The External Tank Program

Historian's Corner: by Joe Marcus

One of Lockheed Martin's most significant aerospace program wins was achieved during the competitive proposal cycle for the Space Shuttle External Tank. The External Tank (ET) was the component of the Space Shuttle launch vehicle that contained the liquid hydrogen fuel and liquid oxygen oxidizer. During lift-off and ascent it supplied the propellants under pressure to the three Space Shuttle Main Engines in the orbiter. Ten seconds after the main engines were cut off, the ET was jettisoned and re-entered the Earth's atmosphere.

Launch of Space Shuttle Columbia

Typical ET separation after achieving orbit.

This ET product was of a size range beyond Lockheed Martin Denver's experience base of years of Titan Rocket production that featured a 10-foot diameter product. This required significant rethinking in how the production process should be adjusted to accommodate parts handling, welding, and testing of products that approach 30 feet in diameter. The program was centered at the customer's own Michoud Assembly Facility outside of New Orleans, Louisiana, and the contract was won following an intense competition with the Boeing Company in 1973.

The Boeing Company's prior experience in the Michoud facility included production of the Saturn V SI-C stage, which was 33 feet in diameter. But very creative Lockheed Martin (then Martin Marietta) folks assembled an exceptional team of specialists who put together a proposal that appealed to the customer, the NASA organization based at the George C. Marshal Space Flight Center in Huntsville, Alabama. The win by Lockheed Martin was significant because, by design, the tanks were expendable after each launch. This led to an eventual production contract to build well over 100 articles. In fact, 135 ET's flew missions and an additional 6 were in the build process or substantially complete but not commissioned to fly.

In setting up the factory at Michoud, the Lockheed Martin team had assembled a well-considered factory flow, and included plans to utilize a number of existing facility features used in the prior moon rocket program. This efficient approach allowed the Lockheed Martin team to bid the ET proposal on a very desirable low-cost, low-risk basis, and the contract was awarded in mid-1973.

To assure the continued success of the ET Program for the NASA customer, the company carefully selected strong general managers to run the operations through the years. The LM team at Michoud after the proposal win included such notables as George Smith, Ken Timmons, Rick Davis, Tom Marsh, and Dennis Deel. These managers were believers that customer satisfaction was the ultimate objective for running any large, complex program. They listened to the customer's requirements and desires and followed through to assure success.

As the ET design evolved over the opening years of the contract, the final sizes and features were solidified. The ET system consisted of three basic major elements: the Liquid Oxygen tank, the Intertank joining structure, and the Liquid Hydrogen tank.

The Liquid Oxygen (LOX) vessel featured a bullet-nosed configuration to enhance aerodynamics. Its volumetric capacity was 19,744 ft^3 and the base diameter was 27.6 feet. The proof pressure test for the LOX tank was elegantly simple in that it used a simple standpipe extending above the forward end of the tank to achieve the require aft dome proof pressure value.

The Intertank structure was the interface at the aft mounting flange of the LOX tank and continued with a 27.6 foot diameter and featured a massive structural beam at its midpoint that was designed to take the full forward thrust loads of the solid rocket boosters on each side of the ET.

The aft tank of the ET stack was the Liquid Hydrogen (LH_2) tank. Its capacity was 53,488 ft^3 and, like the LOX tank and Intertank, had a base diameter of 27.6 feet. The LH_2 tank also featured provisions for critical attachments with the Shuttle Orbiter Spacecraft. These orbiter attachments had to bear the full thrust and aerodynamic load between the Shuttle and the ET for all launch and flight regimes.

The LH_2 tank presented a number of significant challenges to the design, analysis and ground test disciplines. The first reality was that the propellant, liquid hydrogen, has such a low density that a pneumatic proof test was virtually a requirement, since any reasonable test liquid (like water) would cause a significant overdesign of the tank with a resulting adverse weight impact. The second reality was that since the LH_2 tank had to absorb and resolve all the flight dynamic loads imposed by the orbiter and other impacts by the solid rocket boosters, significant point loads in proof test would need to be applied simultaneously with the application of proof internal pressures. This combination of proof pressure and application of large point loads represented a significant test risk that had to be dealt with comprehensively.

The answer to this risk issue was to create the LH_2 tank proof test facility, also known as the Building 451, which was designed and built at a remote site location from the main Michoud Assembly Facility factory. The primary reason for the remote location was that if a catastrophic test failure occurred on an LH_2 tank under pneumatic proof pressure test values, the potential damage to adjacent buildings and employees could be non-trivial. The Building 451 had blow-out panels that would quickly vent large volumes of escaping gas in case of a tank failure. This would enable most of the facility to survive a tank failure with minimum disruption. Other features built into Building 451 included a simulated Intertank interface ring at the front of the LH_2 tank, and a number of hydraulic actuator cylinders located in the vicinities of Shuttle Orbiter and Solid Rocket Booster interface points. All testing was performed from a remote, "bomb shelter-like" building wherein the test conductors and observers could safely monitor all test pressures and loads required to properly proof test the LH_2 tanks. In the history of the ET program, no catastrophic failure of an LH_2 tank ever occurred in the proof test.

As the program evolved, it was clear that payload weight capability of the Orbiter would have to be enhanced in order to make the placement of the International Space Station a practical reality. For each pound of ET weight reduction, the Orbiter would gain nearly a pound of additional payload capacity. Design, stress, and weights specialists examined virtually all aspects of the original, standard weight ET. Their analyses determined that a number of areas on the ET were initially designed somewhat conservatively. This enabled strategic thinning of select materials and reduction of section sizes without adversely affecting flight integrity or margins of safety. An additional weight savings was achieved by discontinuing the application of the white protective paint layer over the insulation foam, which saved an additional 600 pounds. These efforts resulted in lightweight versions of the tank being built that reduced total weight by approximately 11,000 pounds. This greatly enhanced Shuttle cargo weight capability, which was key to enabling the build of the International Space Station.

Other interesting aspects of the ET program included the following:

- The ET was judged as the backbone of the Shuttle flight configuration as it provided the structure to join the Orbiter vehicle and the Solid Rocket Boosters together as a flight system.
- The ET was 153.8 feet tall, taller than the Statue of Liberty (151 feet).
- There were approximately 480,000 parts in each ET.
- Dry weight of the original, standard weight ET was approximately 78,000 pounds.
- Liquid Oxygen weight on the ET was 1,359,142 pounds.
- Liquid Hydrogen weight on the ET was 226,237 pounds.
- Propellant flow rates during flight were 17,592 gallons per minute for LOX, and 47,365 gallons per minute for LH_2.

Typical ET approaching final assembly steps

For decades, the Space Shuttle program relied heavily on the ET to enable effective delivery of critical humans and cargo to orbit. The entire proposition of taking manned space exploration to higher levels of achievement, such as the International Space Station and the corresponding scientific exploration and analyses, is noble. The Shuttle system proved to be a reliable workhorse to take man into the 21st Century. Although sadly there was loss of human life during the Space Shuttle Program (Challenger and Columbia), the determined advancement of human space flight and our understanding of previously unexplored horizons was a rich reward.