# Thermal Barriers Developed for Solid Rocket Motor Nozzle Joints

Space shuttle solid rocket motor case assembly joints are sealed with conventional O-ring seals that are shielded from 5500 °F combustion gases by thick layers of insulation and by special joint-fill compounds that fill assembly splitlines in the insulation. On a number of occasions, NASA has observed hot gas penetration through defects in the joint-fill compound of several of the rocket nozzle assembly joints. In the current nozzle-to-case joint, NASA has observed penetration of hot combustion gases through the joint-fill compound to the inboard wiper O-ring in one out of seven motors. Although this condition does not threaten motor safety, evidence of hot gas penetration to the wiper O-ring results in extensive reviews before resuming flight. The solid rocket motor manufacturer (Thiokol) approached the NASA Glenn Research Center at Lewis Field about the possibility of applying Glenn's braided fiber preform seal as a thermal barrier to protect the O-ring seals. Glenn and Thiokol are working to improve the nozzle-to-case joint design by implementing a more reliable J-leg design and by using a braided carbon fiber thermal barrier that would resist any hot gases that the J-leg does not block. The proposed new seal arrangement is shown in the following illustration. This illustration also shows joints 1 through 5, which are other sites where the thermal barrier could be used.
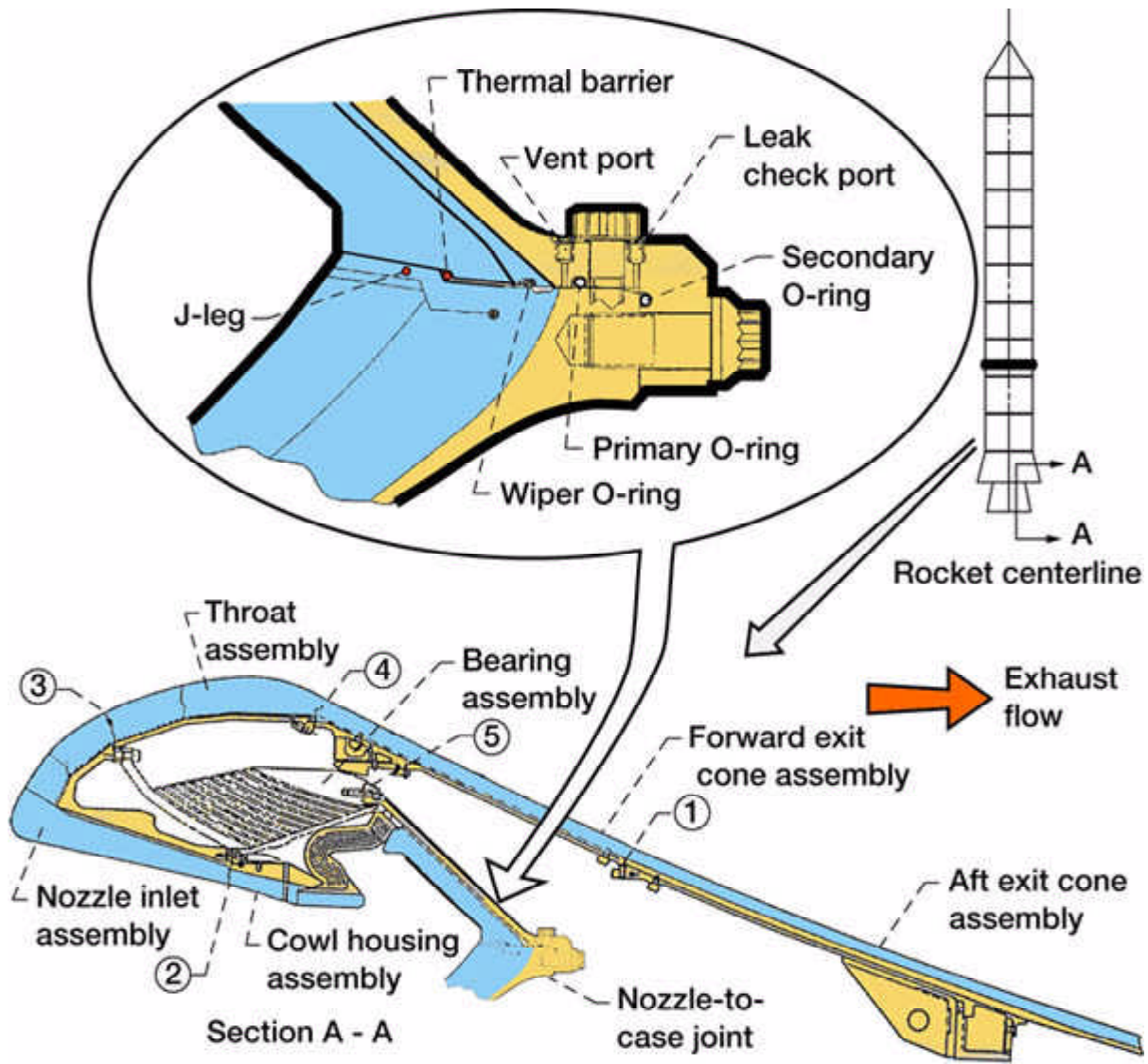
Potential shuttle solid-rocket-motor nozzle joint locations (circled numbers) for thermal barrier. Top: Enlarged view of nozzle-to-case joint showing J-leg, wiper, primary and secondary O-rings, leak check port, and proposed thermal barrier location. Bottom: Overall nozzle cross section (half view).

