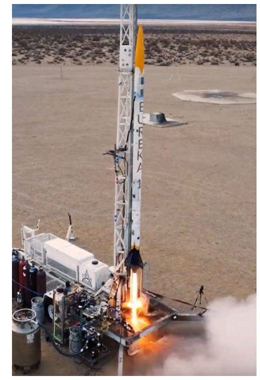
Boedeker Plastics, Inc. Assists Space Enterprise at Berkeley (SEB) with Ablative Composite - Doubling Liner Life in Developmental Rocket Engine Tests.

Intro:



Space Enterprise at Berkeley (SEB), founded in October 2016, is a student-run team at the University of California, Berkeley dedicated to achieving spaceflight with a liquid-fueled rocket.

Despite being relatively young, SEB is highly ambitious, having launched 12 test rockets and conducted 20 static hotfires. They have gained expertise designing in-house-developed automatic electronic regulators, throttle and thrust vector-controlled engines, custom sensors and telemetry systems, and additively manufactured rockets.

Challenge: Specify and Design an Ablative Liner that Will Protect the Aluminum Combustion Chamber at High Temperatures in Rocket Engine

The SEB team faced the challenge of finding a lining material that would function as an ablative thermal barrier to protect an aluminum rocket engine combustion chamber (see Figure 1) from temperatures up to 3,000°F.

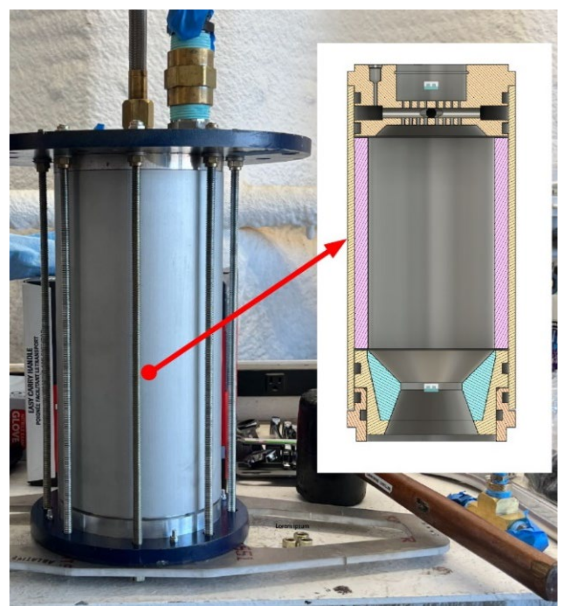


Figure 1 Cross Section View of Aluminum Chamber - Ablative Lining Surfaces shown in Pink (Chamber) and Blue (Nozzle Section)

In this application, an ablative material is a thermal protection system designed to absorb and dissipate extreme heat through controlled material erosion. As the material heats up and gradually burns away, it carries intense heat away from the rocket's structure, creating a protective barrier that prevents the underlying aluminum chamber from reaching critical temperatures that could lead to structural failure. The ablative material must be carefully selected and engineered to withstand high temperatures and thermal stresses, providing effective thermal protection while minimizing weight and maximizing performance.

Solution: Phenolic CE (Canvas Electric) Composite Tubing Providing 2X Longer Life in Ablative Lining Rocket Chamber Application

The SEB team contacted Boedeker Plastics, Inc. to discuss material options. Given the application requirements for extreme temperatures and the desired ablative heat shield properties, a Phenolic CE composite tube was selected for testing.

Phenolic resins are known to exhibit ideal properties for ablative applications. A NASA Technical Note from 1967 describes the suitability of phenolic materials for ablative applications. The study found that Phenolics undergo controlled thermal decomposition over a temperature range of 350°C /662°F to 850°C / 1562°F. During this thermal decomposition process, phenolics absorb significant amounts of heat and form a char that provides thermal protection. This char and the endothermic decomposition process effectively insulate underlying structures from extreme temperatures, making phenolic polymers highly suitable for heat shield applications (Sykes, 1967).

The SEB team designed the new ablative lining system using Phenolic CE. The new liner succeeded (see Figure 2 below) and has outperformed the previous ablative lining material by 2X.

