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Effect of Downstream Pressure in Tuning the Flow Control Orifices of Pressure Fed Reaction Control System Thrusters

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Abstract : Introduction: In launch vehicle missions, Reaction Control thrusters are being used for the three-axis stabilization of the vehicle during the coasting phases. A pressure-fed propulsion system is used for the operation of these thrusters due to its less complexity. In liquid stages, these thrusters are designed to draw propellant from the same tank used for the main propulsion system. So in order to regulate the propellant flow rates of these thrusters, flow control orifices are used in feed lines. These orifices are calibrated separately as per the flow rate requirement of individual thrusters for the nominal operating conditions. In some missions, it was observed that the thrusters were operated at higher thrust than nominal. This point was addressed through a series of cold flow and hot tests carried out in-ground and this paper elaborates the details of the same. Discussion: In order to find out the exact reason for this phenomenon, two flight configuration thrusters were identified and hot tested in the ground with calibrated orifices and feed lines. During these tests, the chamber pressure, which is directly proportional to the thrust, is measured. In both cases, chamber pressures higher than the nominal by 0.32bar to 0.7bar were recorded. The increase in chamber pressure is due to an increase in the oxidizer flow rate of both the thrusters. Upon further investigation, it is observed that the calibration of the feed line is done with ambient pressure downstream. But in actual flight conditions, the orifices will be subjected to operate with 10 to 11bar pressure downstream. Due to this higher downstream pressure, the flow through the orifices increases and thereby, the thrusters operate with higher chamber pressure values. Conclusion: As part of further investigatory tests, two numbers of fresh thrusters were realized. Orifice tuning of these thrusters was carried out in three different ways. In the first trial, the orifice tuning was done by simulating 1bar pressure downstream. The second trial was done with the injector assembled downstream. In the third trial, the downstream pressure equal to the flight injection pressure was simulated downstream. Using these calibrated orifices, hot tests were carried out in simulated vacuum conditions. Chamber pressure and flow rate values were exactly matching with the prediction for the second and third trials. But for the first trial, the chamber pressure values obtained in the hot test were more than the prediction. This clearly shows that the flow is detached in the 1st trial and attached for the 2nd & 3rd trials. Hence, the error in tuning the flow control orifices is pinpointed as the reason for this higher chamber pressure observed in flight.

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