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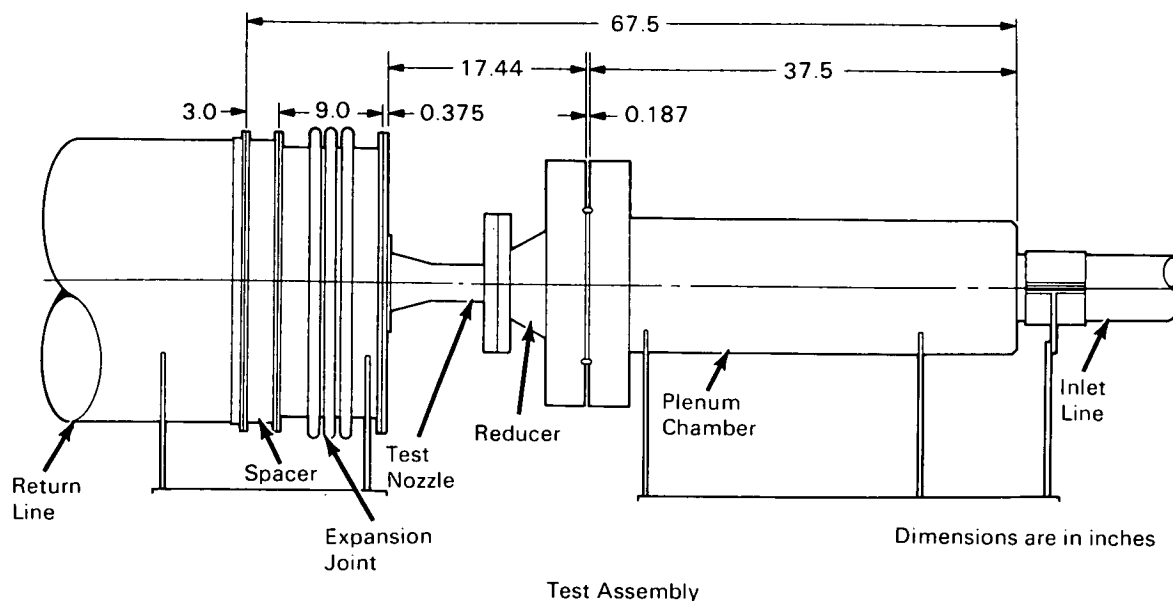
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Experimental Investigation and Analysis of Two Sources of Nozzle-Thrust Misalignment



Irregularities in a nozzle's surface and asymmetry of the throat can produce measurable and possibly significant side forces. An investigation is reported (see Note 2) of the possible effects of nozzle-surface irregularities and throat asymmetry on the position of the nozzle's thrust vector. Such irregularities and asymmetry can result from delamination or erosion of a nozzle's ablative materials during firing of a rocket. The objects of the investigation were: (1) to determine whether (and if so to what extent) an exaggerated asymmetry in the nozzle throat's cross section displaces the thrust vector; and (2) to extend flat-plate protrusion data to nozzle flow to determine to what extent a protrusion to the flow, in the nozzle's expansion region, displaces the thrust vector.

Experiments were conducted in a three-dimensional gas-flow test facility (see fig.). The flow channel was a gas line tapping a 21-in. hypersonic wind tunnel downstream from the heated-air supply and upstream from the inlet valve to the test section. In air-supply potential the auxiliary flow channel essentially equaled the wind tunnel: maximum supply pressure, about 660 psia; maximum rate of air flow, 10 lb/sec. The temperature of the supply could be controlled between 90° and 1350°F.

For both nozzles all pressure data expressed as ratios relative to the plenum supply pressure were essentially independent of test-supply pressure. For both, the net side force, summed over the nozzle's expansion ratio, reached a maximum and then con-

(continued overleaf)

tinued to decrease as the nozzle was traversed along its axis, leveling-off at a minimum overall value for the asymmetric-nozzle case.

The characteristics of the perturbed-unperturbed pressure-ratio profile approached those of pressure-ratio profiles found earlier for flat-plate, turbulent-boundary-layer flow over two-dimensional protrusions; the differences were probably due to the three-dimensional nature of the experimental protrusion.

The asymmetric nozzle's net side-force profile maximum proved to be not solely attributable to the particular geometry of the test nozzle. A highly simplified three-dimensional flow-field analysis gave reasonably good parity with the asymmetric-nozzle experimental data.

It is believed that a two-dimensional asymmetric-nozzle parametric analysis predicts the correct trend of change in magnitude of induced nozzle side force with a decreasing degree of throat asymmetry. Asymmetry in the region of the nozzle's throat produces an oscillatory type of net side-force axial profile. By use of mean values of the localized static pressure and Mach number, scaling laws for flat-plate supersonic flow over a protrusion can be applied to irregularities in the nozzle expansion cone for an approximate indication of the perturbed-pressure profiles and therefore the induced side forces.

For a first estimate of the induced side force, a rough surface-pressure integration should be carried

out with use of axial-pressure profiles obtained by a two-dimension flow analysis in the plane of the desired side-force direction.

Note:

The following documentation may be obtained from:
Clearinghouse for Federal Scientific
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Single document price \$3.00
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Reference:

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Patent status:

Inquiries about obtaining rights for the commercial use of this invention may be made to NASA, Code GP, Washington, D.C. 20546.

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