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A PRELIMINARY CONCEPT FOR THE DESIGN OF MAGNETS AT TARGET LOCATIONS

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ABSTRACT

A new concept of magnets with long poles is proposed for utilization in very high radiation environments, for example, at target stations. The main advantages are the possibility of locating the magnet coils at regions of low radiation field level and the elimination of vacuum joints between magnets. These two features should overcome maintenance limitations with present designs.

CONCEPT

The TRIUMF KAON Factory Proposal[1] shows magnets at targets in the experimental halls which are similar in concept to the ones that we use in our present meson lines. These magnets are situated about 50 cm from the meson targets and when removed for servicing we see radiation fields of several hundred rads/hour. The KAON factory operation will make the residual radiation problem much more severe and present maintenance methods will have to be considerably changed. It is felt that they are now at their limit. Our present magnets do not lend themselves to repair by remote manipulators in a hot cell and a considerable amount of effort is needed to remove them from the beam lines if they do need attention. This means that in practice we usually send someone in to do a 'hot repair' if it is at all possible.

The problems that we have experienced with magnets are nearly all connected with the coils such as the breakage of ceramic insulators or leakage at brazed water fittings. The other source of problem associated with the magnets is the vacuum joints (which allow the magnets to be removed from the beamline). These joints which use indium seal rings are nominally remotely changeable using tools at a distance. Unfortunately, they tend to pressure weld with time and are sometimes very difficult to separate. Once separated the mating faces then have to be cleaned to remove residual sheared indium metal still bonded to the seal face.

We need a concept which eliminates these types of problems and the following ideas are our first thoughts on such a new concept. At a workshop at TRIUMF in June 1986 we put forward a suggestion which we have started to look at in more detail. This suggestion was that magnets should not be designed with coils adjacent to the field gaps but should have long poles with coils remote from the beam tube and shielded from the radiation. Such a magnet, a dipole, is shown in Fig. 1.

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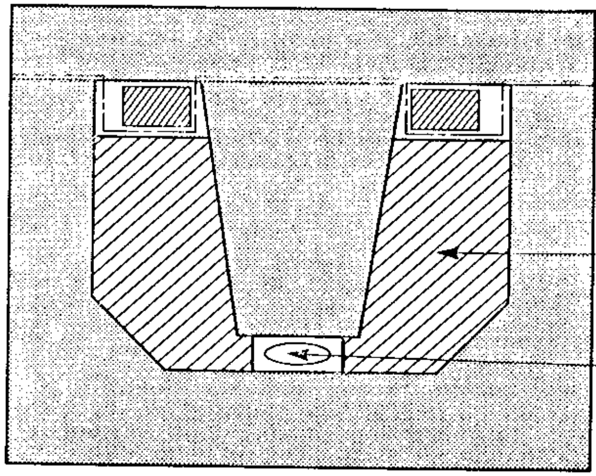

Fig. 1. Proposed dipole with long pole.

It is easy to see that this magnet could be designed so that if the coil needed to be serviced it could be removed without exposing the beam tube. The lower part of the magnet is made only from iron and non-magnetic materials. Once installed and aligned it would be permanently in place. The vacuum tube could be welded in and so the troublesome vacuum joints can be eliminated. Figure 2 shows a POISSON plot for a 15 kG dipole with a 6 in. air gap. The uniform field extends out to ±6 in. The coils are situated 55 in. above the beam plane; at this location the radiation levels are reduced about 5

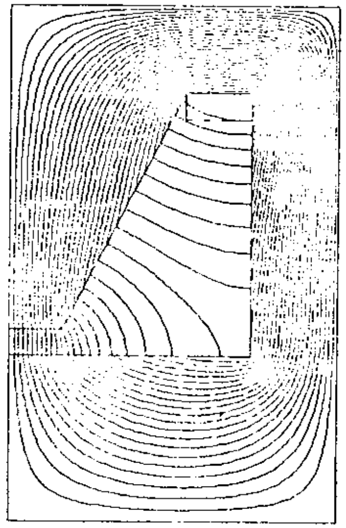

Fig. 2. Semi dipole field profile

orders of magnitude.

