LIQUID HELIUM DUMP CONCEPT FOR A LARGE SCALE
SUPERCONDUCTING MAGNETIC ENERGY STORAGE PLANT

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ABSTRACT

Superconducting Magnetic Energy Storage (SMES) is a potentially cost effective technology for electric utility load leveling. Design concepts and cost estimates of SMES plants capable of delivering 5000 MWh daily have been previously identified. An important feature of a large commercial plant is a system that will reliably shut down the magnet by thermally dissipating the stored energy in the event of an imminent or actual loss of superconductivity. To prevent damage to the coil during such a protective energy dump, the entire coil must be driven "normal", i.e., resistive rather than superconducting, in a short period of time. This requires rapid removal of the liquid helium coolant surrounding the coil.

This paper describes a simple system that has been developed to rapidly remove the liquid helium from the helium vessel which surrounds the coil. The system has only a small number of active components, no external helium storage, and is practical to reset and maintain.

INTRODUCTION

The design of large superconducting magnets for electrical energy storage has progressed to a stage where SMES appears commercially feasible for utility use.1,2 Energy is stored in a magnetic field supported by current in the superconducting coil. The principle of operation of a SMES plant is shown schematically in Fig. 1. Engineering efforts to date have produced a cost effective, constructible concept by focusing on design of the coil, conductor, support components, and the helium and vacuum vessels. The arrangement of these components, constructed in an open trench, is shown in Fig. 2.
One additional aspect of plant design requiring careful attention is the provision for a safe shut-down of the plant in the unlikely event of an imminent or actual loss of superconductivity. The only currently identified events which could lead to a loss of superconductivity in a well designed coil are low liquid helium level resulting from a helium vessel breach or increased thermal load caused by a loss of vacuum. If one of these events occurred while the coil was charged, there would be no opportunity for normal coil discharge, which could take hours. Therefore, the stored energy would be dissipated as heat in the coil. To avoid excessive voltages and to prevent thermal damage to the coil, a controlled procedure is required, so that the entire coil becomes normal and the energy is dissipated uniformly rather than locally. This procedure, called a coil protective energy dump, requires that the helium bath which usually surrounds the coil be removed in a matter of seconds. The subsequent energy dissipation takes approximately 5 minutes for a fully charged coil, which warms to ambient temperature.

The specific objective of the work described in this paper was to establish a reliable system for rapid removal of liquid helium in the event of a coil protective energy dump. The only previously reported concept for helium removal was based on the use of large quantities of externally stored ambient temperature helium gas to drive the liquid helium from the helium vessel through a large number of large active valves. Because of the inherent complexities and cost of that system, due to the need for simultaneous actuation of numerous components which are inaccessible for maintenance, the alternative system reported here was developed. The following guidelines were used for this work:

1. For reliability, minimize the number and complexity of active components, specify passive components wherever possible, and locate active components in an accessible location.

2. The temperature of the injection or driver gas which displaces the liquid must be consistent with thermal-electrodynamic requirements to avoid excess coil voltage and overheating of the conductor. Calculations have shown that 30 K is an approximate upper limit on the injection gas temperature.4,5