MECHANICAL DESIGN OF THE LAMPF MEDIUM RESOLUTION SPECTROMETER AND CEBAF SHORT ORBIT SPECTROMETER MAGNETS

V. E. Hart, E. D. Bush Jr., S. A. Schilling
Los Alamos National Laboratory
Los Alamos, New Mexico, USA

Abstract

The Medium Resolution Spectrometer (MRS) magnet assembly was built at the Los Alamos Meson Physics Facility (LAMPF) in 1989 and is being duplicated for the Short Orbit Spectrometer (SOS) at the Continuous Electron Beam Accelerator Facility (CEBAF). Utilizing existing designs, fabrication technology, and tooling from the MRS will save substantial costs and time for the SOS. The MRS/SOS assemblies consist of a quadrupole-dipole-reverse dipole QD (-D) configuration with dipole gaps of 16 cm and 1.7 T field. Net bend angle of the particles is minimized by the reverse polarity dipole. The magnet assemblies have spacer blocks between solid return yokes to establish precision pole gaps, are less than 5 meters long, and weigh 91 m ton. The poles have faces which are chamfered and shaped to a fifth order polynomial contour and a Purcell filter at the base for enhanced field homogeneity. The poles are utilized as part of the vacuum system by sandwiching aluminum sand cast vacuum chambers between the pole faces. The vacuum chambers and electrical coils are fitted to concave and convex pole contours.

Introduction

The LAMPF MRS and the CEBAF SOS magnet assemblies are essentially exact copies [1]. The MRS is shown schematically in Fig. 1 with design parameters given in Table 1. The MRS was commissioned in 1990 and the SOS is scheduled for completion in 1993. The size, weight, shape complexity, gap width restrictions, etc. presented a variety of design and fabrication challenges which were solved successfully.

Mechanical Design and Fabrication

Quadrupole Assembly

The horizontal focusing quadrupole is positioned as close as possible to the upstream entrance to MRS (BM-01) and is designed to accommodate small scattering angles. The poles and yokes are uniquely designed in pairs such that top and bottom sections are magnetically de-coupled. The side yokes are removable and quad coils are positioned so that beam interception by magnet structures is minimized. Stainless steel shim blocks are bolted in place between the poles to provide support and rigidity. The quad is mounted directly on the front dipole spacer as shown in Fig. 1. Braces and field clamps were added between the quad and dipole to reduce undesirable magnetic field interactions and deflections.

Dipole Assembly

The dipole assembly has two dipoles of opposite polarity which share common yoke plates of 305 mm thickness. The yoke plates weigh 23,000 kg each and are machined on all surfaces to maintain the 160 mm pole gap to +0.250/-0.000 mm and +/-0.127 mm parallelism. Position and rotational tolerance of poles and yokes with respect to each other was held to +/-0.254 mm by using blind dowels in all mating parts. The entire magnet assembly was generated on a CAD system with all parts being located to a common coordinate system.

The poles for BM-01 and BM-02 have complicated contoured shapes that are generated by fifth and sixth order

