SSCL-Preprint-487

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May 1993
Distribution Category: 414

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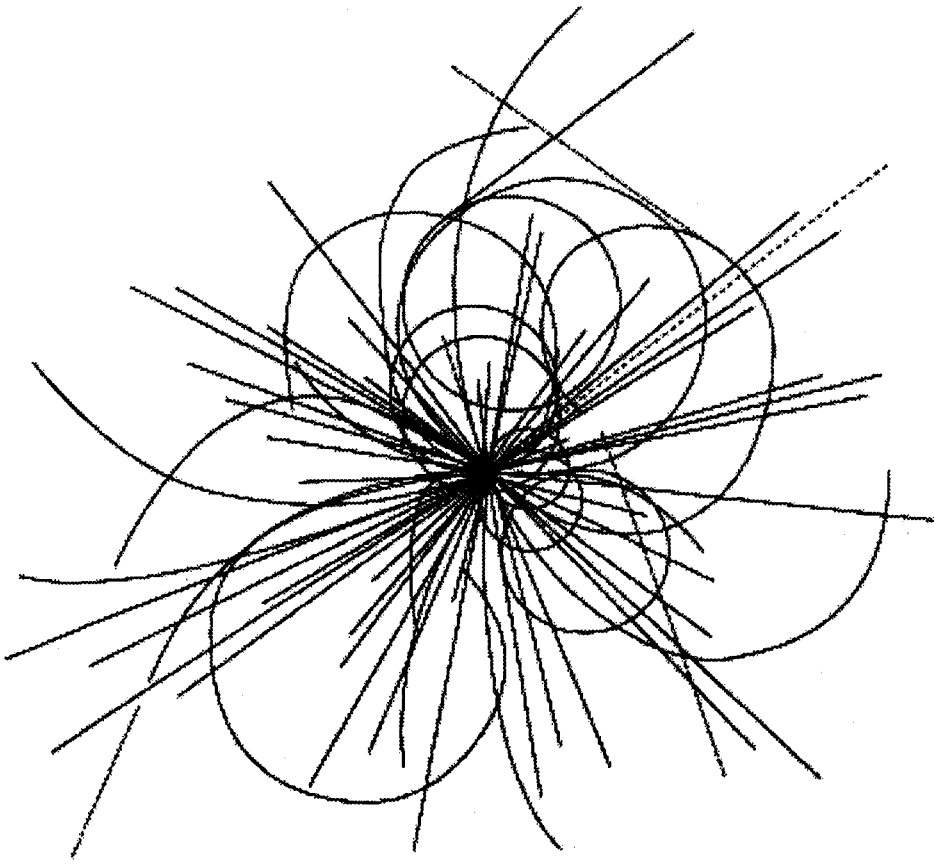

Superconducting Super Collider Laboratory

To be published in *Supercollider 5* SSCL-Preprint-487

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May 1993

*Presented at the Fifth Annual International Symposium on the Super Collider, May 6–8, 1993 San Francisco, CA.
†Operated by the Universities Research Association, Inc., for the U.S. Department of Energy under Contract No. DE-AC35-89ER40486.

AN ENGINEERING DESIGN STUDY OF ALTERNATIVE DESIGN OPTIONS FOR THE FORWARD TOROIDS OF THE SSC SDC DETECTOR

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ABSTRACT

The Muon Forward Toroids (MFTs) are 3-meter-thick sections of magnetized iron located at both ends of the detector proposed by the Solenoidal Detector Collaboration (SDC). The forward calorimeter and the outer muon chamber layers are supported by the MFT. This paper investigates viable and cost effective construction alternatives for the MFTs.

INTRODUCTION

The SDC detector is a major SSC experiment located at the IR8 site of the east campus. The total weight of the detector is approximately 32,000 metric tons.

The MFTs are located at both ends of the Muon Barrel Toroid (MBT) and are designed to be moved out of the MBT to facilitate access to the detector components located inside the MBT. The shape, dimensions, magnetic field distribution, and the overall tolerances of the MFTs must satisfy the physics goals of the experiments and other requirements of the detector.

The principal objective of this work was to develop cost-effective methods of fabrication and assembly of the MFT steel and its support system that will meet these requirements.