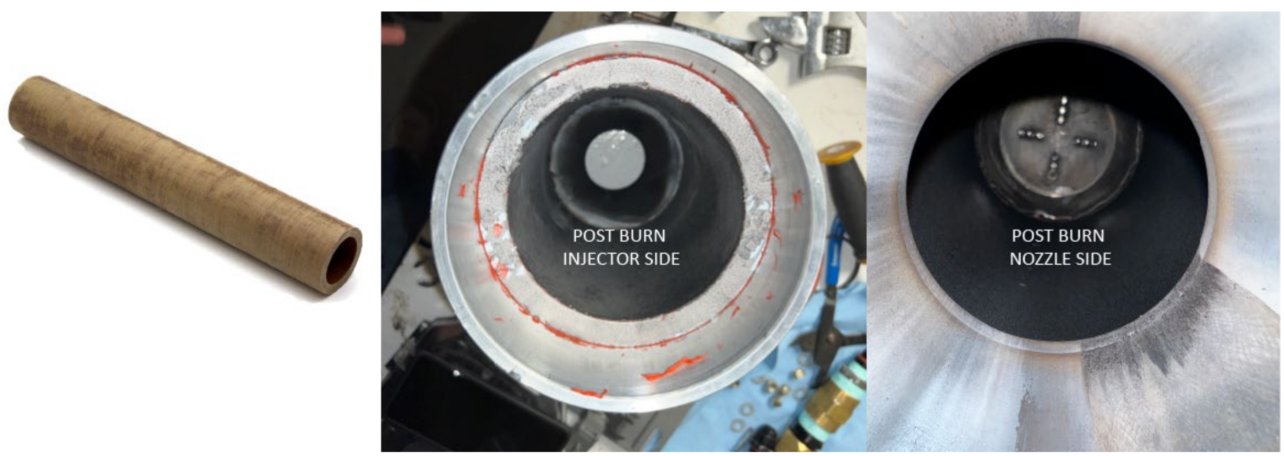


Figure 2 Phenolic CE Tube and Post Burn Photos of the Injector and Nozzle Sections of the Chamber show the charred ablative Phenolic Liner and Aluminum that protects as the SEB team test fired the rocket engine.

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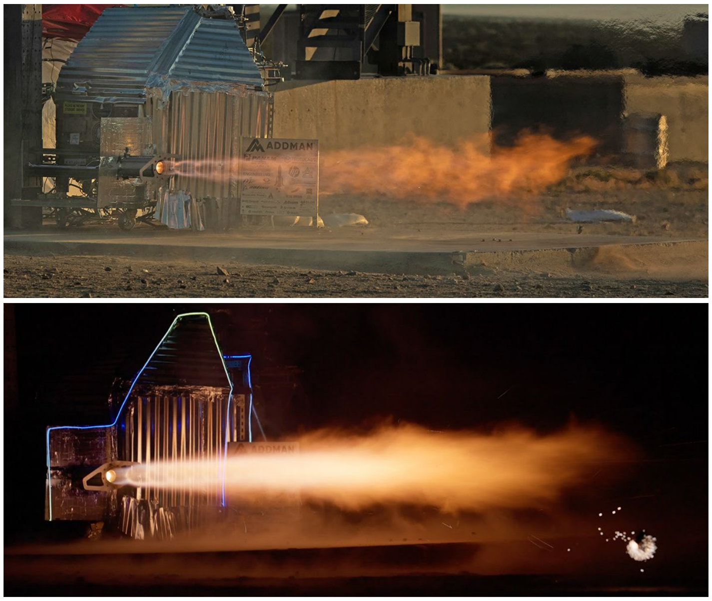

Figure 3: Burn 1 and Burn 2 of static hotfire testing with the same ablative liner.

One of the SEB team members commented, "In our previous experience with this type of engine, we have seen a distinct pattern and uneven wall thickness on the liner after a burn due to some combination of our burn duration, propellant choice, injector type, and liner material and thus switched out the liners for a second attempt. For our first time testing this new design, we were surprised to see such successful results and used the same liner twice in a row for both tests."

Reference:

Sykes, G. F. Jr. (1967). *Decomposition characteristics of a char-forming phenolic polymer used for ablative composites*. NASA Technical Note D-3810