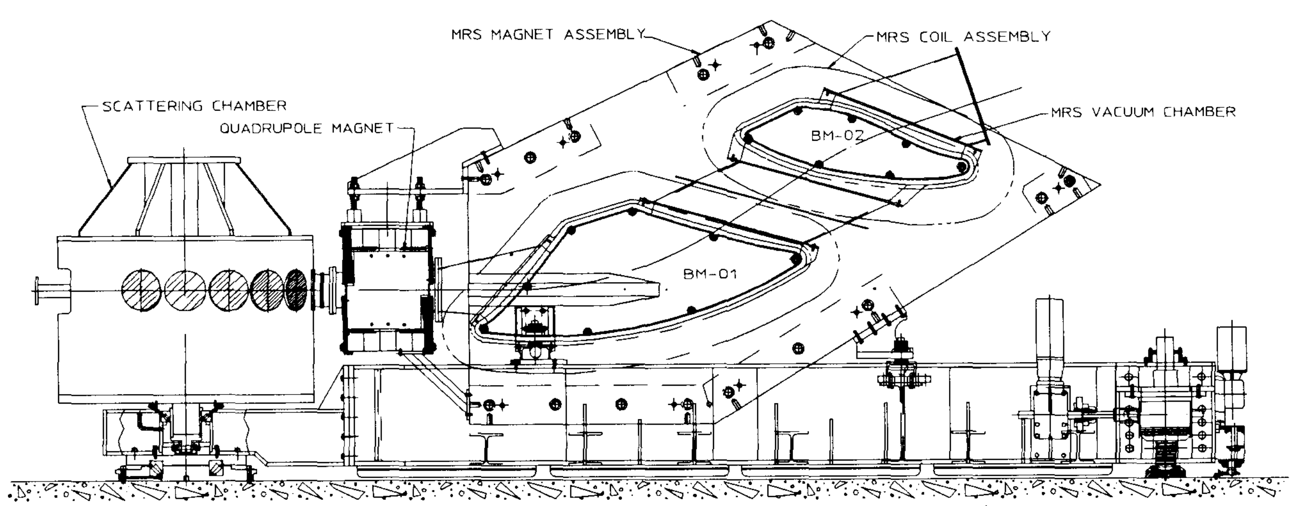

FIG. 1 LAMPF MEDIUM RESOLUTION SPECTROMETER (MRS) ASSEMBLY

TABLE I
MRS DESIGN PARAMETERS

	MS-QM	MS-BM-01	MS-BM-02
MAGNETIC PARAMETERS			
GAP (in)	5	6.3	6.3
B (kG)	13	19.5	19.5
PHYSICAL			
TURNS/LAYER	15	12	14
LAYERS/COIL SECTION	8	14	14
TOTAL TURNS	240	336	392
COIL			
COND. SECTION(in*in)	0.34	0.65	0.65
MEAN TURN L (in)	70	274	199
COIL L (ft)	1,400.00	7,672.00	6,500.67
ID (in)	0.18	0.363	0.363
COPPER AREA (in2)	0.09	0.31	0.31
WEIGHT (#/ft)	0.33	1.19	1.19
TOTAL WEIGHT (#)	466.85	9,154.24	7,756.60
COIL WIDTH (in)	6.05	8.60	10.00
COIL HEIGHT (in)	3.32	10.00	10.00
ELECTRICAL			
NI (A*turns)	192000	275823	275823
CURRENT (A)	800	821	704
CURRENT DENS (A/in2)	9,298.71	2,666.62	2,285.68
RESISTANCE (ohms)	0.1537612	0.2354858	0.1995327
VOLTAGE (V)	123.01	193.31	140.40
POWER (kW)	98.41	158.69	98.79
COOLING			
NO. WATER CIRCUITS	48	28	28
TEMP RISE (F)	20	20	20
FLOW (GPM)/CIRCUIT	0.70	1.94	1.21
LENGTH/ CIRCUIT (ft)	29.17	274.00	232.17
PRESS. DROP (#/in2)	35.20	77.88	28.25

polynomial equations as shown in Fig. 2. Faces of the poles are chamfered for precision field forming and have a 51 mm step for vacuum envelope sealing. The base of the poles have 6.35 mm spaces that function as Purcell filters for enhanced field homogeneity. Pole thickness is 355.6 mm.

The vacuum envelope for the spectrometer bore presented a problem since it was not practical to increase the gap to allow enough space for a vacuum chamber. The very large vacuum areas would have required thick stiffeners. Solutions included welding the vacuum chamber to pole pieces (not very desirable) or to have a vacuum can which sealed on the pole faces. The latter option was pursued with choices of a welded or cast vacuum envelope. A weldment to fit the pole shapes would be very complicated and require extensive heat treatment and machining to obtain a stable part. Past experience with the LAMPF LEP CLAMSHELL SPECTROMETER has shown that an aluminum sand cast vacuum can was possible and performed as required (vacuum in the 5x10-6 Torr range). Successful castings for the MRS were made and are in service. Castings for the SOS which used the MRS patterns and molds have been cast and are presently being helium leak checked. The vacuum can inside profile is machined to match the pole piece contours to within 0.381 mm (see Fig. 3) and the can is held between two poles with a 0.076 mm interference compression fit. BM-01 and BM-02 vacuum cans are connected together during assembly using a special field installed single convolution bellows connector.

