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Measurements of Pipe Insulation Thermal Conductivity at Below Ambient Temperatures Part I: Experimental Methodology and Dry Tests

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ABSTRACT

Mechanical pipe insulation systems are installed around cold cylindrical surfaces, such as chilled pipes, which often work at below ambient temperatures in industrial and commercial building applications. The thermal performance of pipe insulation systems is affected by local ambient conditions and might vary gradually with time. Most published data are extrapolated from flat slab configurations of the insulation materials, but the measured thermal conductivity from flat slabs might over or under estimate the actual thermal conductivity of cylindrical shaped pipe insulation systems due to radial configuration and longitudinal split joints. A methodology for measuring thermal conductivity of cylindrical shaped pipe insulation systems exists in the ASTM standards but it is based on a heated pipe approach with outward heat flow. If the average temperature of the pipe insulation system is below ambient temperature then a more accurate prediction of the pipe insulation actual thermal conductivity is needed for the design of insulation systems in chiller pipe applications.

In this paper, a novel experimental apparatus to measure the thermal conductivity of mechanical pipe insulation systems at below ambient temperatures is presented. The new apparatus was validated with two pipe insulation systems, cellular glass and Polyisocyanurate (PIR), used to benchmark our measurements against data available in the public domain. The thermal conductivity of additional three pipe insulation materials, that is, fiberglass, flexible elastomeric and phenolic, was also measured at several insulation temperatures at below ambient and in dry non-condensing ambient conditions. Correlations of the pipe insulation thermal conductivity were developed based on insulation specimen average temperature and wall thicknesses. Corresponding uncertainties of the measurements and the edge effects of the longitudinal butt joints are also critically analyzed in this paper. This paper is the first part of the pipe insulation measurements under dry non-condensing conditions and the measurements under wet condensing conditions will be presented in a following paper.

INTRODUCTION

Heat exchangers inside buildings are often adopted to provide air conditioning, cooling and dehumidification to the zones of buildings. A cold fluid, usually water or water-glycol solutions, is used to transport and distribute the refrigerating capacity from central chillers to the liquid-to-air heat exchangers and a network of chilled pipes is installed inside the building structure. The surface temperature of these pipelines is commonly at 40°F (4.5°C) and below the dew point temperature of the surrounding ambient air. Mechanical insulation systems are installed around these cold pipes to limit the heat gain in the pipelines and to prevent moisture condensation on their surface. Insulation jackets, vapor retarders, and vapor sealing of the joints and fittings are normally adopted to create a barrier to the moisture ingress into permeable insulation. However, experience shows that mechanical pipe insulation systems are not completely vapor tight and inevitably moisture accumulates in permeable insulation (ASHRAE 2009). The fact that the pipe surface temperature is below the ambient room temperature has three main implications:

1. there is a temperature gradient across the insulation system that drives a radial inward heat flow, that is, sensible heat is

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