Thermal Analysis of an RTV-655 Prototype Propellant Tank and a Test on the Use of Aerogel for Space Applications

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Background

RTV-655 (Room Temperature Vulcanized Silicone 655) is a rubber polymer with a low thermal conductivity, low density, and high flexibility. Its properties make it a useful tool for space propellant tank applications, and it has the property of curing after a few days at room temperature.

Polyimide Aerogels are ultra-lightweight polymers with an extremely low thermal conductivity and density made by cross-linking various elements. They are one of the lightest solid materials available today. [1]

Thermocouples are devices to measure temperatures. They use two dissimilar metals and can tolerate a wide range of measurable temperatures

Cryogenic liquids are liquids that operate at approximately −150 °Celsius or 123 Kelvin, the temperature at which many space propellants operate.

Goal of the Study: To test the practicality of RTV-655 as a tank material for space use and establish a ground level for the testing of aerogel in a similar tank, thereby comparing the two and determining the utility of them in a space environment for long term cryogenic propellant storage. [2]

Experimental Design: After analyzing and compiling test results from the RTV-655 tank, an aerogel/RTV prototype tank will be constructed. This tank again will be tested and compared to the RTV tank to see if aerogels make a better material for space propellant tanks.

Aerogel Tank Construction

Method: Construction of an aerogel prototype tank requires both the mixing and pouring of RTV and the piece by piece laying of aerogel. To start the process, 10 parts of the RTV-655A substance is mixed with 1 part of the RTV-655B binding agent. After stirring to combine the parts, the mixture is placed in a vacuum chamber to release air pockets that may weaken it. Once fully outgassed, the RTV-655 is poured into a mold in the shape of the tank and cured. The remainder of the RTV-655 is refrigerated to slow down the curing process. After curing, the aerogel is laid onto the tank one piece at a time and fixed to it with drops of RTV-655, which has the property of curing to itself. After one full layer of aerogel, a thinner layer of RTV-655 is added and one more layer of aerogel is placed onto the tank. This entire process is repeated for the other half of the tank, and a final layer of RTV-655 is added and cured between the two pieces, leaving a small opening for cryogenic testing.

Figure 1. Construction of aerogel tank with stabilization apparatus and heat gun.

Progress: After 6 weeks of building, one half of the tank has been nearly completed, with one layer of aerogel embedded between two layers of RTV-655. Further works would most likely complete the construction and testing of the aerogel tank and compare the results to an established baseline.

Hypothesis: The expected result of the aerogel tank is that it will dissipate less heat than the RTV-655 tank and hold up better to cryogenic testing in regards to space applications.

RTV-655 Tank Thermal Test

Method: After being hooked up to extensometers, pressure sensors, thermocouples, and supply valves the RTV-655 tank was ready for testing. It went through four stages of testing: precool (cooling to cryogenic temperatures), pressurization (boiling the liquid nitrogen inside the tank), constant liquid (keeping a constant amount of liquid), and boil off (letting the liquid boil out of the tank).

Results:

