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Comparison of an Impedance Heating System to Mineral Insulated Heat Trace for Power Tower Applications

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ABSTRACT

A non-conventional type of heating system is being tested at Sandia National Laboratories for solar thermal power tower applications. In this system, called impedance heating, electric current flows directly through the pipe to maintain the desired temperature. The pipe becomes the resistor where the heat is generated. Impedance heating has many advantages over previously used mineral insulated (MI) heat trace. An impedance heating system should be much more reliable than heat trace cable since delicate junctions and cabling are not used and the main component, a transformer, is inherently reliable. A big advantage of impedance heating is the system can be sized to rapidly heat up the piping to provide rapid response times necessary in cyclic power plants such as solar power towers. In this paper, experimental results from testing an impedance heating system are compared to MI heat trace. We found impedance heating was able to heat piping rapidly and effectively. There were not significant stray currents and impedance heating did not affect instrumentation.

BACKGROUND

In a solar, molten-salt central-receiver power plant, heliostats focus sunlight on to a receiver mounted on top of a centrally located tower. The heat transfer fluid, molten nitrate salt (60% sodium nitrate, 40% potassium nitrate), is pumped from a "cold" storage tank and heated by the illuminated receiver from 290°C to 565°C. The hot salt is stored in a "hot" tank where it can be used to produce steam to power a Rankine turbine and generate electricity (Chavez, *et al, 1995*). The key advantage of molten salt is its useful operating temperature range is well matched to the Rankine thermodynamic cycle.

Unfortunately, nitrate salt has a high freezing point (approximately 220°C) (Cook, McMordie, 1989), so all the salt piping must be heated. Mineral insulated (MI) heat tracing has been used extensively in molten salt applications to maintain the temperature of piping and components above the salt freezing point, typically at 290°C. If mineral insulated heat trace is not installed correctly it can be unreliable, cause non-uniform heating, especially in large pipes, or cause difficulties with controlling pipe temperature. In addition, the amount of power applied to the pipe by heat trace is limited by its watt density and physical constraints of attaching the cables to the pipe. This makes the thermal response of the system relatively slow - limiting the rate at which the plant can be brought into operation and reducing overall plant efficiency.

Most problems with heat trace in this application can be traced to a lack of quality control in the design and installation. An example of the consequences of improperly installed heat trace is the initial installation of heat trace in the Solar Two 10 MWe power plant. In some heat trace circuits, the heat trace cable was made too long for the pipe length and valves in that circuit. The installers doubled back the heat trace in portions of the pipe which caused localized overheating and spallation of metal from the pipe. These pieces of metal became entrained in the salt and were trapped in the receiver. Some pieces actually blocked flow to receiver tubes causing them to overheat and warp.

Impedance heating generates heat directly in a pipeline by flowing electrical current through the pipeline or vessel wall by direct connection to a low voltage, high current source from a dual-winding transformer. This type of heating uniformly heats the pipe circumferentially. It has been used in several petrochemical applications at very high temperatures. An impedance heating system can be designed to heat up the piping rapidly so the system can respond quickly. It could be simpler to install and should be much more reliable. It is best suited for long straight runs of pipe without components.

OBJECTIVE OF THE TEST

Manufacturers of impedance heating systems claim thousands of highly reliable systems have been installed in the past thirty years. Despite this track record, there are concerns whether this type of heating system is complementary with high temperature solar thermal