Title: Development of Materials Related to the 60T and 100T Magnets

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Development of Materials Related to the 60T and 100T Magnets

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Center for Materials Science

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In the past year, the effort in materials science related to the 60T and 100T magnets at Los Alamos has been concentrated in three areas: a) development of a fabrication route for Cu-Ag wire in collaboration with Handy and Harman and IGC and b) investigation of the mechanical properties of a variety of potential high strength high conductivity materials c) selection of the reinforcement materials for the coils and development of a fabrication route for these materials. The selection of the conductors and reinforcement materials is based on their mechanical properties and electrical properties at cryogenic temperature (-196°C). We have taken the approach of trying to relate the properties both to design requirements and to the service life of magnet. Thus, we have given some consideration both to the role of the internal stresses developed during the fabrication on the elastic-plastic transition and on the mechanical and thermal stability of heavily drawn wires. The feasibility of the fabrication route and the cost of manufacturing the materials must also be considered. We have emphasized the need to develop a fabrication route capable of producing the conductors with homogeneous mechanical and electrical properties and with a cross-section of 8.6mmx5.2mm and 146m in length or longer for a 100T magnet. After optimization of the fabrication routes, we have produced 8.6mmx5.2mmx1.6mm corner radius Cu-Ag materials with a flow stress at -196°C larger than 1 Gpa at a true strain $\epsilon=0.002$. We are planning to producing the longer lengths of wire using the optimized fabrication route.

GlidCop Al-15 and Al-60 are produced by internal oxidization of the Cu-Al powder, extrusion and cold drawing. The final wire sizes are 5.2mmx8.6mmx1.6 corner radius, 6.7mmx11mmx1.6 corner radius and 7.5mmx12.5mmx1.6 corner radius. These materials have been tested and are currently being used in 60T magnet.

Cyclic softening, which is the strength decrease due to the fatigue, was investigated using mainly Cu-Ag, GlidCop Al-15 and GlidCop Al-60 in the cold rolled and drawn conditions. The fatigue test results in liquid nitrogen showed less cyclic softening than at room temperature. In all the experimental conditions, the rounding of the stress-strain curve resulting from internal stresses was less prominent after the fatigue test. The internal stresses are thought to be due both to the non-uniformity of the deformation and compatibility of two phases in co-deformation. For the magnet design, the materials are strained essentially in the elastic range. Therefore, it appears that the contribution of the internal stress to the strain-stress curve can be diminished by stretching the materials by a small additional tensile strain, by reverse bending or by low temperature thermal cycles and this may be of value in optimizing of the overall production route and fabrication of the magnet.

The reinforcement vessel can be considered as a pressure vessel operating at -196°C. The materials for the reinforcement should have sufficient stiffness, strength and toughness for the service requirements. We have compared the Young's modulus, yield stress and fracture toughness of different cryogenic materials which can be used as reinforcement materials.

The survey was first conducted by selection of suitable candidate materials with good cryogenic properties. Six materials have been considered; maraging steel C250, maraging steel C300, Inconel 718, Nitronic-40, MP35N, and Elgiloy. Due to the larger sizes (cylinders as large as 1.1m in diameter) of the reinforcement materials, the materials with different geometries have been fabricated and tested in order to measure the tensile strength, fracture toughness, and thermal expansion. In addition, the cylinders with and

without holes have been tested to simulate the mechanical behavior at the cryogenic conditions in structures containing defects.