National Aeronautics and Space Administration

NASAfacts

Return to Flight External Tank, ET-119

Preparing the External Tank

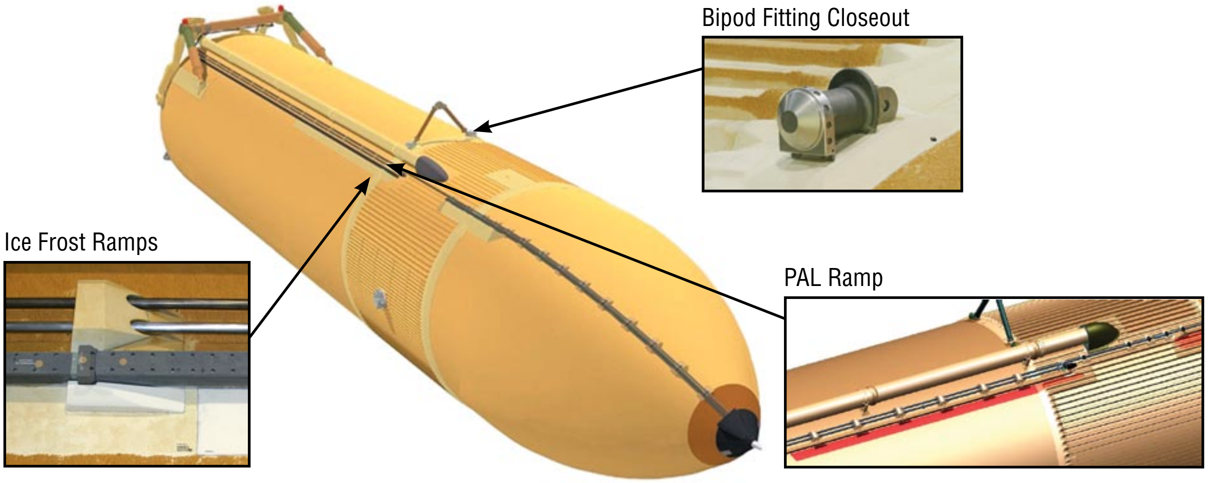
About six hours before Space Shuttle Discovery's launch, the bright orange 15-story-tall fuel tank is loaded with 535,000 gallons of liquid hydrogen and oxygen. Just before liftoff, these super cold liquids are mixed and burned by the shuttle's three main engines, which gulp it at a rate equal to emptying the average size backyard swimming pool in 20 seconds.

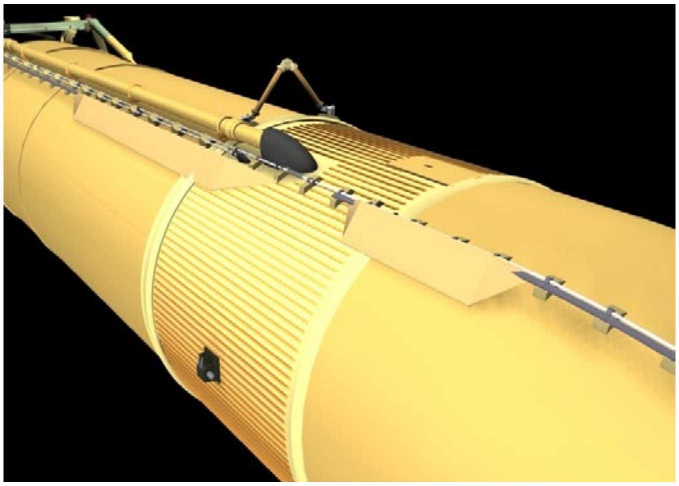
The external tank's aluminum skin is a tenth-of-an-inch thick in most places and is covered with polyurethane-like foam averaging an inch thick, which insulates the propellants, prevents ice formation on its exterior, and protects its skin from aerodynamic heat during flight. About 90 percent of the foam is applied by automated systems, while the remainder is applied manually.