The thermal resistance of Glenn's braided carbon fiber thermal barriers was assessed by exposing them to burn tests at temperatures representative of the rocket thermal environment. The thermal barriers were placed in the hottest part of the flame of an oxyacetylene torch at 5500 °F, and the amount of time needed to completely cut through them was measured. Thermal barrier designs with diameters of 0.20 and 0.26 in. resisted the flame for over 6 minutes before they were completely cut through, more than three times longer than the burn time for the shuttle's solid rocket motors.

A test fixture was developed that allows the temperature drop to be measured across and along a thermal barrier when the barrier is in a compressed state and subjected to rocket-

simulating narrow jets of hot gas at upstream temperatures of 3000 °F (see the photograph). Tests performed on the 0.20- and 0.26-in.-diameter thermal barriers showed that they are excellent insulators, causing temperature drops of 2500 to 2800 °F through their diameters. Gas temperatures measured only one seal diameter downstream from the thermal barrier were within the Viton[1] O-ring temperature limit of 600 °F. The test fixture also measured the jet-spreading feature of the rope seal. Results show that the 0.082-in. hot incoming jet was spread over a wide section of the braid (>1 in.), as measured by multiple cold-side thermocouples.
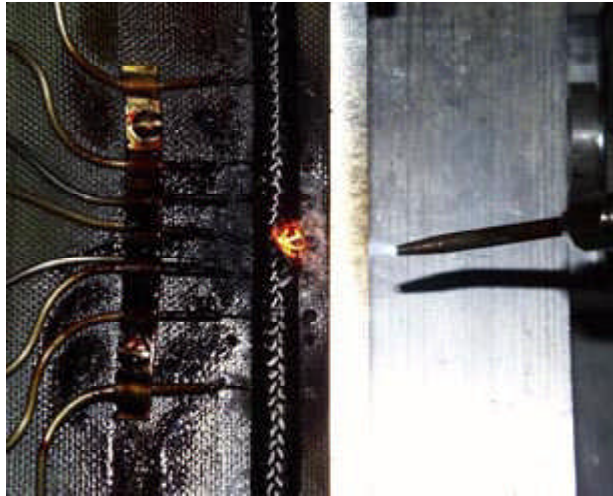
Temperature-drop fixture showing a flame on the thermal barrier.

To simulate a rocket environment, Thiokol performed subscale rocket "char" motor tests in which the 0.26-in-diameter thermal barrier was subjected to hot gas at 3200 °F for an 11-sec rocket firing, simulating the maximum downstream joint-cavity fill time. The thermal barrier reduced the incoming hot gas temperature by 2200 °F in an intentionally oversized gap defect, spread the incoming jet flow, and blocked hot slag, thereby offering protection to the downstream O-rings. These results were consistent with those from the temperature-drop tests performed at Glenn.

