Return to Menu

Cryoinsulation Material Development to Mitigate Obsolescence Risk for Global Warming Potential Foams

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Project Description

Cryoinsulation foams currently being qualified for the Space Launch System (SLS) core stage are non-ozone-depleting substances (ODP) and are compliant with current environmental regulations. However, these materials contain the blowing agent HFC-245fa, a hydrofluorocarbon (HFC), which is a Global Warming Potential (GWP) substance. In August 2014, the Environmental Protection Agency (EPA) proposed a policy change to reduce or eliminate certain HFCs, including HFC-245fa, in end-use categories including foam blowing agents beginning in 2017. The policy proposes a limited exception to allow continued use of HFC and HFC-blend foam blowing agents for military or space- and aeronautics-related applications, including rigid polyurethane spray foams, but only until 2022.

The blowing agent industry and foam industry proactively began evaluating new low GWP blowing agents in 2013 for use in nonaerospace foam applications. Foams used for cryoinsulation of aerospace vehicles require unique formulations tailored specifically to meet cryogenic and aerothermal requirements. Development of low GWP foam systems will require evaluation, testing, reformulation, development, and qualification before use on a flight vehicle.

Under the Advanced Development Group initiative, the EM41 Thermal Protection System (TPS) team performed a market survey of low GWP foams as risk mitigation to proactively evaluate low GWP foams. The leading replacement blowing agents under consideration by the primary aerospace foam manufacturers are hydrofluoroolefin (HFO) molecules. However, the foam industry has not yet developed a viable way of incorporating HFO blowing agents into foam formulations. Current formulations have a very short shelf life and cannot pass building code burn tests. Ascent heating for aerospace applications is an even more severe heating environment.

Since stability issues with HFO blowing agents make them not immediately ready for aerospace applications, other low GWP blowing agents were evaluated including HFC-365mfc, pentane, carbon dioxide (CO_2), and methyl formate/Ecomate®. Figure 1 shows the insulation values of foams formulated with each blowing agent.

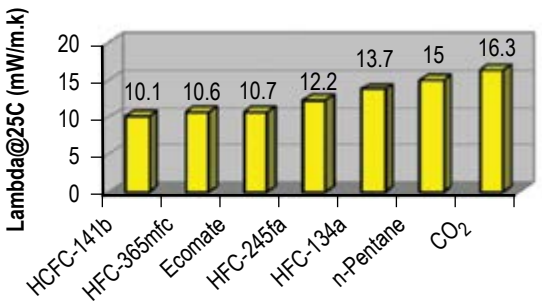

Figure 1: Insulation values of foams formulated with various blowing agents.

The table shows the ODP and GWP values for each blowing agent. Although HFC-365mfc has good insulation properties, it does not provide a significant reduction in GWP. Using pentane as a blowing agent requires class I/division I facilities and processing equipment since it is flammable. While these facilities exist in NASA Marshall Space Flight Center's (MSFC's) Building 4765, they are cost prohibitive for manufacturing facilities such as the NASA Michoud Assembly Facility (MAF). The most promising two candidates are CO_2 and methyl formate/Ecomate.

ODP and GWP values for various blowing agents.

Application	Blowing Agent	ODP	GWP
Space Shuttle External Tank	HCFC-141b	0.11	725
SLS Core Stage	HFC-245fa	0	1,030
Future Applications	HFOs	0	<25
	HFC-365mfc	0	794
	Pentane	0	<25
	Methyl Formate	0	<25
	CO_2	0	1

The company Icynene uses CO_2 as the blowing agent in a foam product named ProSeal Eco (MD-R-210). Although CO_2 is the most environmentally friendly choice, it provides poor insulation, so foam would likely have to be applied thicker, increasing the weight of the vehicle. MSFC coordinated with Icynene to obtain sprayed foam samples and liquid component samples of ProSeal Eco for testing. The company Foam Supplies Incorporated (FSI) uses methyl formate (trade name Ecomate) to formulate foam products. Methyl formate provides low GWP and foams formulated with it provide good insulation. MSFC also shared a list of required material properties with FSI so chemists at FSI can formulate a foam product with Ecomate that is specific to aerospace needs.

Anticipated Benefits

Proactive efforts to develop low GWP replacement foams would improve the affordability and reliability of the SLS core stage in future years. When the EPA begins regulating GWP materials, the current blowing agent will be subject to a phase-out period during which availability will decline, cost will increase, and NASA will be required to negotiate with the EPA for a waiver while a replacement material is sought.

Potential Applications

Applications for low GWP cryogenic foam insulation include the SLS core stage, future SLS exploration upper stages, composite cryotanks, in-space storage vessels, and commercial crew vehicles.

Forward Work

The MSFC EM41 TPS Development Team will continue to evaluate low GWP foams and blowing agents as risk mitigation. Initial in-house tests such as reactivity, density, and plug pull tension tests will provide early indications of foam performance. EM41 will remain aware of EPA policy changes and industry advances in low GWP blowing agents for foams.

References

"Transitioning to Low GWP Alternatives in Building/Construction Foams," U.S. Environmental Protection Agency, <http://www.epa.gov/ozone/downloads/EPA_HFC_ConstFoam.pdf>, February 2011.