Protuberance Air Load (PAL) Ramps

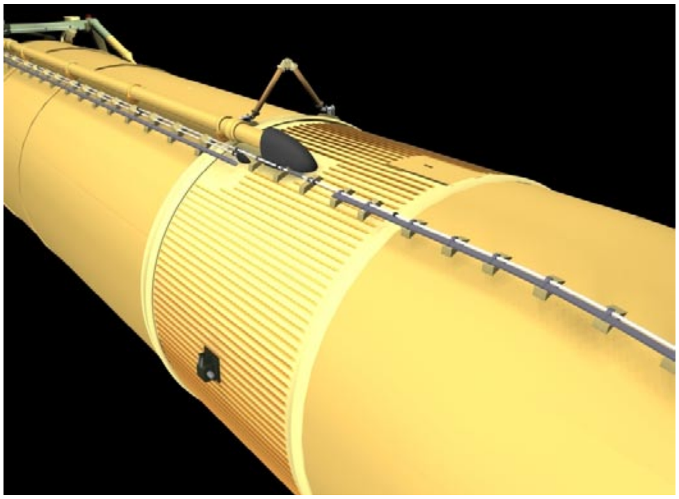
ET-119 is the first external tank to fly without Protuberance Air Load Ramps – manually sprayed wedge-shaped layers of foam along the pressurization lines and cable tray on the side of the tank. They were designed as a safety precaution to protect the tank's cable trays and pressurization lines from air flow that could potentially cause instability in these attached components. Previously, there were two PAL ramps on each external tank. One was near the aft end of the liquid oxygen tank, just above the intertank, and the other was below the intertank, along the upper end of the liquid hydrogen tank. Both ramps extended about 5 feet into the intertank area. The liquid oxygen PAL Ramp was 13.7 feet long and the liquid hydrogen PAL Ramp was 36.6 feet long. The weight of foam removed was 37 pounds total.

During the STS-114 mission in July 2005, video analysis indicated a piece of foam – approximately 36 inches long at the longest point and approximately 11 inches wide at its widest point – was lost from the external tank. The location of the foam loss was approximately 15 feet below the flange that joins the intertank to the liquid hydrogen tank, or approximately 20 feet from the top of the liquid hydrogen PAL ramp. The event occurred at 127 seconds into the flight. The imagery review, as well as on-orbit and post-flight inspections, indicated the debris did not impact Discovery.





PAL Ramps are manually sprayed wedge-shaped layers of foam along the tank's pressurization lines and cable tray.



External tank with PAL Ramps removed for the STS-121 mission.

The external tank project has spent nearly three years testing and analyzing the aerodynamics of the cable trays and pressurization lines to determine the need for the ramps. Enhanced structural dynamics math models were created to better define the characteristics of this area of the tank and scaled models of the tank were tested in wind tunnels at the Marshall Space Flight Center in Huntsville, Ala.; NASA's Langley Research Center in Hampton, Va.; NASA's Glenn Research Center in Cleveland, Ohio; and at the Canadian National Research Council wind tunnel in Ottawa. A full-scale model of this section of the tank also was tested in a wind tunnel at the Arnold Engineering and Development Center at Arnold Air Force Base, Tenn. Computational fluid dynamics work was completed on full-stack (tank, boosters and orbiter) models to better determine the aerodynamic flow in this area.

Following STS-114, external tanks at NASA's Kennedy Space Center, Florida, were returned to the Michoud Assembly Facility outside New Orleans for detailed inspection of these PAL ramps as part of investigative work to understand and identify the most likely root cause of the foam loss.

Two teams were assigned to review foam performance and determine the most likely root causes. One team, composed of NASA's top government and contractor experts on the space shuttle external tank, investigated the foam loss with the intent of determining root cause. Another team, chartered by the Space Operations Mission Directorate at NASA Headquarters in Washington, performed an independent engineering assessment of work required to resolve the foam loss issue.

Three redesign options were studied as possibilities for future improvements to the external tank. These included removing the PAL Ramp from the tank; modifying the PAL ramp to a smaller configuration (mini-ramp); and installing a trailing edge fence on the back side of the cable tray. The no-PAL Ramp option was chosen because recent testing of actual flight hardware demonstrated the current cable tray design did not pose an instability concern.