The MRS coils were bifilar wound in two layer pancakes to match the pole contours. Each coil has a 19 mm uniform space between it and the pole outside surface. Coil design criteria are given in Table 1. Each pole has a seven pancake (14 layer) coil section surrounding it. The coil winding and casting mold used to produce the MRS coils will also be used for the SOS magnet coils. The coil sections are banded together, supported on cushioned custom fitted pads, and separated by brass compression jacks as shown in Fig. 4. The coil mounting has proven to be very rigid and no movement has been detected during magnet use.

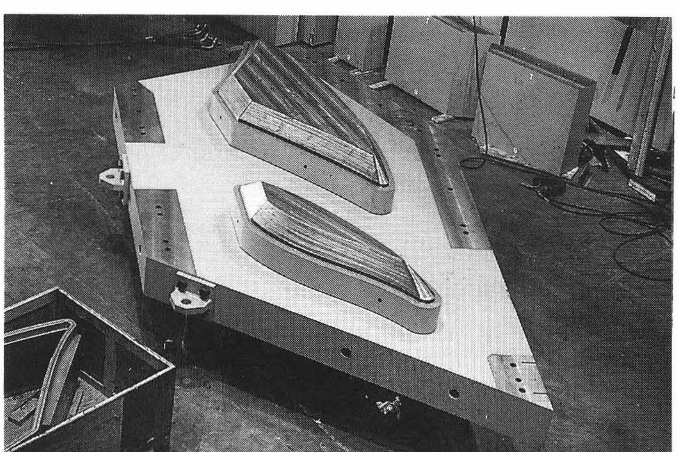

Fig. 2 MRS Pole Pieces

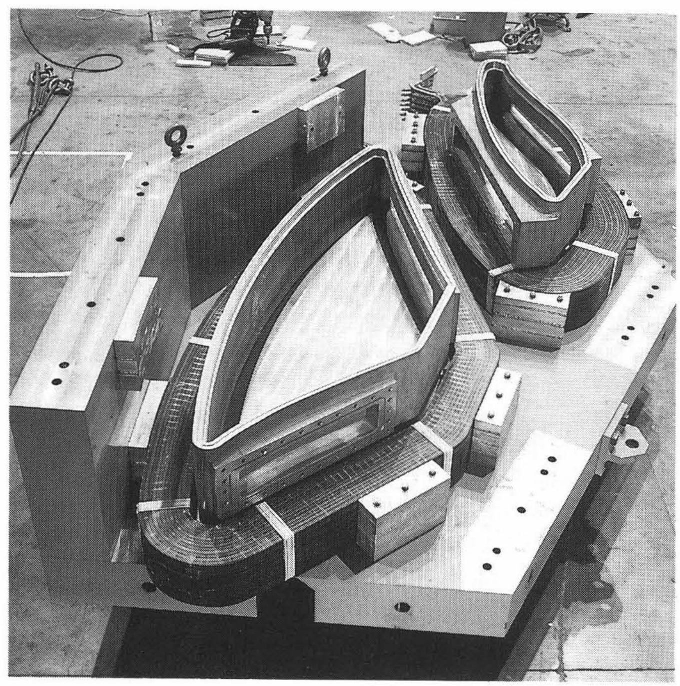

Fig. 3 MRS Sand Cast Aluminum Vacuum Cans

A list of suppliers for material and services is shown in the appendix.

