NASA TECH BRIEF

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Volumetric Calibration of a Propellant Utilization System

The problem:

To develop a method of calibrating capacitance-type propellant mass sensors that provide meaningful mass units accurate to within 1 percent of the total load. Previous calibration techniques required special propellant loadings and acceptance test firings of each stage to meet the required 1 percent accuracy.

The solution:

The volumetric method of propellant-utilization-system calibration with an indication of onboard propellant accurate up to 1 percent. Neither special propellant loading nor acceptance test firing of each stage is required. When an unavoidable replacement of the mass sensor is necessary, recalibration of the system is also possible without special propellant loading. This method provides significantly increased flexibility for vehicle operation.

How it's done:

The propellant mass sensor is a continuous, coaxial cylindrical capacitor whose inner element has varying radii. The rate of change in mass sensor radius with height is directly proportional to the rate of change of the propellant tank volume with height. However, manufacturing tolerances in the fabrication of the mass sensor and the propellant tank cause a mismatch to exist between the two. To achieve the required sensing accuracy, the amount of mismatch must be determined and the system adjusted to correct it.

During the fabrication of the propellant tank, numerous spherical and cylindrical radii measurements are made and recorded. Critical tank assembly and sensor mounting location are also measured. These dimensions are corrected (based on results of full-scale tank tests) to account for dimensional change caused by thermal and pressure effects during loading. The unique volume versus height relation is then computed from the resulting dimensions. The difference between this volume and the nominal volume represents the portion of the tank-to-sensor mismatch due to tank-fabrication tolerances.

The sensor portion of the tank-to-sensor mismatch is determined from room-temperature calibration by the sensor manufacturer. The sensor-electrical output as a function of height is determined by these calibrations. The electrical output is corrected for the thermal effects that change the sensor geometry during propellant loading. The amount of change over the entire sensor length is determined experimentally by completely immersing the sensor in the propellant during several normal stage propellant loading operations. The difference between the manufacturer's thermally corrected test data and the nominal sensor design output is the sensor portion of the mismatch.

The final mismatch adjustment is made by determining the mass equivalents of the volume and sensor output deviations from nominal at a common height. This is done by multiplying the volume deviation by a selected density. The sensor output deviation is adjusted based on the linear relationship of the dielectric constant of the propellant and the propellant density (the Clausius-Mossotti relation). The mass deviation divided by the density-corrected sensor output deviation at a common height is the volumetric calibration slope correction to the nominal sensor design slope.

Notes:

1. This innovation may be of interest to petroleum and chemical processing industries.

2. Requests for further information may be directed to:

> Technology Utilization Officer
> Marshall Space Flight Center
> Huntsville, Alabama 35812
> Reference: B70-10156

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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> McDonnell-Douglas Company
> under contract to
> Marshall Space Flight Center
> (MFS-14943)