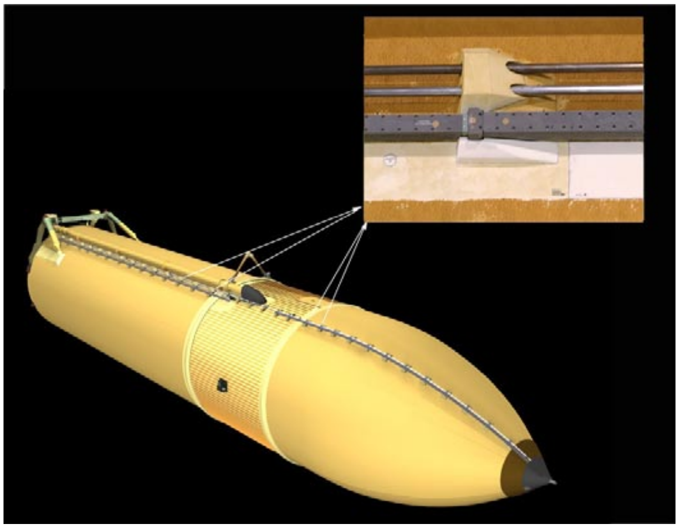
A detailed verification and validation plan addressed the entire spectrum of changes needed to remove the PAL ramp, including foam elimination and impacts to the attached hardware, including cable trays, pressurization lines and support brackets. Engineering processes included detailed modeling of the tank to validate any changes. Additional tests are planned to ensure that required design safety factors have been maintained on all components.

Rigorous analysis and testing is under way to establish that the external tank can be flown safely without the PAL ramps. Testing to verify aeroelastic, aerodynamic and aerothermal loads was completed, indicating that flying the tank without the PAL ramp did not pose additional instability, pressure or heating concerns.

Wind tunnel testing and computational fluid dynamics testing, using computers to study liquids and gases in motion, will verify that the design environments provided to the External Tank Project envelope the flight environment.

Ice Frost Ramps

The main propulsion system pressurization lines and cable trays are attached along the length of the tank at multiple locations by metal support brackets. These metal brackets are protected from forming ice and frost during tanking operations by foam protuberances called ice/frost ramps. There are 34 ice/frost ramps on the tank, 12 on the liquid oxygen tank, six on the intertank and 16 on the liquid hydrogen tank. The size of the ice/frost ramps is dependent upon location. The smaller ramps on the liquid oxygen tank are roughly 1.5 feet long by 1.5 feet wide by 5 inches high. Each weighs about 12 ounces. The larger ramps on the liquid hydrogen tank are roughly 2 feet long by 2 feet wide by 1 foot high. They weigh approximately 1.7 pounds each.

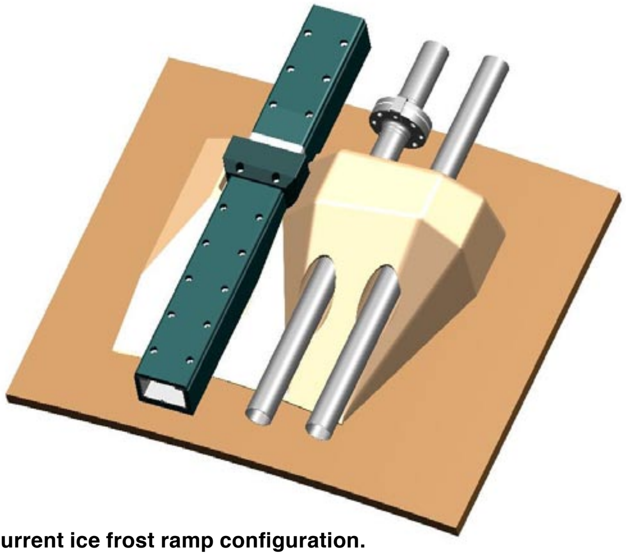


Ice/frost ramps are foam segments that protect against ice and frost formation. There are 34 ice/frost ramps on the external tank.

Ascent/on-orbit imagery from STS-114 indicated foam loss from three liquid hydrogen ice/frost ramps. One piece of foam was approximately 7 inches by 2 inches, in a location approximately 15 feet from the top of the liquid hydrogen PAL ramp.