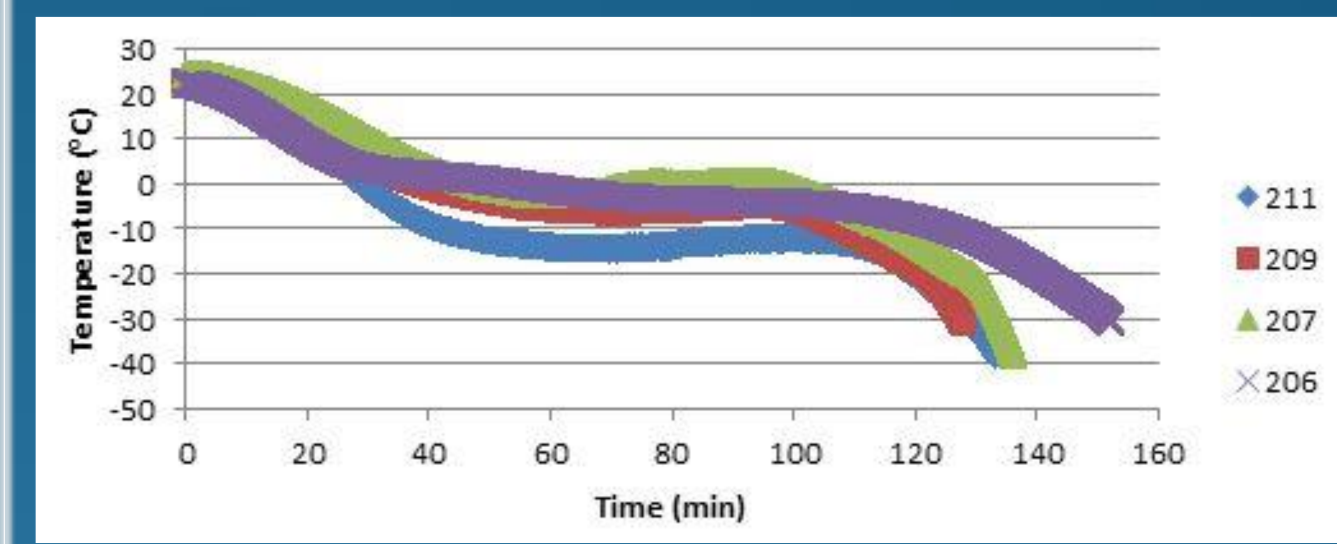

Figure 2. A composite temperature-time graph from the top outside thermocouple from the precool stage.

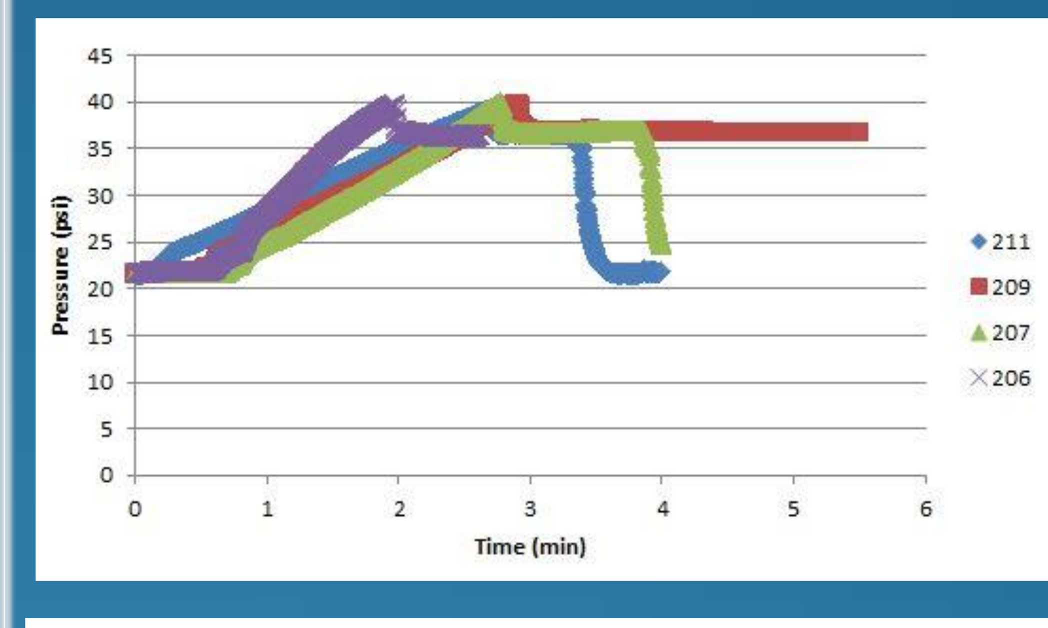

Figure 3. A composite pressure-time graph from the pressurization stage.

