NASA Facts

National Aeronautics and
Space Administration

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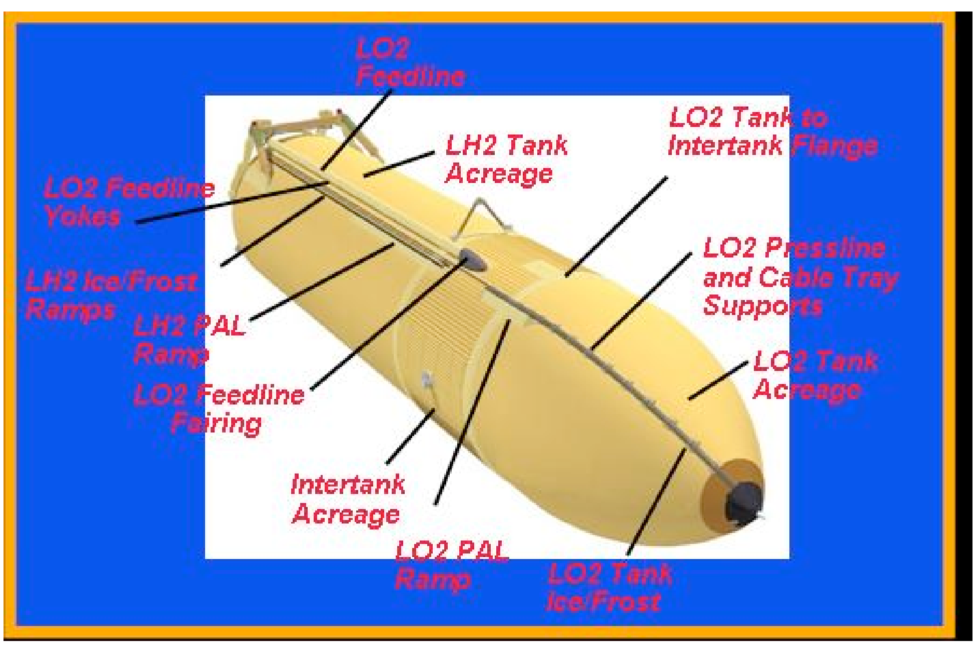
External Tank Return to Flight Focus Area

Thermal Protection System

NASA's Space Shuttle Program has initiated an aggressive program to minimize any debris that could be produced by the Space Shuttle's elements: the Orbiter, the External Tank, the Solid Rocket Boosters and the Main Engines. The Shuttle's External Tank Project Office has completed a top-to-bottom assessment of the tank's Thermal Protection System and has examined all areas where the tank's foam insulation, a component of the Thermal Protection System, is prone to loss.

Because the tank is not retrievable, engineers must rely on testing, computer analysis, and video and photographic imaging to determine if there is a possibility of debris created during launch and ascent. These tests and analyses help determine the potential for foam loss and the possible ways to improve the overall safety of the External Tank.



External Tank Thermal Protection System

The project office is also investigating new techniques that will allow the foam to be inspected for internal defects without damaging it. The initial focus is on manually sprayed closeout, or final, foam applications. Although they are not yet fully developed, non-destructive evaluation techniques like backscatter radiography and terahertz imaging could offer an additional level of verification for the foam.

Backscatter radiography involves inspection of a part by detecting the X-rays that are scattered back from the part when it is illuminated with an X-ray source. It was originally developed for military use at the University of Florida in Gainesville, Fla.

Terahertz imaging is a relatively new technology based on the terahertz (THz) range of the electromagnetic spectrum. A defect will cause the wave to reflect back to the receiver.

The main advantage of a terahertz imager is that it does not emit any radiation, capturing pictures of the natural terahertz rays emitted by almost all objects. Occupying a portion of the spectrum between infrared and microwaves, from 10^{11} to 10^{13} Hertz, terahertz waves can pass easily through some solid materials, like walls and clothes, and can also be focused as light to create images of objects. The terahertz imaging is being developed in conjunction with NASA's Langley Research Center in Langley, Va.

In addition to developing new non-destructive evaluation (NDE) techniques, the Project Office has created a stringent process control system to ensure that all newly-applied foam meets NASA specifications.

The new process controls include the institution of high fidelity mockups, video recording of processes, simplification of application design, acquisition of all process parameter data and the institution of detailed spray instructions.

FOAM FACTS

The Space Shuttle's External Tank is covered with spray-on foam insulation that serves to insulate the tank before and during launch. The foam is one of two components in the External Tank's Thermal Protection System, or TPS.

There are two basic Thermal Protection Systems on the External Tank: One is low-density, closed-cell foam. The other Thermal Protection System component is a denser composite material called ablator, made of silicone resins and cork. An ablator is a material that dissipates heat by eroding.

The closed-cell foam used on the tank acreage is a Spray-On-Foam-Insulation often referred to by its acronym as SOFI (pronounced so -FEE). The composite material is Super Lightweight Ablator, known as SLA (pronounced slaw).

The External Tank uses ablators on areas that are subjected to extreme heat, such as the aft dome near the engine exhaust and on protuberances that are exposed to aerodynamic heating, such as the cable trays.