This type of design is essentially a blending of the magnet and the steel shielding into a single entity. It achieves the objectives of eliminating the vacuum joints upstream and downstream of the magnet, and the coils are in a relatively low radiation field. Furthermore the parts of the magnet with the highest residual radiation levels should never have to be exposed during a maintenance procedure.

QUADRUPOLES

Quadrupoles are not quite so simple. At SIN suspended half quadrupoles are now used following their thin meson target.[2] These magnets can be readily removed for servicing and replaced but the coils are still adjacent to the beam gap.

Figure 3 shows a half quadrupole with long poles and the coils 80 in. from the beam plane. It has all the features of the dipole just described, and the void would be filled with non-magnetic material. It has a semi-aperture of 5 in. and a field of 8 kG at the pole tip. The disadvantage of half quadrupoles is that the semi aperture has to be larger than for a regular design and the beam sees a dipole field component. A specific triplet must be used to make the beam transport achromatic at the start of each channel.

We looked for a way of making a four pole magnet having the above features. Such a magnet is shown in Fig. 4. This is an open-sided quadrupole with only two coils which again can be remote. The disadvantage of this design, at present, is that the harmonics deteriorate as the magnet is made non-symmetrical. Table I shows that the magnetic centre shifts as the coil is displaced away from the centre. The dipole and the third harmonic terms become larger as the magnet is made more non-symmetrical. It is interesting that the 6th, 10th and 14th do not seem to be affected. At TRIUMF we are looking into the design of a quadrupole with specific harmonics for a spectrometer application. This means we can probably alter the pole profile to improve the harmonics. Also we can increase the steel on the side yokes and long poles to reduce the iron ampere turns. These two methods should lead us to a more acceptable solution.

Table I. Comparison of harmonic content as magnet poles are lengthened asymmetrically, values in percent.

Harmonics #	Symmetrical Magnet	Non-Symmetric Coil	Pole Elongated 10 in	Pole Elongated 20 in
1	0.05	5.30	12.60	21.50
2	100.00	100.00	100.00	100.00
3	0.13	2.10	4.61	8.25
6	0.05	0.04	0.07	0.07
10	0.18	0.18	0.17	0.16

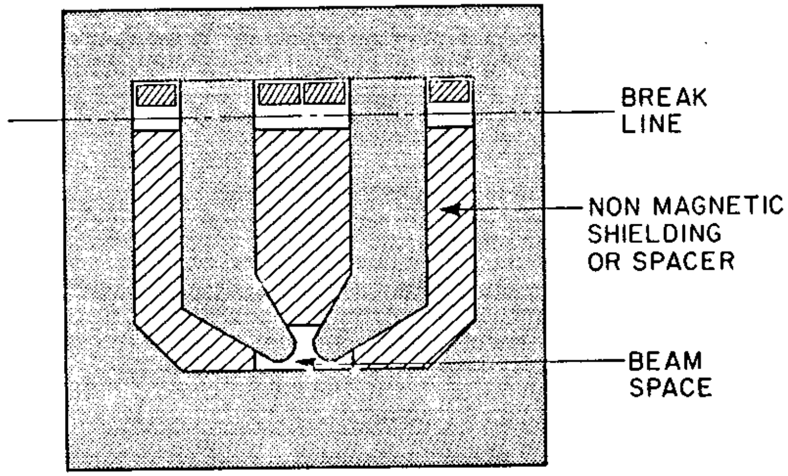

Fig. 3(a). Half quadrupole with long poles.