Nondestructive evaluation techniques and dissection activity on one tank in the inventory (ET-120) which had undergone several pre-flight sequences of cryogenic chill-down and pressurization to flight-like levels revealed cracks in ice/frost ramps. During dissection of one crack, a portion of the base foam was found to have vertical and horizontal cracks which separated into layers near the substrate, or base aluminum skin of the tank..

Options to resolve the ice/frost ramp cracks are being studied, including the possibility of reshaping the ramps to reduce thermal stresses in the foam and to reduce the amount of foam used on each ramp. Wind tunnel tests are being conducted to verify the possibilities for any redesign.



Current ice frost ramp configuration.

The Space Shuttle Program management made a decision in April 2006 to fly the ice/frost ramps in their current configuration. The rationale for doing so was based on several factors including the performance of the ice/frost ramps on previous flights. Any design changes would need to be thoroughly tested and certified before modifying the tank. To do otherwise could result in more uncertainly instead of reducing risk of the tank.

Small foam ramps, called ice/frost ramp extensions, have been added to the ice/frost ramp locations where the PAL ramps were removed. The new extensions were added to make the geometry of these ice/frost ramps consistent with other locations on the tank.

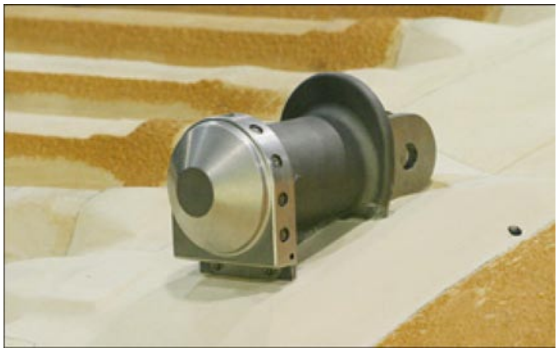
Testing and analysis continues for modifications to the ice frost ramp. New cameras will allow better insight into the current ramp performance, which will help in the redesign effort. Flying the current ice/frost ramps limits the design changes on the tank, which has already undergone a significant redesign with the removal of the Protuberance Air Load (PAL) ramp.

Bipod Closeout

Ascent/on-orbit imagery from STS-114 documented a 7-inch-by-8-inch divot, or lump of missing foam, near the tank’s left hand bipod attachment fitting. The bipod fittings use electric heaters to prevent ice buildup – a potential debris source – on bipod fittings. The bipod design requires cabling to operate the heating system and includes eight circuits – four for each bipod fitting – that run from the external tank ground umbilical carrier plate to the heaters which are under the fittings themselves. These fittings connect the external tank to the orbiter through the shuttle’s two forward attachment struts.

Analysis indicates a probable cause of the divot during the STS-114 mission was cryoingestion, where gases are pulled or ingested through leak paths into regions under the foam at cryogenic temperatures. These gases condense into liquid during tanking on the launch pad, and later exand back into gases during ascent as the tank structure warms. This rapid expansion can cause increases in pressure under the foam, potentially causing divots to be liberated. For the bipod, the leak path for this gas could have been through the heater or temperature sensor wiring harness. Another potential contributor to the cryoingestion scenario is the voids found in the material used to bond the wire harnesses to the substrate. These voids can act as reservoirs for the liquid nitrogen ingested through the harness.

To correct these problems, electrical harnesses that service the bipod heaters and temperature sensors were removed and replaced with improved versions that are designed to reduce the potential for nitrogen leakage from the intertank through the cables into the cryogenic region near the bipod fittings. Void spaces beneath the cables were eliminated by using an improved bonding procedure to ensure complete adhesive coverage.



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Instrumentation

External Tank ET-119 has the same development flight instrumentation (DFI) suite as External Tank ET-118, which is the fuel tank designated for the STS-115 mission. Instrumentation, to make measurements during flight, includes accelerometers in both the liquid oxygen and liquid hydrogen cable trays.

Space shuttle external tank ET-119 rolls out at NASA's Michoud Assembly Facility in New Orleans in February 2006., headed to NASA's Kennedy Space Center, Fla., to help launch Space Shuttle Discovery on its next mission, STS-121.

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