Final Assembly and Installation

The complete magnet steel assembly was shop test

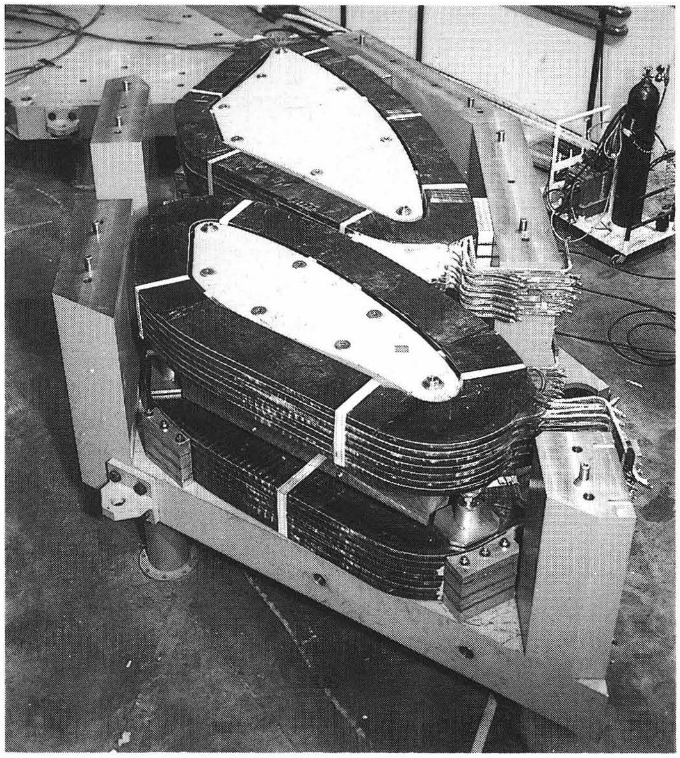

Fig. 4 MRS Magnet Assembly (One Yoke Removed)

assembled and critical tolerances such as pole gap and distance between pole sealing surfaces were measured. The vacuum cans were machined to fit the as built space. Assembly of the yokes and poles was measured by a jig transit to be reproducible to within 0.076 mm. The magnet was disassembled for shipment to Los Alamos.

All magnet components were re-assembled at LAMPF as shown in Fig. 4. The horizontal position assembly sequence was done in the following order: (1) yoke (2) poles (3) coils (4) yoke spacers (5) vacuum cans (6) poles (7) vacuum connector (8) coils (9) yoke. A helium leak check was performed on the complete vacuum envelope prior to installing the top yoke.

The magnet was successfully powered and field mapping measurements [2] made in the horizontal position. A rigging contractor was hired to move the assembled magnet to the LAMPF Experimental Area "B", rotate it 90 degrees, lift and transport the magnet to the support structure.

Conclusion

The MRS assembly complete with air pad support structure and scattering chamber is shown in Fig. 5. The success of the MRS has made the SOS reproduction a much easier and less costly task. Significant savings (~$125k) of engineering time and tooling costs for the SOS fabrication have been made possible by utilizing MRS designs and tooling.

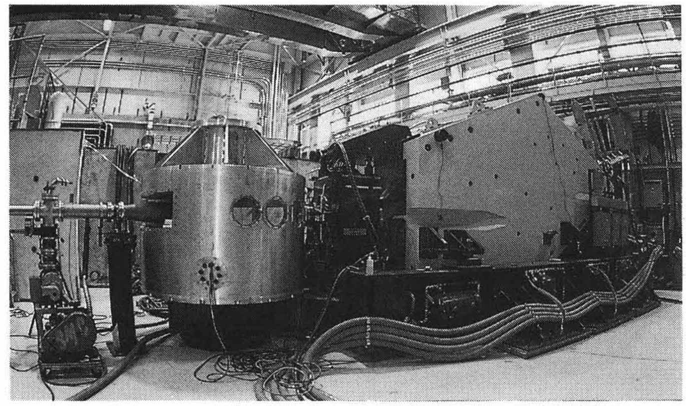

Fig. 5 MRS in LAMPF Area "B"

Acknowledgments

The authors would like to dedicate this paper in memory of NOBUYUKI TANAKA, a staff physicist at LAMPF whose supportive efforts with the engineers, designers, and technicians helped in a large way to make the MRS project a success.

MP-8 personnel from the following areas made significant contributions to the MRS fabrication project: Engineering Staff, Drafting, Magnet Fabrication and Mapping, Mechanical Support, Alignment, Vacuum, and Power Supply. MP-10 personnel were responsible for commissioning the MRS and its operation.

References

1. H. E. Jackson, R. S. Kowalczyk, D. H. Potterveld, B. Zeidman (ANL), R. L. Boudrie, V. E. Hart (LANL), "A Short Orbit Spectrometer for Hall "C".
2. B. L. Weintraub, S. F. Archuletta, M. G. Mays, M. P. Harrington, G. A. Montoya (LANL), "Magnetic Field Measurement of the MRS Dipole Magnets", 11th International Conference on Magnet Technology, Vol. 2, pg. 1176.

Appendix

List of companies supplying material and services for the MRS Magnet Fabrication:

1. Magnet Steel - Creusot-Marrel, Rive-de-Gier, France
2. Coil Conductor - Outokumpu Oy, Pori, Finland
3. Sand Castings - Sunset Foundry, Kent, Washington
4. Magnet Machining - R.O. Schulz, Elmwood Park, IL
5. Coil Winding - Elma Engineering, Palo Alto, CA