BNL-29197

1981 Particle Accelerator Conference - March 11-13, 1981

CONF-810314--94

e71

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ISABELLE SUPERCONDUCTING POWER DISTRIBUTION SYSTEM*

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Summary

A superconducting power distribution system has been designed which in addition to powering main magnet windings, will provide power for both individual and series connected magnet trim and correction windings.

The proposed design utilizes two main and 42 trim superconducting leads arranged in two busses, which are routed through the magnets and their interconnectors. Since these leads must be maintained at cryogenic temperature, they are all located within the primary coolant system.

The ISABELLE configuration, which is essentially a hexagon with rounded corners[1], can be divided into six essentially identical sextants. The portion of magnet lattice in the curved part of the sextant is called the regular bending section, while the magnet lattice in the straight areas at the end of the arcs is called the matching section. At the end of the matching regions are located lead pots, where superconducting leads penetrate the cryogenic environment and connect to normal conductors which span the experimental areas. In addition, at each of three locations within the curve, there is a provision for a twelve lead "minipot" penetration.

Quality assurance associated with correctly connecting 40 leads at each of the many magnet interconnectors is not a trivial problem. A combination of positive lead identification, complete wiring instructions for each interconnection, visual inspections, individual magnetic testing and progressive system testing will be used to assure that proper connections are made.

Ring Wide Circuits

Ring wide circuits are those which are powered by a single power supply and are continuous through the entire ring. They consist of the main magnet power circuit (including bypass circuitry) shown in Figure 1; the sextupole correction circuits (b_2) shown in Figure 2; the octupole (b_3), decapole (b_4) and duodecapole (b_5) correction circuits all shown in Figure 3 and the quadrupole trim circuits (b_1) depicted in Figure 4.