The closed-cell foam used on the tank was developed to keep the propellants that fuel the Shuttle's three Main Engines at optimum temperature. It keeps the Shuttle's liquid hydrogen fuel at minus 423 degrees Fahrenheit and the liquid oxygen tank at minus 297 degrees Fahrenheit -- even as the tank sits under the hot Florida sun -- while preventing a buildup of ice on the outside of the tank.

The foam insulation must also be durable enough to endure a 180-day stay at the launch pad, withstand temperatures up to 115 degrees Fahrenheit, humidity as high as 100 percent, and resist sand, salt, fog, rain, solar radiation and even fungus. Then, during launch, the foam must tolerate temperatures as high as 1,200 degrees Fahrenheit generated by aerodynamic friction and rocket exhaust. Finally, when the External Tank returns to Earth and begins reentry into the atmosphere -- about 30 minutes after launch -- the foam helps hold the tank together even as temperatures and tank pressurization inside work to break up the tank, allowing it to safely disintegrate over a remote ocean location.

Though the foam insulation on the majority of the tank is only 1-inch thick, it adds 4,823 pounds to the tank's weight. Insulation on the liquid hydrogen tank is somewhat thicker -- between 1.5 to 2 inches thick. Though the foam's density varies with the type, an average density is about 2.4 pounds per cubic foot. The average NCFI – NCFI is an acronym for North Carolina Foam Industries-- density is 2.27 pounds per cubic foot.

The tank's foam is polyurethane-type foam composed of five primary ingredients: polymeric isocyanate, a flame retardant, a surfactant, a blowing agent, and a catalyst. A surfactant controls the surface tension of a liquid and thus cell formation. The blowing agent – originally CFC 11-- creates the foam's cellular structure by making millions of tiny bubbles or foam cells.

Application of the foam, whether automated by computer or hand-sprayed, is designed to meet NASA's requirements for finish, thickness, roughness, density, strength and adhesion. As in most assembly production situations, the foam is applied in specially designed, environmentally controlled spray cells and sprayed in several phases, often over a period of several weeks. Prior to spraying, the foam's raw material and mechanical properties are tested to assure it meets NASA specifications. Multiple visual inspections of all foam surfaces are also performed after the spraying is complete.

Most of the foam is applied at Lockheed Martin's Michoud Assembly Facility in New Orleans when the tank is manufactured, including most of the "closeout" areas, or final areas applied. These closeouts are done either by hand pouring or manually spraying. Some additional close-outs are completed once the tank reaches Kennedy Space Center in Cape Canaveral, Fla.

There are four specially engineered closed-cell foams used on the tank. The larger sections of the tank are covered in NCFI 24-124, which accounts for 77 percent of the total foam used on the tank.

NCFI 24-57, which has a slightly different formulation than NCFI 24-124, is used on the aft dome, or bottom, of the liquid hydrogen tank. PDL 1034, hand-poured foam used for filling odd-shaped cavities, and BX 250/265 foam is used on the tank's "closeout" areas. During the early days of the External Tank's development, PDL was an acronym for Product Development Laboratory, the first supplier of that foam.

NCFI 24-124 and NCFI 24-57 are mechanically sprayed foams; BX 250/265 is manually-applied, or hand-sprayed.

Environmental Protection Agency

In 1987, the United States and 45 other nations adopted the "Montreal Protocol on Substances that Deplete the Ozone Layer." Under the Protocol, class I ozone depleting compounds, such as Chlorofluorocarbon 11 known as CFC 11 -- the Freon-based blowing agent used in the production of the External Tank's foam -- was to be phased out of production by the end of 1995. Production of these compounds after 1995 is allowed only by "Essential Use Exemption" and must have Montreal Protocol approval.

After extensive testing the External Tank Project proposed hydro chlorofluoro-carbon HCFC 141b as the CFC 11 replacement. HCFC 141b is a blowing agent more environmental regulation compliant. At the same time, the Environmental Protection Agency allowed the External Tank program to continue use of stockpiled supplies of CFC 11until HCFC 141b was certified for use on the Space Shuttle and phased in.

However, in 1999, the EPA proposed to expand its regulations by implementing a ban on nonessential products that release class I ozone-depleting substances under section 610 of the Clean Air Act. Under the proposed rule, sale and distribution of BX 250, used to insulate part of the External Tank, would have been banned because it contains CFC 11. NASA asked the EPA to revise the proposed rule to provide an exemption for BX 250 and other foam containing CFC 11 used in applications associated with space vehicles.

The EPA allowed the exemption but limited it to the Thermal Protection System of the Shuttle's External Tank and only allowed the use of CFC 11 as a blowing agent when no other chlorofluorocarbons are used in the foam product.

The "new" foam containing HCFC 141b was first used on the liquid hydrogen tank aft dome of ET-82 and flew on STS-79 in 1996. The foam was implemented on the tank's acreage, or its larger portions, beginning with ET-88, which flew on STS-86 in 1997. In December 2001, BX-265, which contains HCFC 141b, first flew as a replacement of BX-250. However BX250 continued to be flown as BX-265 was implemented step wise through the manufacturing process.