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Hydride Compressor Sorption Cooler and Surface Contamination Issues

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ABSTRACT

An 18K continuous-duty hydrogen sorption cryocooler is being developed at JPL for the Planck spacecraft, a mission to map the cosmic microwave background beginning in 2007.[1] The cooler uses six individual compressor elements (CEs) filled with the hydriding alloy $LaNi_{4.78}Sn_{0.22}$ to provide high-pressure (50bar) hydrogen to a Joule-Thomson expander and to absorb low-pressure (~0.3bar) gas from liquid hydrogen reservoirs cooled to ~18K. Recently, residual-gas analysis (RGA) showed methane, water, and possibly CO in these hydride beds after cycling during initial operation of laboratory tests of the Planck engineering breadboard (EBB) cooler. These contaminants have caused problems involving plugged J-T expanders. As the beds were initially exposed to hydrogen gas of 99.999+% purity, the contaminants probably come from reactions with residual hydrocarbon species on surfaces inside the hydride bed. Improved processes that ensure a residue-free initial hydrogen fill will be followed by repeated fill-purge cycles to reduce sources of condensible contaminants.

The hydride bed in each CE is contained in an annular volume called a "gas-gap heat switch,"[1,2] which serves as a reversible, intermittent thermal path to the spacecraft radiator. The gas-gap is either "off" (i.e., its pressure <1.3 Pa), or "on" (i.e., hydrogen gas at ~4 kPa). The hydrogen pressure is varied with an independent hydride actuator containing $ZrNiH_x$. Early EBB cooler tests showed increasing parasitic heat losses from the inner beds, suggesting residual pressures in the gas gap during its "off" state. RGA measurements showed that this pressure rise was due entirely to hydrogen[3]. This gas accumulation has serious end-of-life implications, as the ZrNi actuator has limited storage capacity and any excess hydrogen would necessarily affect its operation. The strongly temperature-dependent rate of hydrogen accumulation in the gas gap volume has been found to range from ~$4x10^{-8}$scc/s at 293K to ~$5x10^{-5}$scc/s at 525K, consistent with rates reported by others for similar metals[4]. This accumulation was shown to be due to both outgassing from metallic surfaces in the gas gap and hydrogen permeation through the inner sorbent bed wall. Most of the surfaces of the gas gap volume are covered with electroplated Au/Ni films, which are sources of hydrogen outgassing. Hydrogen ^{15}N depth profiling measurements showed that the Ni substrate film contained several times the volumetric H-atom content of any other metallic component in the gas gap region. In an attempt to reduce outgassing, changes to the surface treatment of gas gap structures are being considered. These include varying purge-bake cleaning methods, leaving low-temperature surfaces unplated, and removing specific metallic structures from the gas gap volume.

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