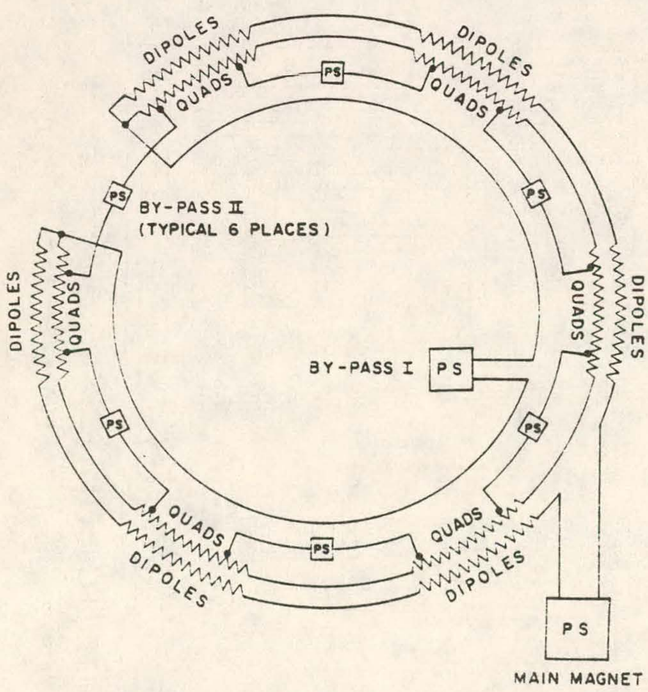

FIG. 1 MAIN POWER AND BY-PASS CIRCUITS

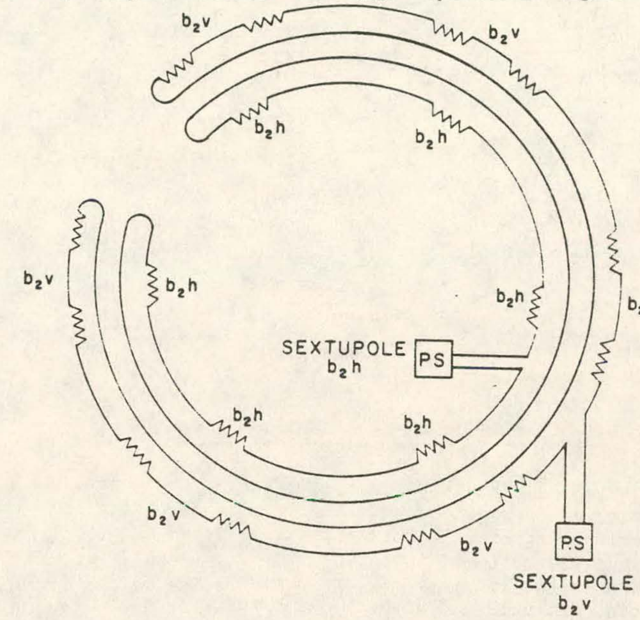

FIG. 2 SEXTUPOLE CORRECTION CIRCUITS

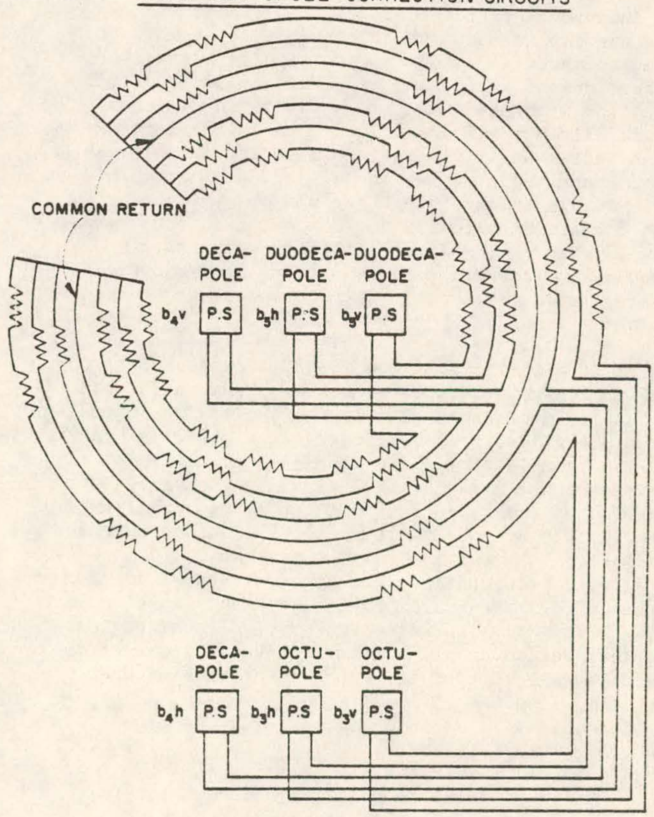

FIG. 3 MULTIPOLE CORRECTION CIRCUITS

*Work performed under the auspices of the U.S. Dept. of Energy.

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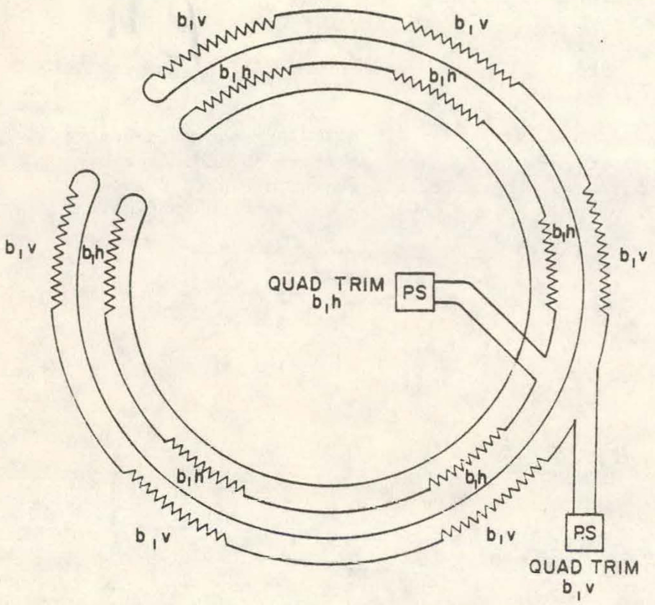

FIG. 4 REGULAR QUAD TRIM CIRCUITS

As can be seen in Figures 2, 3 and 4, there are two types of correction and trim circuits depending on whether the magnet is a horizontally or vertically focusing quadrupole or in the case of a dipole, its location in the lattice. Figure 3 also shows that the octupole, decapole and duodecapole correction circuits all have a common return, greatly reducing the number of required leads.