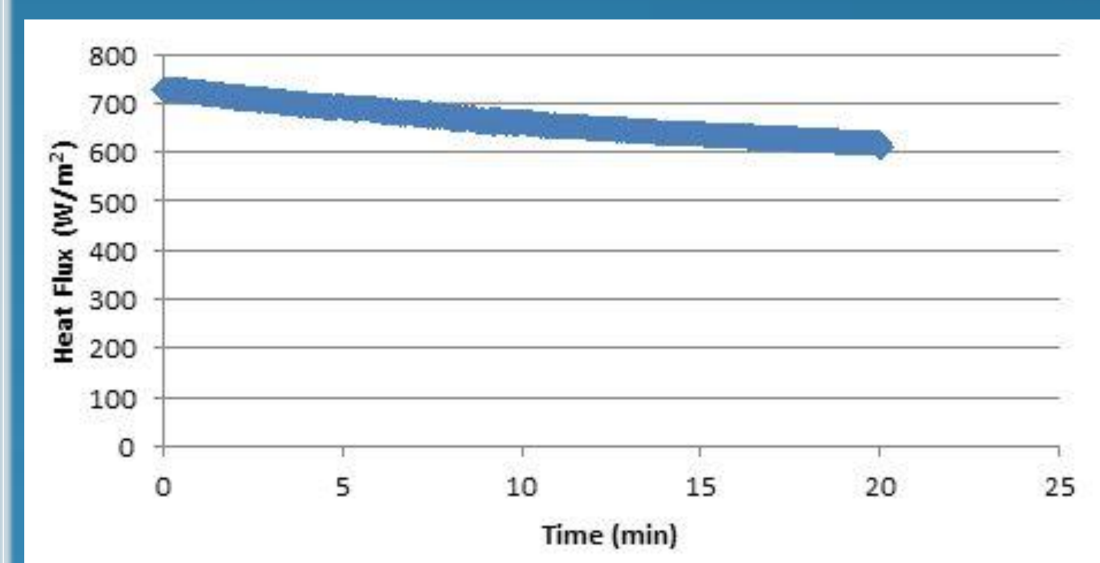

Figure 4. An averaged heat flux-time graph from the constant liquid phase from the vapor and top outside thermocouples.

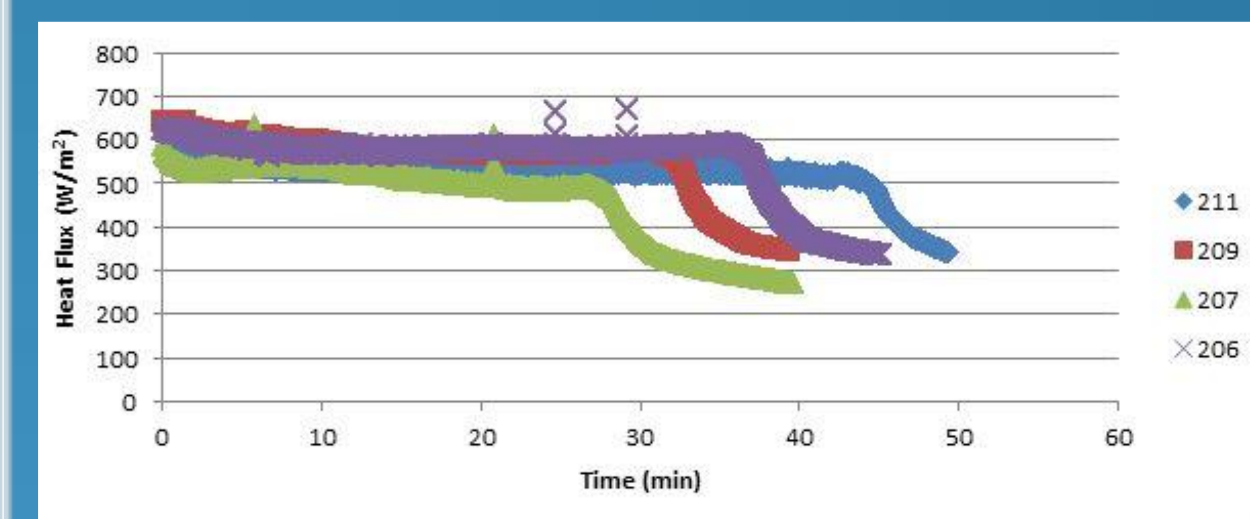

Figure 5. A composite heat flux-time graph from the boil off stage from the vapor and top outside thermocouples

Conclusion: The RTV tank helped to establish ground level statistics for the further testing of our aerogel tank. On its own, the space-qualified RTV stood up to the testing conditions, and the above graphs accurately reflected our predictions for each stage.

Conclusion and Future Work

These results showed the feasibility of RTV-655 as a lightweight material insulator. Though current metal propellant tanks have heavier insulating materials, an RTV-655 tank could be applied as a better material than many ordinary metals in a cryogenic propellant tank [3]. Future works on this topic would most likely extend the building and testing of an aerogel-embedded tank and compare the data, proving or disproving the hypothesis at hand.

References

[1] Dunbar, Brian. "Aerogels: Thinner, Lighter, Stronger." *NASA Aeronautics*. NASA, 28 July 2011. Web. 13 July 2015. [2] NASA. "Cryogenic Propellant Storage and Transfer Project." *NASAfacts*. National Aeronautics and Space Administration, Sept.-Oct. 2013. Web. 13 July 2015. [3] Pumroy, David W., Douglas S. Williams, and William A. Parker. *American Institute of Aeronautics and Astronautics* (2015): n. pag. Web. 13 July 2015.

Acknowledgments

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