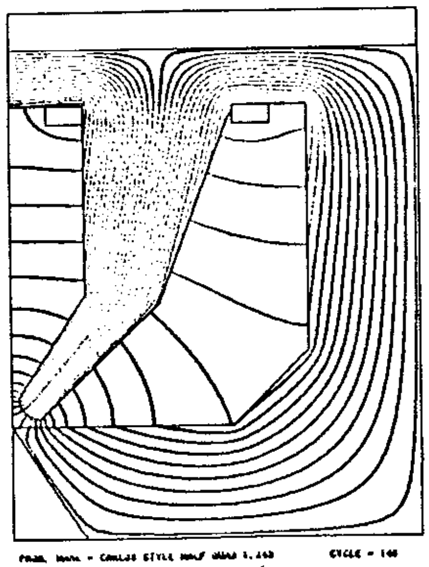

Fig. 3(b). Half quadrupole field configuration.

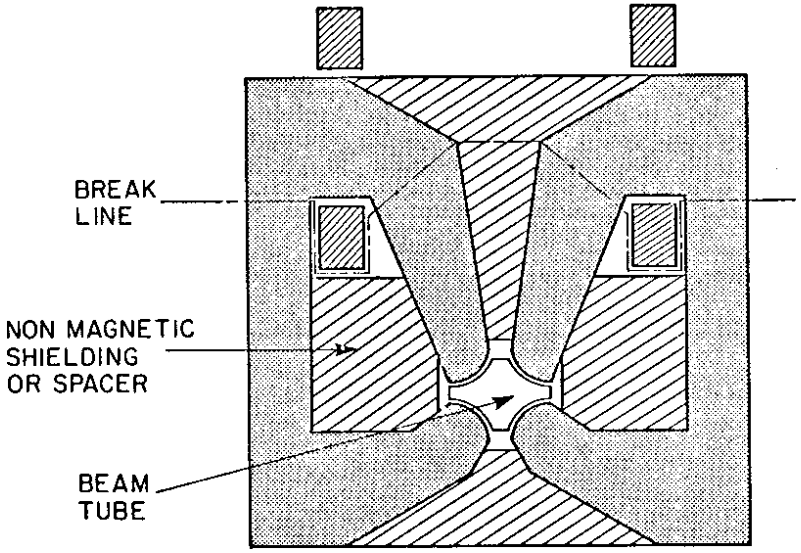

Fig. 4(a). Proposed asymmetric long pole quadrupole.

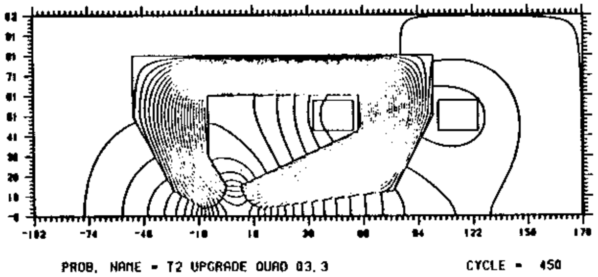

Fig. 4(b). Asymmetric quadrupole field configuration.

OTHER PROBLEMS

The magnets will be subject to nuclear heating from particles scattered at the target. Iron poles and non-magnetic spacers will have to be directly cooled by water tubes passing through them. If the magnetic flux densities are reasonable and the cooling passages are small then the perturbation of the field should not be serious.

The heat input rate is 1 W/cm^3, so a pole of width 40 cm and a length of 2.50 m will have a heat input of 200 kW in a height of 20 cm. Assuming that cooling tubes 1 cm diameter are used, it will be necessary to have tube spacing of about 15 cm to keep the temperature differential in the steel below 100 C.

The non-magnetic parts of the magnet can be made from 300 series stainless steel, brass, copper, lead, etc. The choice will be made as a function of cost, radiation shielding effectiveness and thermal conductivity.

CONCLUSIONS

This article describes the basic ideas but much work remains to complete a full design of a 'long pole' magnet.

The long poles make flux leakage between adjacent magnets more serious than usual so we will probably have to use guard plates and there may be limitations on how closely together elements can be placed.

We have presented a preliminary concept which eliminates some of the problems of using magnets in high radiation areas. The vunerable parts of the magnet have been removed from the high radiation region and there should be no reason to have vacuum joints before or after the magnet.

ACKNOWLEDGEMENTS

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