An apparatus and method have been developed for measuring the rates of leakage of heat into pipes carrying liquids, the purpose of the measurements being to quantify the thermal performance of the insulation system. The apparatus is designed primarily for testing pipes used to carry cryogenic liquids, but can also be used for measuring the thermal performance of other insulated pipes or piping systems.

The basic measurement principle is straightforward: The outer surface of the pipe insulation is maintained at a fixed warmer temperature. The interior of the pipe is maintained in a narrow fixed lower-temperature range by means of a regular liquid (e.g., water) that is pumped through the pipe at a known flow rate or a cryogenic liquid (e.g., nitrogen) that is saturated at atmospheric pressure and replenished until steady-state conditions are achieved.

In the case of water or another liquid pumped through, the inlet and outlet temperatures are measured and heat-leak power is calculated as the mass flow rate of the liquid multiplied by the specific heat of the liquid multiplied by the inlet-to-outlet temperature rise of the liquid. In the case of liquid nitrogen or another low-temperature boiling liquid, the heat-leak power is calculated as the rate of boil-off multiplied by the latent heat of vaporization of the liquid. Then the thermal-insulation performance of the pipe system can be calculated as a function of the measured heat-leak power, the inner and outer boundary temperatures, and the dimensions of the pipe.

The apparatus can test as many as three pipes simultaneously. The pipes can have inner diameters up to ≈15 cm and outer diameters up to ≈20 cm. The lengths of the pipes may vary; typical lengths are of the order of 18 m.

Two thermal guard boxes — one for each end of the pipe(s) under test — are used to make the inlet and outlet fluid connections to the pipe(s) (see figure). The connections include bellows that accommodate thermal expansion and contraction of the pipes. The guard boxes have been previously used to obtain desired sink temperatures: In comparison with an infrared lamp, a slat heater box provides a greater degree of sink temperature uniformity for a test-object surface that includes multiple areas with differing optical properties. This advantage can be seen by solving gray-body radiation equations for some representative cases of test objects for which the emissivity or absorptivity at wavelengths <4 µm (denoted α) differs from the emissivity or absorptivity at wavelengths >4 µm (denoted ε). [The term α is often denoted solar absorptivity because most of the power of solar radiation lies in the wavelength range below 4 µm, while the term ε is often denoted infrared or thermal emissivity because most of the power of room-temperature objects lies in the wavelength range >4 µm.] Figure 2 presents the results of one such calculation that illustrates the superiority of a slat heater box over an infrared lamp, in that the sink temperature is much less sensitive to α/ε in the case of the slat heater box.

This work was done by Eugene Ungar of Johnson Space Center. Further information is contained in a TSP (see page 1). MSC-23023

System for Testing Thermal Insulation of Pipes
Thermal and flow conditions are carefully controlled to minimize errors.

John F. Kennedy Space Center, Florida

Figure 1. A Slat Heater Box surrounds an object under test and is heated to a controlled temperature.

Figure 2. The Sink Temperature of a test object as a function of α/ε was calculated for a representative case of heating with a quartz infrared lamp at 10-percent power and a representative case of a slat heater box occupying a third of the field of view, with an emissivity of 0.865 and slat temperature of 410 K.
Langley Research Center has developed electrical-impedance-based ice-thickness gauges and is seeking partners and collaborators to commercialize them. When used as parts of active monitoring and diagnostic systems, these gauges make it possible to begin deicing or to take other protective measures before ice accretes to dangerous levels. These gauges are inexpensive, small, and simple to produce. They can be adapted to use on a variety of stationary and moving structures that are subject to accumulation of ice. Examples of such structures include aircraft, cars, trucks, ships, buildings, towers, power lines (see figure), power-generating equipment, water pipes, freezer compartments, and cooling coils.

A gauge of this type includes a temperature sensor and two or more pairs of electrically insulated conductors embedded in a surface on which ice could accumulate. The electrical impedances of the pairs of conductors vary with the thickness of any ice that may be present. Somewhat more specifically, when the pairs of conductors are spaced appropriately, the ratio between their impedances is indicative of the thickness of the ice. Therefore, the gauge includes embedded electronic circuits that measure the electrical impedances, plus circuits that process the combination of temperature and impedance measurements to determine whether ice is present and, if so, how thick it is. Of course, in the processing of the impedance measurements, the temperature measurements help the circuitry to distinguish between liquid water and ice.

The basic design of a gauge of this type can be adapted to local conditions. For example, if there is a need to monitor ice over a wide range of thickness, then the gauge can include more than two sets of conductors having various spacings.

This work was done by Leonard Weinstein of Langley Research Center. Further information is contained in a TSP (see page 1).

LAR-16093

Electrical-Impedance-Based Ice-Thickness Gauges

Compact, inexpensive gauges provide early warnings of accretion of ice.

Langley Research Center, Hampton, Virginia

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