Individual Circuits

Individual circuits are those which provide power for a winding in one, two or possibly three magnets. The majority of individual circuits are in the matching sections of a ring and power multipole and orbit correction windings which are depicted in Figure 5. Additionally, each quadrupole magnet in the lattice has an individually powered orbit correction winding. For the matching regions, these leads are also depicted on Figure 5. In the curved regions of a sextant, the orbit correction circuits for the quadrupole magnets, shown in Figure 6, will penetrate the cryogenic envelope at the three locations previously identified. To conserve leads these orbit corrections have a common return.

Design Flexibility

It is expected that the ISABELLE design will continue to evolve even after successful initial operation. Some design evolutions anticipated include an increase in the power levels of some correction circuits (maximum trim lead capacity is 300 A) and operation of the machine using alternate individually powered circuits. The primary coolant circuit is essentially all welded with a bolted access port only available at the lead pots. In order to minimize any impact on machine operating schedule, circuit changes should be accomplished either externally to the cryogenic envelope or in the lead pots. Any proposed changes requiring cutting into welded connections must have their benefits carefully weighed against the cost and machine operating time loss.

Specific provisions made for future machine evolution are:

1. The ability to switch polarity of current in some circuits to maintain a common return current within the lead capacity.
2. The ability to energize additional individually powered multipole corrections in the maching region.
3. The ability to series connect certain multipole corrections in the matching section with those in the bending section.

