Thermal Performance of Aged and Weathered Spray-On Foam Insulation (SOFI) Materials Under Cryogenic Vacuum Conditions (Cryostat-4)

Thermal Protection System (TPS) Enhancements

The NASA Cryogenics Test Laboratory at Kennedy Space Center conducted long-term testing of SOFI materials under actual-use cryogenic conditions with Cryostat-4. The materials included in the testing were NCFI 24-124 (acreage foam), BX-265 (close-out foam, including intertank flange and bipod areas), and a potential alternate material, NCFI 27-68, (acreage foam with the flame retardant removed). Specimens of these materials were placed at two locations: a site that simulated aging (the Vehicle Assembly Building [VAB]) and a site that simulated weathering (the Atmospheric Exposure Test Site [beach site]). After aging/weathering intervals of 3, 6, and 12 months, the samples were retrieved and tested for their thermal performance under cryogenic vacuum conditions with test apparatus Cryostat-4.

Cryostat-4 is a liquid-nitrogen boiloff calorimeter designed to determine the apparent thermal conductivity (k-value) of thermal insulation systems under actual-use cryogenic vacuum conditions. The method is comparative in that the total heat load to the test chamber includes a minor but repeatable parasitic heat leakage rate. The residual gas supplied to the vacuum chamber is nitrogen. The boiloff flow from the test chamber is in direct proportion to the total heat transfer rate through the thickness of the test article. Flow rate is typically averaged over the liquid level from 4 to 0 percent (near empty) to calculate the comparative k-value.

The SOFI test articles were 203 mm in diameter, with a nominal thickness of 25.4 mm. Tests were conducted starting at ambient pressure (760 torr) and working down, decade by decade of vacuum-pressure increments, to high vacuum (below 1×10^{-3} torr). At least eight cold vacuum pressure tests were performed for each test series. The warm boundary temperature (WBT) was approximately 293 K and the cold boundary temperature (CBT) was approximately 78 K. Figure 1 shows the installation of a SOFI test article.

The foams were tested in the baseline, aged, and weathered conditions. Here *baseline* means that the specimens were not weathered and only slightly aged. Specimens with rind were necessarily sanded down to a flat surface finish for good thermal contact with the warm and cold sides of the cryostat.

Surface Temperature Measurement	
Sensor	**Location**
T1, T3	Cold Boundary Temperature (CBT)
T2	Top of Cold Mass
T4, T5	Warm Boundary Temperature (WBT)
VC1, VC2, VC3	Vacuum Chamber Exterior
VC4, VC5, VC6	Heater Temperature

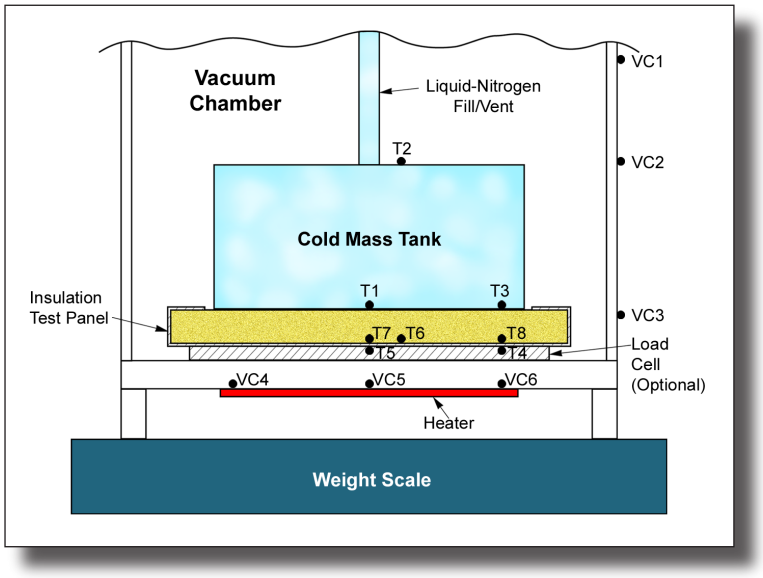

Figure 1. The SOFI test specimen is installed between the cold mass tank and the warm boundary of insulation in Cryostat-4.

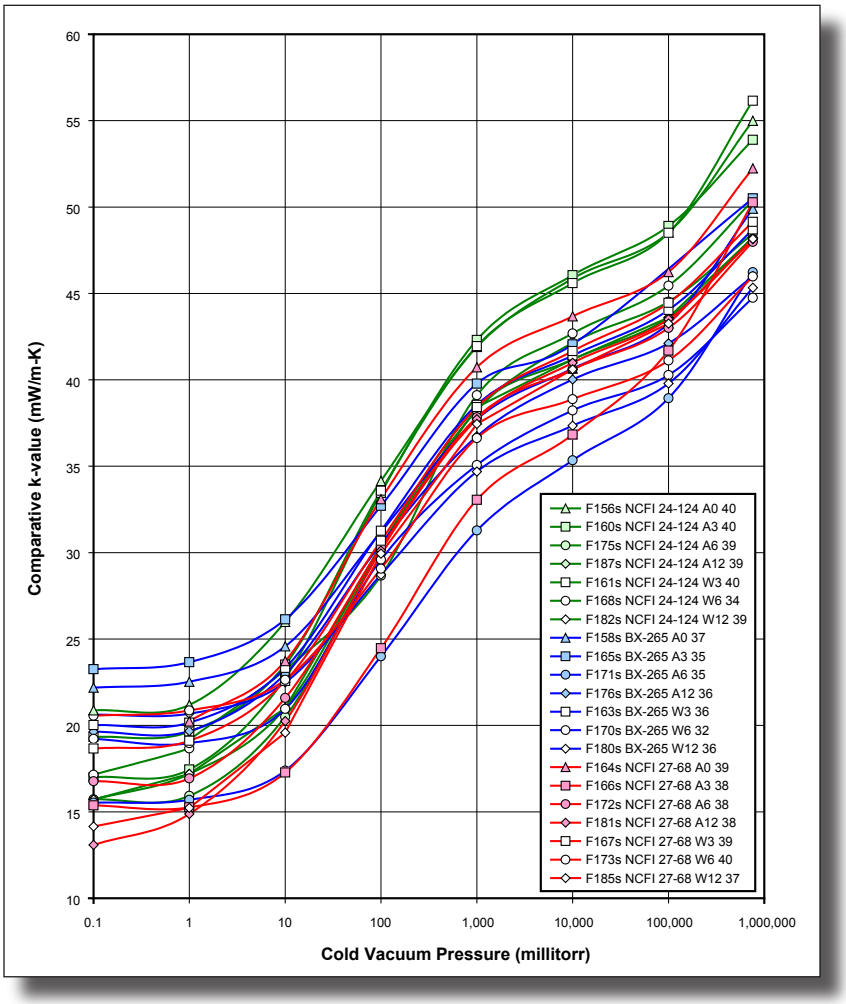

Figure 2. The variation of comparative k-value with cold vacuum pressure for all Cryostat-4 SOFI test specimens. The boundary temperatures are 293 K and 78 K. The residual gas is nitrogen.

Figure 2 shows the results for the cryogenic thermal-performance testing of the aged and weathered SOFI materials. The apparent thermal conductivity (k-value) is reported in the standard SI units (milliwatts per meter Kelvin), but these numbers are comparative and may only be applied among the test specimens listed in this report.

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