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Design Requirements Definition Report for ICCS for Large Scale MHD Magnets

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NOTICE

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for
ICCS for Large Scale MHD Magnets

1.0 Introduction

The establishment of the Design Requirements Definition for Internally-Cooled Cabled Superconductors (ICCS) for large scale MHD magnets is called for as Task I of the conductor development program being performed by MIT for the Pittsburgh Energy Technology Center (PETC) under Contract DE-AC22-84PC70512.

This work, which was started August 21, 1984, has accomplished the completion of the draft Design Requirements Definition as presented in this report. This is a draft in that it is incomplete in some areas, including certain conductor design parameters (copper resistivity, ratio of copper to superconductor, maximum tensile load, etc.), splice details, dimensional tolerances, surface finishes, etc.

2.0 Technical Approach

In order to establish a conductor design requirements definition, it is necessary to know the requirements which the MHD system imposes on the magnet and also to know the design characteristics of the magnet that will be needed to meet those requirements.

Requirements which retrofit-type MHD systems impose on magnets have been determined based on information obtained from PETC, from contractors working on Advanced Power Train studies, and from others in the MHD community. This information was supplemented with information on magnet requirements obtained from earlier studies.

Since the scope of the Advanced Power Train studies does not include magnet design, preconceptual design work necessary to establish magnet characteristics has been done by MIT.

The magnet design requirements, the characteristics of a typical retrofit-size MHD magnet preconceptual design that was developed by MIT, and the supporting engineering and analysis are described in technical progress reports issued to date under Contract DE-AC22-84PC70512. This work has served as the basis for the conductor design requirements which are presented in Section 3.

3.0 Design Requirements Definition

This section contains a summary of the functional requirements, system interfaces, design criteria, and design parameters (typical) that constitute the Design Requirements Definition for ICCS for large scale MHD magnets.

3.1 Functional Requirements

The major functional requirements of the conductor are:

1. To carry the magnet design (operating) current continuously at the design magnetic field and temperature at which the conductor operates, with negligible power loss.

2. To withstand mechanical, electrical, and thermal disturbances associated with coil charging and steady-state operation without reverting to the normal (nonsuperconducting) state.

3. To withstand the structural loading (transverse compression, axial tension, bending, and pressure) inherent in the magnet application, without damage or loss of performance capability. (Note: No intermediate structure is provided within the winding bundles.)

4. To remain leak tight when operating in a vacuum environment with internal helium pressure at all levels up to maximum (quench) pressure.

5. To withstand emergency discharge conditions, involving operation in the normal (non-superconducting) state with zero cooling during the discharge cycle, without damage or loss of performance capability.

6. To carry internal helium coolant at design flow and within design pressure drop limits under both cooldown and emergency discharge (quench) conditions.

7. To be fabricable in essentially continuous lengths (without intermediate splices) as required for the coil design.

8. To be capable of being joined (spliced) with acceptable power losses per joint.

9. To be capable of being wound at room temperature into coils with design minimum bend radii and without the need for heat treatment after winding.

10. To survive the winding process without degradation of conductor electrical performance or operational structural integrity.

3.2 System Interfaces

Major interfaces with the magnet system are:

1. Connections to magnet electrical power supply system (via vapor-cooled leads).

2. Connections to helium coolant system and emergency vent system (via insulating transitions).

3. Contact with supporting structure (via electrical insulation).

4. Vacuum environment.

3.3 Major Design Criteria

Major design criteria applicable to the conductor are:

1. The conductor shall be suitable for use in superconducting magnets which are required for early commercial MHD power generators. The conductor design shall be well adapted for economical manufacture in the quantities needed, and for economical fabrication into coils of the types used in MHD magnets.

2. The conductor design shall be state-of-the-art. Materials and construction shall be adequately developed and substantiated by experience in the superconducting magnet community.

3. The conductor design and manufacturing technology shall be scalable to meet requirements for future commercial-size MHD magnet systems (MHD channel outputs 500 to 1000 MW; central fields up to 6 T).

4. The conductor design shall minimize cost, including overall cost of assembled coils and of accessory systems.

5. Structural design of the conductor shall be in accordance with the following interim standard:

   "Structural Design Basis for Superconducting Magnets",
   H.D. Becker, Francis Bitter National Magnet Laboratory,
   Massachusetts Institute of Technology, August, 1980.

6. The conductor shall conform with the following codes and standards where applicable:
   a. American National Standards Institute (ANSI)
   b. American Society for Testing and Materials (ASTM)
   c. American Welding Society (AWS)

3.4 Design Parameters (typical)

Performance	
Maximum field at conductor (T)	6.9
Operating temperature (K)	4.5
Operating pressure, helium (MPa)	0.25
Design current at operating pressure, temperature, and maximum field (kA)	18
Critical current at operating pressure, temperature, and maximum field (kA)	24
Stability margin[a], minimum (mJ/cm^3)	40[b]
Quench heating temperature rise, maximum (K)	120[b]
Materials	
Conductor	NbTi/Cu
Min. copper resistivity ratio at 4.5 K, 0 field	(TBD)[c]
Sheath	Type 304 LN, 316 LN St. Steel, or equivalent
Copper to superconductor ratio	(TBD)
Dimensions	
Sheath outside dimensions (cm)	2.08 × 2.08
Sheath outside corner radius (cm)	0.673
Sheath thickness (cm)	0.165
No. of strands	486
Strand diameter (mm)	0.7
Void fraction	0.32
Mechanical	
Minimum bend radius (cm)	30
Maximum continuous length required (m)	1650
Maximum length between vents (m)	825
Maximum internal pressure (MPa)	100
Maximum compressive load (on side) (MPa)	40
Maximum axial tensile load	(TBD)
Internal flow resistance (max. allowable)	(TBD)
Durability (in magnet)	
Service life (years)	30
No. of cooldown/warmup cycles	60
No. of charge/discharge cycles	600

a. The stability margin is the maximum energy that the ICCS can absorb without quenching, when operating at design current, field, and temperature. It is normally expressed as mJ per cm^3 of wire.

b. Tentative. Subject to change when further analysis and testing are performed.

c. TBD = To Be Determined

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