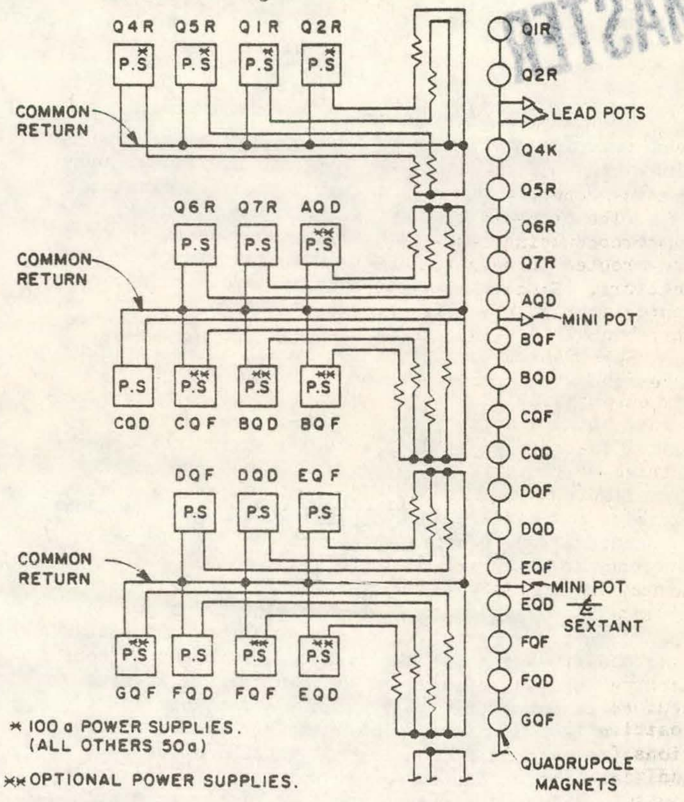

FIG. 5 ORBIT CORRECTION CIRCUITS & POWER SUPPLIES

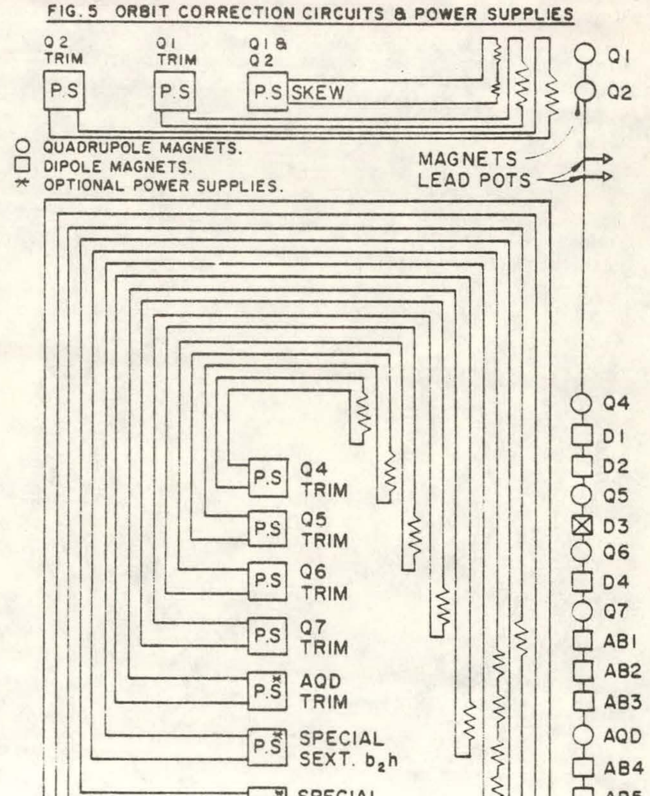

FIG. 6 INDIVIDUALLY POWERED CIRCUITS IN INSERTION REGION.

matching region.

3. The ability to series connect certain multipole corrections in the matching section with those in the bending section.

In addition, each of the three "minipots" has one spare 100 A capacity penetration. Within the cryogenic envelope there are two spare 300 A capacity leads which run the lengh of the sextant and three more which run the length of the bending region of the sextant.

Quality Assurance Aspects

There are 360 regular* dipoles, 72 regular focusing quadrupoles and 66 regular defocusing quadrupoles in each ring of ISABELLE. All magnets of each type will be identical in design. This is a fundamental requirement for economically producing the large number of magnets required for ISABELLE. It follows that the internal main, trim and correction power lead connection will also be identical in each type of magnet.

The preceeding requirements, dictate that at some magnet interconnections, trim leads must be cross connected to achieve the required circuitry. Assuring that correct connections of 40 trim leads are made at approximately 2000 interconnections in the machine will be accomplished by a four part approach consisting of: positive lead identification, individualized connection instructions for each magnet interconnection, redundant visual inspection (including photographic records) and redundant electrical/magnetic testing.

The trim leads consist of a flat superconducting braid wrapped with Kapton tape. Over the Kapton, a braided fiberglass sleeve is woven. The fiberglass sleeve on each of the 40 trim leads will have its own special colors woven in, providing unique lead identification.

Each magnet interconnection will have a wiring instruction which indicates where to connect or terminate each lead. This form will have places for the technician performing the job and an inspector to sign for each connection or termination. In addition, color photographs will be taken as a record of the connections.

*"Regular" in this case means each type magnet is of identical design to the others of its type. There are 6 "irregular" dipoles and 36 "irregular" quadrupoles in each ring.

The electrical testing will consist of "HiPot" tests to ground and between leads at 5 kV for the main bypass leads and at 3 kV for the trim leads.

A system continuity check will then be made using 40 coded voltages applied to the trim leads at the source end of a string of magnets and checked at the receiving end of each new magnet added to the string.

A magnetic polarity test will then be performed. This test will use a 2 axis Hall probe fixture inserted in the bore of the magnet. Each trim or correction winding (three per magnet) will be energized one at a time, using a low current level. The probe will sense field direction thus checking the wiring to the windings.

Satisfactory completion of these tests will assure that the 40 trim lead connections are correctly wired.

Acknowledgements

The author wishes to thank Mr. J. G. Cottingham for his guidance and contributions to the design reported on in this paper.

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