EVALUATION OF A FRACTURE FAILURE MODE IN THE SPACE SHUTTLE HYDROGEN PRESSURIZATION SYSTEM FLOW CONTROL VALVES

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Abstract

During acceptance testing of the Space Shuttle Endeavour's hydrogen flow control valves (GH2 FCVs), used in the Orbiter's fuel tank pressurization system, two of the valves experienced fracture of the poppet flange. The poppets are made of 440C, a high strength, wear resistant, low ductility, martensitic stainless steel. The investigation which was initiated to determine the cause of these failures is traced in this paper. All aspects of the poppet processing that may have introduced a defect were assessed. This included machining, heat treating, passivation, assembly, and test. In addition, several potential failure modes were investigated. These included static overload, dynamic overload (particle impact), fatigue, and hydrogen embrittlement. The extensive investigation revealed no obvious cause of the failures, but did result in a recommendation for a different material application.

Introduction

Three flow control valves, one per engine system, are used to control the flow of gaseous hydrogen from the fuel turbopump outlet of each engine through the Orbiter to the External Tank (see Figure 1). The hydrogen gas pressurizes the ullage volume above the liquid hydrogen in the fuel tank to maintain the structural capability of the tank, under the dynamic pressure loads of flight, and to maintain net positive suction pressure at the engine fuel pumps.

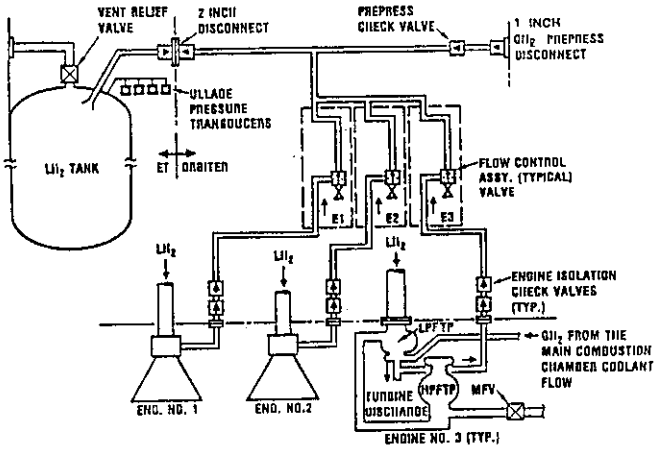

Figure 1. Shuttle Hydrogen Pressurization System

The GH2 FCV is designed to supply the high pressure hydrogen gas at either of two preselected flow rates through a poppet controlled by feedback from pressure sensors in the external tank. The poppet is solenoid operated to the low flow position and spring and pressure assisted to the high flow position (see Figure 2). The stroke of the poppet is adjusted by installing shims to alter the positions of the poppet stops. The gas passes through the valve's annular orifice, created between the poppet and its sleeve, at sonic velocity (see Figure 3). Thus the pressure and flow rate of the gas are controlled to meet the requirements of the external tank.