A Glenn-developed braided carbon fiber thermal barrier was successfully evaluated at NASA Marshall in an MNASA–10 rocket, a one-fifth-scale version of the reusable solid rocket motor (RSRM) used to launch the space shuttle. The specimen was tested in the redesigned nozzle-to-case joint configuration. During the 29-sec rocket firing, an intentional flaw in the nozzle insulation allowed hot combustion gases to reach the thermal barrier as evidenced by soot observed on hardware upstream of the thermal barrier 5 in. on each side of the flaw (see the final photo). Posttest inspection revealed no soot downstream of the thermal barrier and no damage or erosion to either the thermal barrier or to downstream O-rings that the thermal barrier is designed to protect.
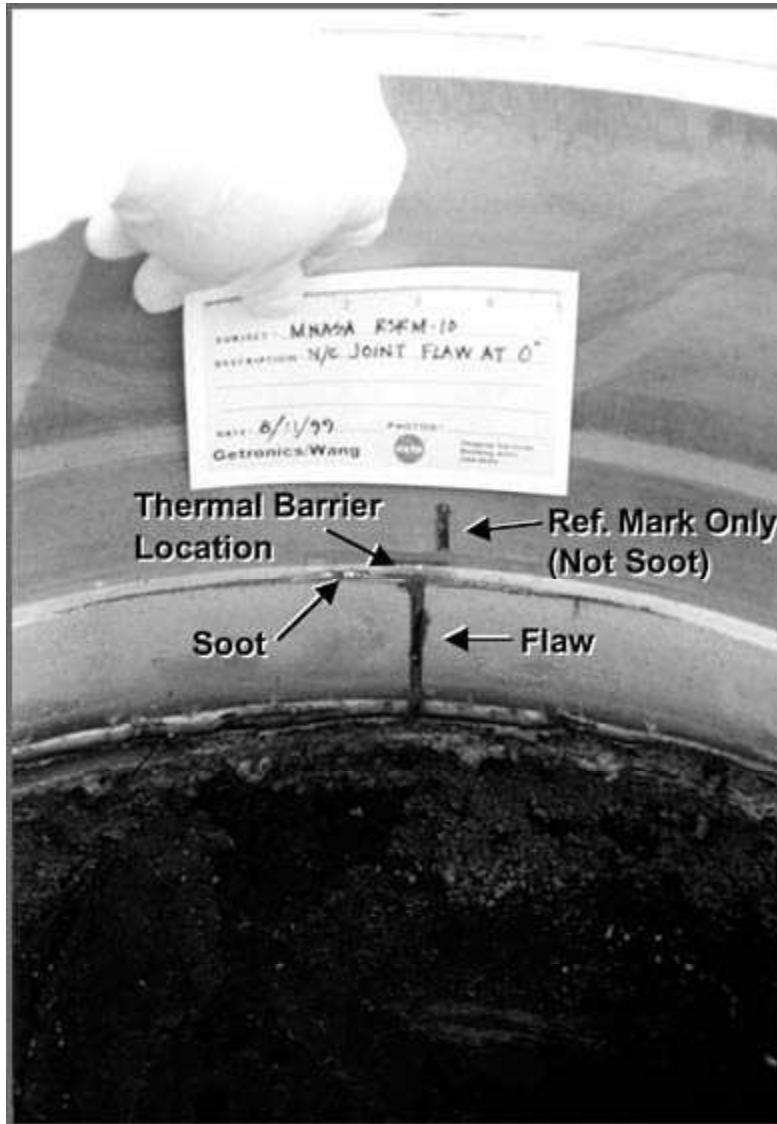
NASA Glenn thermal barrier feasibility proven in MNASA–10 RSRM. (Specimen was removed from the nozzle-to-case joint for this photo.)

The Glenn-developed carbon thermal barrier is the primary candidate being considered by Thiokol for the space shuttle RSRM nozzle-to-case joint redesign to prevent Viton O-ring damage. Thiokol is continuing to perform qualification tests of the Glenn-developed thermal barrier for the nozzle-to-case joint and has expressed interest in using the thermal barrier in joints 1 through 5 of the solid rocket motor nozzle. Thiokol is planning to perform full-scale RSRM static tests using the thermal barrier in January 2001 (no joint defect) and in May 2002 (with joint defect) to qualify the new design for its first shuttle flight in September 2002.

Find out more about this research at the Mechanical Components Branch http://www.grc.nasa.gov/WWW/5900/5950/.

Bibliography

Steinetz, B.M.; and Dunlap, P.H., Jr.: Development of Thermal Barriers for Solid Rocket Motor Nozzle Joints. NASA/TM—1999-209278 (AIAA Paper 99–2823), 1999.

[1]Viton is a registered trademark of DuPont.

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Special recognition: 1996 NASA Invention of the Year awarded to the fiber preform seal, precursor to the thermal barrier