Base Thermal Environment of Delta Vehicle with Six Strap-On Motors

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Theme

IN-FLIGHT base heating measurements from the Delta launch vehicle using six strap-on solid-propellant motors for thrust augmentation of the Thor first stage booster are presented and compared to similar measurements from two earlier configurations (Models DSV-2C and 2L) having three strap-on solids and to measurements from the basic Thor Model DSV-2A (without solids).

Contents

During its long history as a first stage booster, the Thor has undergone several modifications to increase vehicle performance. Such changes have included the utilization of three solid motors for thrust augmentation. The most recent modifications have increased the number of solids from three to six (Fig. 1). The first stage vehicle is propelled by a single, LOX/RJ-fueled, liquid, main engine with a burn time of 220 sec. Thiokol Castor I and Castor II solids were used for the six-solid vehicle thrust augmentation. The motors have identical external dimensions but different thrust characteristics. The Castor I motors were fired at lift-off (simultaneously with the core vehicle engine) and burned for approximately 42 sec (16,000 ft alt). At 31 sec (7200 ft alt), the Castor II motors were ignited (allowing an overlap of about 10 sec with the first set) and burned until 68 sec (46,000 ft alt) after lift-off. Jettison of the spent Castor I and Castor II motor cases occurred at 90 and 95 sec, respectively.

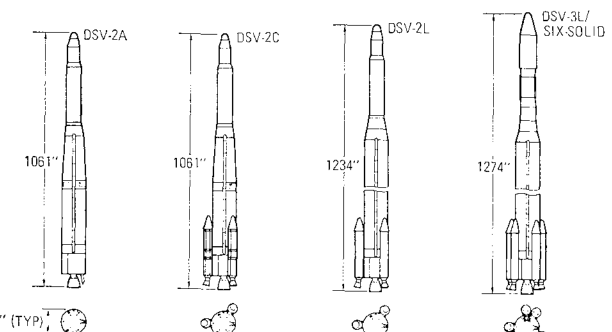

Fig. 1 Vehicle configuration.

It is evident from earlier flight test data and associated analysis that the primary contributors to the base heating on the Thor are radiation from the solid particle core of the solid motor plumes, and both radiation and convection from recirculating and recombusting fuel-rich, turbine exhaust gases.

Composite plots of the flight base heating rate measurements obtained from asymptotic calorimeters and radiometers are presented in Fig. 2. Comparison of the radiometer and calorimeter composite plots indicates higher levels on the radiometers than on the calorimeters during the subsonic flight (below 7000 ft alt), when Castor I solid motors were operating. It would appear that significant convective cooling occurred at the calorimeter surfaces, presumable the result of cool boundary-layer air being drawn into the base area by the ejector-like action of the solid motor exhausts; the effect was not sensed at the radiometer surfaces which were protected by sapphire windows.

An estimate of the net radiation level from the Castor I motors was made by comparing the radiometer outputs from the six-solid vehicle to the calorimeter data from the DSV-2A vehicles at the 1000 ft alt. Since recirculation was not a predominant factor on either configuration at this altitude, the measured radiation level of about 10 Btu/ft^2 sec on the six-solid version can be compared to the background (main engine, verniers, and turbine exhaust) level of about 3 Btu/ft^2 sec on the DSV-2A vehicle. It is evident from this comparison that the solid motors add no more than 7 Btu/ft^2 sec. The precise increment could not be established since the calorimeter on the DSV-2A vehicle (as on the six-solid vehicle) may have been convectively cooled. A similar comparison of DSV-2C and DSV-2L radiometer data to the DSV-2A data verified the maximum increment in heating due to the solid motors, and indicated essentially equivalent radiation from Castor I and Castor II motors. Further analysis of the data indicated that the solid motor radiation remained at a nearly constant level throughout solid motor operation.

It is evident from the time integrals of the data that although higher peak heating rates were experienced on the six-solid vehicle, the integrated heat input to the base was little changed from the levels on the three-solid configurations. An integral of 1100 Btu/ft^2 was the highest reading on the six-solid vehicle base plane; this integral was less than 25% above the highest previous value.

Although the additional solid motors increased the heating only slightly, the motors shifted the heating from a predominately convective environment to a radiative one. Nevertheless, significant convective peaks were noted during vehicle transonic flight and during motor tailoff and startup.

