channel, will also operate over a wide range of fields. A test model of this channel which gives field reduction of 6 kG is shown in Fig. 6. The final version will be enclosed similarly to the coaxial channel. It is basically a rectangular iron pipe with a current sheet between the iron and the circulating beam to compensate, in the circulating beam region, for effect of iron. The current sheet gives a further reduction to the field in the deflected-beam region, as does the return-current path. The iron occupies approximately one-half the magnet gap and thus saturates at relatively low fields. Therefore, one current setting in the outside current sheet will give undisturbed field in the circulating beam region from about 25% energy to full energy.

Since there is a single preferred beam path for all conditions of operation, the field inside the channel must be maintained proportional to the cyclotron field. To achieve this condition, an additional pair of current sheets is placed inside the iron pipe. These have a relatively small influence on the field outside the channel. By controlling two currents the desired field can be achieved inside the channel without disturbing the field for the circulating beam. A desired field gradient can be incorporated into the channel by proper distribution of the iron and conductors. The compensated iron channel is easier to build and uses less power than the coaxial channel, but requires a larger orbit separation at the entrance.

As shown in Fig. 7, the beam crosses the major portion of the fringe field at nearly right angles to the contour lines. This provides a deflected beam path with a minimum energy dispersion and angular divergence. The magnetic channels, as now installed, will uniformly lower the base field along the deflected beam path; however, coaxial and compensated iron channels can be constructed with a field gradient to provide a strong-focusing system.

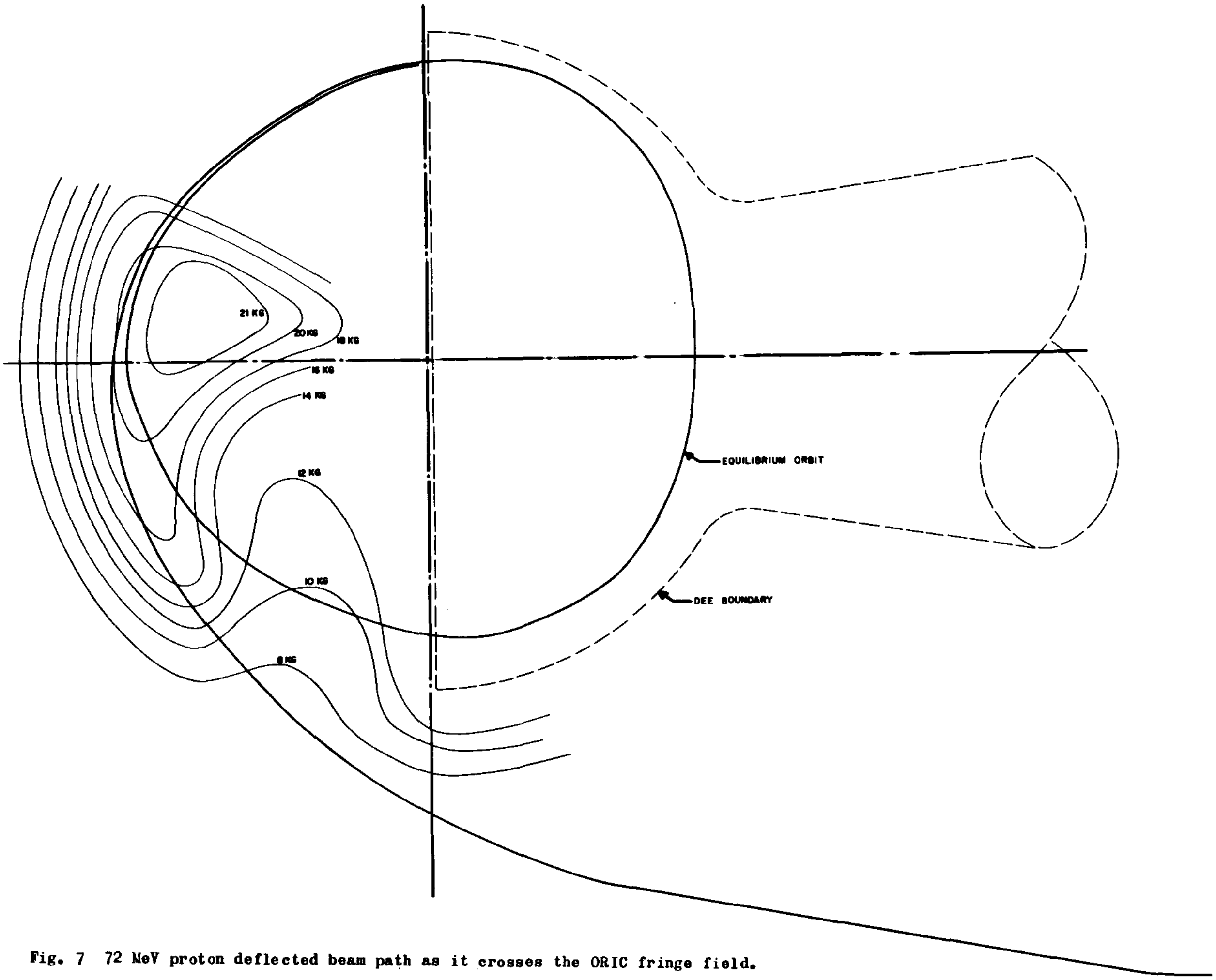

Fig. 7 72 MeV proton deflected beam path as it crosses the ORIC fringe field.

DISCUSSION

BLOSSER : What is the power consumption for the different channels?

JONES : In the coaxial channel a 5 kG reduction in the field requires about 200 kW, that is for a length of 25 cm. The iron channel, for a length of 1 m and a field reduction of about 6 kG requires about 75 kW.

GRUNDER : Your beam is not energy analysed by the fringing field? Is this correct?

JONES : This is correct. We prefer not to do this because of the beam divergence given by the non-uniform fringing field.

GRUNDER : However the fringing field would improve the energy resolution of the analysing system. Do you know how great this improvement would be?

JONES : I think that the detrimental effect of fringing field on the beam divergence would cancel any improvement of the energy resolution.