GENERAL DESCRIPTION

Each MFT is made up of two 1.5-meter-thick steel sections (MFT1 and MFT2), as shown in Figure 1. The forward detector system, including the Forward Calorimeter, is supported by the MFT. Each forward toroid assembly weighs about 3075 metric tons, the forward detection system weighs about 825 metric tons, and MFT1 and MFT2 weigh about 1075 and 1165 metric tons, respectively. The toroid

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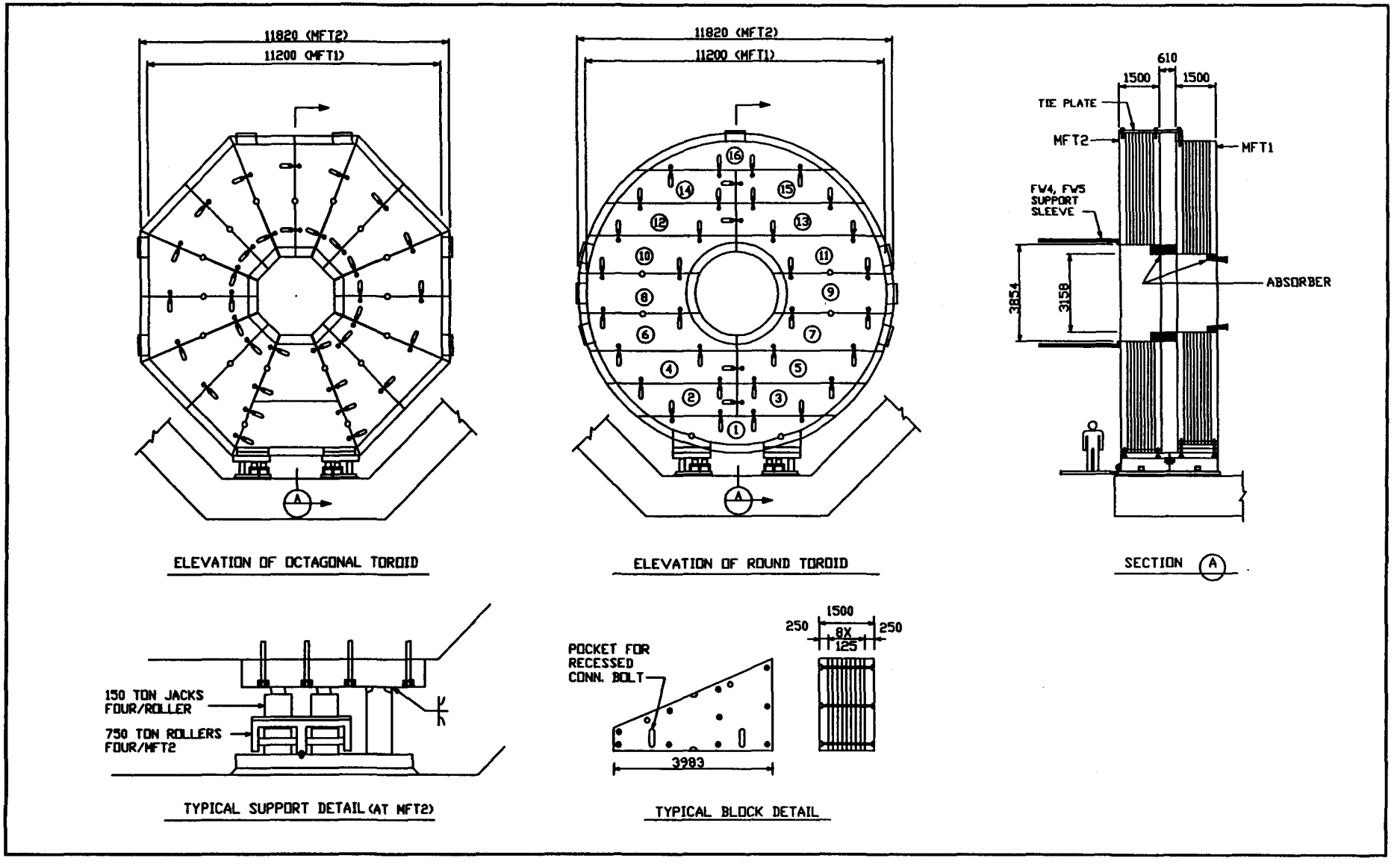

Figure 1. Forward Toroid Alternatives.

assembly is supported on two T-shaped weldments bolted to the underside of the MFT, as shown at the lower left of Figure 1. The supports are equipped with hydraulic jacks and rollers to permit adjustment and movement of the MFT. To reduce costs and construction time in the hall, the steel of the MFT is assembled from blocks of plates bolted together in the fabrication shop.