Since the motors were used only at relatively low altitudes, plume interactions did not occur. Therefore, prolonged heating due to high-velocity recirculation, such as that experienced with closely clustered nozzles, was not observed.

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Index categories: Launch Vehicle or Missile Propulsion System Integration; Launch Vehicle or Missile Flight Testing.

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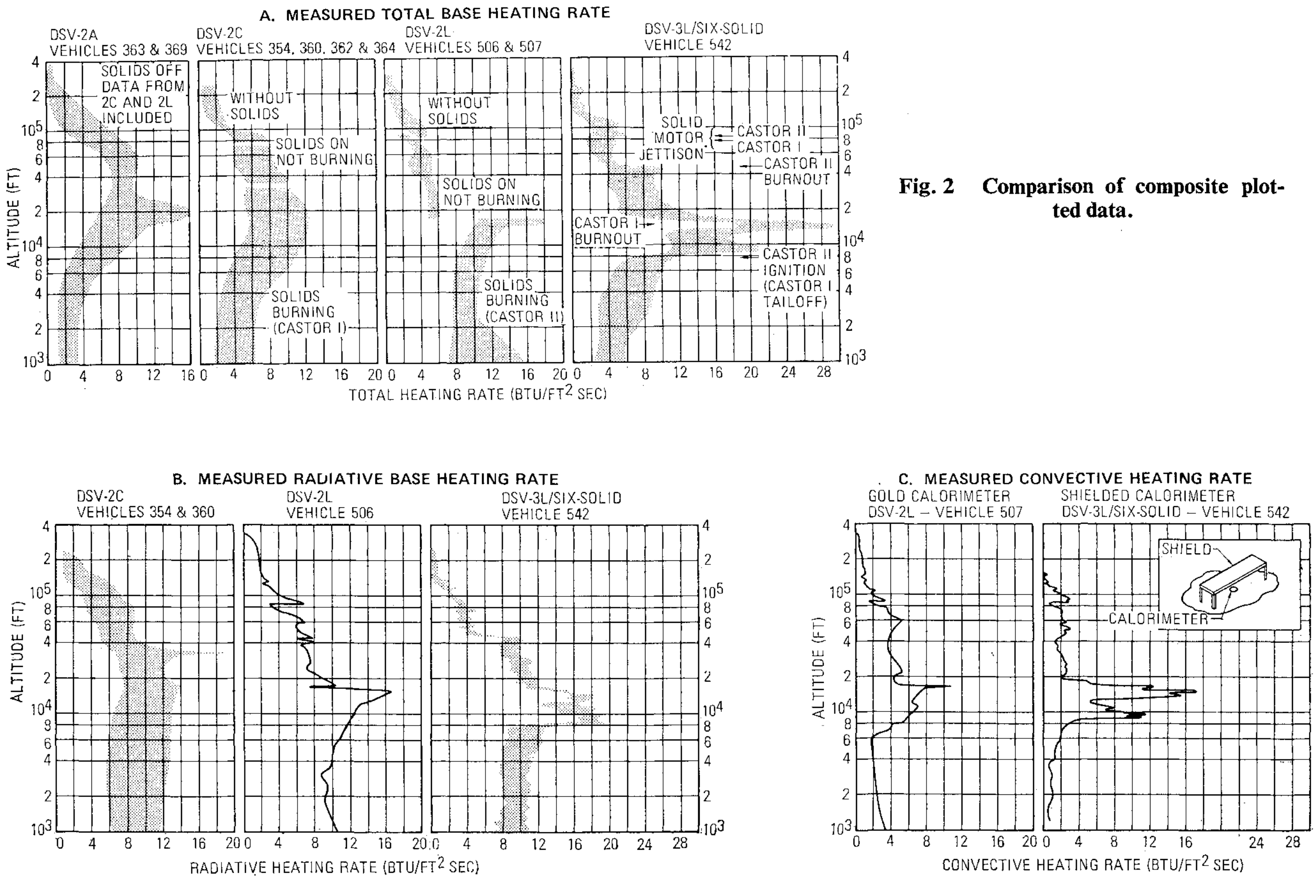

Fig. 2 Comparison of composite plotted data.