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Influence of oil-soaked insulation on the heat loss of thermal oil piping used in high-temperature solar cooling applications

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Abstract

This paper presents recent findings about the influence of oil-soaked mineral wool insulation material on the thermal heat loss of the insulated pipe. Thermal oil is a popular heat transfer fluid in high-temperature solar cooling applications using concentrating collectors, eg parabolic trough or linear Fresnel collectors. Leaks in thermal oil pipes or components thereof, eg. fittings, valves etc., result in thermal oil saturating the surrounding insulation layer. Mineral wool soaked with thermal oil has a higher heat conductivity than pure dry mineral wool. The influence of oil content on the heat loss has been investigated using a test stand with a heated section of insulated pipe. Simulated leaks have been applied and the temperature changes on the outside of the insulation have been observed. Different grades of saturation (0%, 33% and 50%) have been investigated in the work presented, as well as different temperature levels (175°C/347°F and 250°C/482°F) of the thermal oil within the pipe. Thermal conductivity and heat loss are calculated and presented for these.
The results show that an oil content of 33% in mineral wool insulation increases thermal conductivity by a factor of 2.5 to 3, compared to dry, oil-free insulation. An oil content of 50% increases thermal conductivity by a factor of up to 3.3. It was observed that the difference in thermal conductivity between 175°C/347°F and 250°C/482°F of bulk oil temperature inside the pipe is rather negligible, both at 33% and 50% oil content.

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Keywords: Thermal oil, piping, insulation, heat loss, thermal loss, parabolic trough, linear Fresnel, solar collector, solar cooling

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Nomenclature				**Indices**	
A	Area [m^2]	T	Temperature [°C]	amb	Ambient
L	Length [m]	α	Heat transfer coefficient [$Wm^{-2}K^{-1}$]	dry	of dry insulation
Q	Power [W]	δ	Insulation thickness [m]	inside	internal diameter
r	Radius [m]	λ	Thermal conductivity [$Wm^{-1}K^{-1}$]	outside	external diameter

1. Introduction

Thermal oil is a popular heat transfer medium for application temperatures above 100°C (212°F) in heating and cooling applications. In comparison to water as a heat transfer medium, thermal oil mitigates the problems with elevated pressure of water at temperatures greater 100°C (212°F). It is frequently used in high temperature solar cooling applications, e.g. using concentrating collectors such as parabolic trough or linear Fresnel collectors. In such systems, thermal oil is typically used to transfer heat from the solar collector array to either a storage tank or a sorption chiller. Insulated steel piping is usually installed for the transport of the oil. The pipe insulation is a crucial part of the system. Oil piping, especially for larger systems, can easily accumulate to a few hundred meters length. Without insulation, the heat loss from the piping would dramatically reduce the net heat output from the solar array. Typically, rock or mineral wool is used as insulation material, combined with sheet metal cladding on the outside, Fig. 1.

While dry insulation material provides good reduction of heat loss the situation is different when leaks appear. Oil leaking into the insulation, e.g. from a faulty fitting or valve, reduces the thermal resistance of the insulation material and hence increases thermal loss from the pipe. This is due to the fact that thermal oil has a higher thermal conductivity than dry mineral or rock wool. Typical properties for both materials are listed in Table 1.

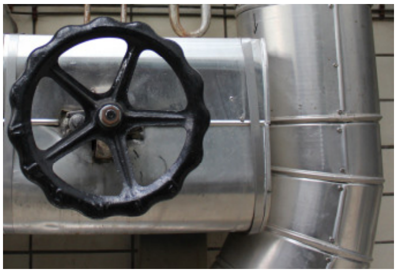

Fig. 1 Example of insulated oil pipe using mineral wool and sheet metal cladding.

Table 1. Typical properties of mineral wool and thermal oil.

Parameter	Dry hydrophobic mineral wool	Thermal heat transfer oil
Density [kg/m^3]	200 (at 40°C/104°F)	1030 (at 40°C/104°F)
Max. operating temperature [°C/°F]	660/1220	380/716
Kinematic viscosity [mm^2/s]	nA (solid)	16 (at 40°C/104°F)
Thermal conductivity [W/(mK)]	0.035 (at 40°C/104°F)	0.128 (at 40°C/104°F)

Experience with existing systems shows that saturated insulation of high-temperature piping drastically increases the surface temperature (and hence the heat loss) of the cladding, up to the point where bodily harm can be caused to operating staff, Fig. 2. The surface temperature shown in the infrared image (on the left of Fig. 2) exceeds 90°C/194°F in sections and would cause serious harm to unprotected skin, e.g. when incidentally touched by staff.