ALTERNATIVE SHAPES INVESTIGATED

Two toroid shapes, one round, one octagonal, and two block shapes, one pie-shaped, one rectangular, were investigated. Each toroid section was assembled from 16 blocks weighing from 60 to 75 metric tons. The octagonal toroid was built from 14 pie-shaped and two trapezoidal blocks, and the round toroid from 16 rectangular blocks. A round toroid assembled from pie-shaped blocks was also investigated. A comparison of the three types of toroid designs investigated is presented at the conclusion of this paper.

BLOCK CONSTRUCTION AND ASSEMBLY

Each block is built in the fabrication shop from vertical plates bolted together by longitudinal high-strength bolts placed along the edges of the block, as shown in Figure 1, Typical Block Detail. To accommodate the recessed holes of the longitudinal bolts and the pockets of the block connection bolts, the outer plates of the blocks are 250 mm thick, while the inner plates are thinner to facilitate flattening the plates by the longitudinal bolts. Because of this arrangement, the flatness tolerance of the inner plates is not critical; however, the outer plates must be rolled to within the required flatness of the finished block.

After tightening the longitudinal bolts, the contact surfaces of each block are machined for proper magnetic continuity and fit. Since the machined surfaces of the rectangular block round toroid alternative are parallel to each other, the angular milling accuracy and resulting flatness of the completed toroid should be easier to achieve.

For uniform flux distribution the eight radial surfaces of the octagonal toroid alternative are separated by nonmagnetic plates tapering from 26 mm to 2.6 mm (approximately), from the inner to the outer corners of the toroid.

The blocks are held together by 64 mm diameter high-strength stud-bolts recessed into the outer block plates. There are four bolts between adjacent blocks. After the bolts are tightened, the slots are plugged with steel inserts to satisfy the MFT ray penetration requirements. To prevent sliding, some of the blocks are tied to each other by 200 mm diameter fitted shear pins.

To provide sufficient stability against overturning in the "Z" direction, and a more uniform distribution of the eccentric weight of the forward detector system to the rollers, MFT1 and MFT2 are tied together with stiff shear transfer plates located on the sides of the toroid.

To ensure the required flatness tolerance of the completed toroid and proper fit of the blocks during assembly in the experimental hall, the toroid blocks are pre-assembled in the fabrication shop. Any tolerance problems and misfits discovered during pre-assembly can be corrected before blocks leave the fabrication shop. After pre-assembly, the blocks are prime-painted and match-marked before shipment to the SSCL. The machined areas of the blocks are not painted.

MATERIAL SPECIFICATIONS

Materials for the MFT and its supports are as follows:

Component	Material Specifications
Plates for block construction	SAE 1010, or equal
Toroid shear keys and bolt pocket inserts	SAE 1010, or equal
Block connecting studs and Z bolts	ASTM F568
Plates for MFT support frame and tie plates	ASTM A36, or equal

FABRICATION TOLERANCES

To meet the physics goals of the experiments and the specification requirements, the fabrication tolerances of the blocks and of the completed MFT must be as follows:

- Tolerance for the total thickness of all plates in a block must be +/- 5 mm.
- Flatness tolerance (maximum deviation from a true flat plane) of the outer vertical block plates must be 10 mm at any location of the plate.
- Angular deviation of the machined contact surfaces of the block must be such that the deviation of any location of the vertical surface of the completed toroid from the true plane is not more than 15 mm.

SUMMARY OF FINDINGS

The structural integrity, method of fabrication, and assembly of octagonal and round-shaped toroids assembled from large blocks were investigated. We found that in comparison with octagonal or round toroids built from pie-shaped blocks, the structural integrity of a round shaped toroid built from rectangular blocks is less dependant on the block-to-block connection bolts, and the fabrication and machining of the blocks is less complicated and should result in better tolerances. The number and total length of the shear pins is also less, however, the total area of the machined surfaces is about 24 per cent more than what is required for toroids assembled from pie-shaped blocks.

Table 1 summarizes the findings on the principal features of the three design alternatives investigated.

Table 1. Comparison of Forward Toroid Shapes.

FEATURES EVALUATED	OCTAGONAL TOROID	ROUND TOROID	
	Pie-Shaped Blocks	Pie-Shaped Blocks	Rectangular Blocks
Plate Material Waste	Moderate	Moderate	Minimum
Toroid Support	Flat plate	Machined plates and shear keys	
Flux Uniformity MBT to MFT	Good	Not as good	Not as good
Flux Uniformity of MFT	Requires tapered spacers	Excellent	Excellent
Block Fabrication	Machining tolerances are critical and more difficult to maintain		Machining tolerances are less critical, easier to maintain
Block Assembly	Not difficult, but requires extra step to install tapered spacers	Not difficult	Easy, fewer shear pins to install