适用于极端环境的环控生保热试验设备研制*

冯红旗[1],李　森[1],杨润泽[1],武　越[2],孙　娟[2]

(1.中国航天员科研训练中心,北京　100094;2.北京卫星环境工程研究所,北京　100094)

摘　要:为满足环控生保系统真空热试验期间氢气、甲烷和 CO_2 等废气排放,以及 CO_2 气体注入的需求,研制了一种热试验设备。该设备采用加热带加热和多层隔热材料保温相结合的方案使管路温度保持在 20℃以上,解决了极端低温下氢气和甲烷中水蒸气冷凝、CO_2 气体结冰的管路堵塞问题;采用掺混高纯氮气的方案将甲烷气体的浓度降至 3.6%以内,低于 4.4%的爆炸阈值,解决了甲烷真空排放的安全问题。经真空热试验考核,所研制的热试验设备运行稳定,工作性能满足研制要求。

关 键 词:氢气排放;甲烷排放;CO_2 气体注入;绝缘加热带;多层隔热材料

中图分类号:TB79　　**文献标识码**:A　　**文章编号**:1002-0322(2023)05-0086-06

doi:10.13385/j.cnki.vacuum.2023.05.14

Development of an Environmental Control and Life Support System Thermal Test Equipment for Extreme Environment

FENG Hong-qi[1], LI Sen[1], YANG Run-ze[1], WU Yue[2], SUN Juan[2]

(*1.China Astronaut Research and Training Center, Beijing 100094, China;*
2.Beijing Institute of Spacecraft Environment Engineering, Beijing 100094, China)

Abstract: A special equipment is developed to meet the emission requirements of hydrogen, methane and carbon dioxide wastes and the injection requirements of carbon dioxide into the sealed chamber during the thermal vacuum tests of the environmental control and life support system (ECLSS) of a spacecraft. The equipment adopts a scheme which combines the electric heating belt and the multi-layer insulation materials to keep the pipeline temperature above 12 ℃. The scheme solves the problem of hydrogen and methane condensation in extreme low temperature conditions and avoids risks of pipe blocking due to carbon dioxide freezing. The scheme also improves the safety level during methane emission via mixing the highly pure nitrogen into methane, solving the safety issue for the emitting methane into vacuum space, since the concentration of methane decreases to within 3.6%, lower than its blasting threshold of 4.4%. Eventually, the stability and the fulfillment of the requirements of the equipment are verified by the practical thermal vacuum tests.

Key words: hydrogen emission; methane emission; carbon dioxide injection; insulated heating belt; multi-layer insulation material

航天器环境控制与生命保障系统(简称环控生保系统)参加载人飞行任务前,需要在热真空容器内随航天器一同完成真空热试验,考核其在不同热工况下的工作性能[1-2]。为模拟宇宙真空和低温环境,热真空容器内部热沉温度≤100K、真空压力≤1×10^{-3}Pa,处于热真空容器内部的设备需承受低温和高真空环境[3-6]。环控生保系统在轨工作时,电解制氧、CO_2 还原和 CO_2 去除等功能单元产生的氢气、甲烷和 CO_2 等含水废气直接向外太空真空环境排放。地面真空热试验期间,这些废气需要依靠外接地面管路,通过热真空容器最终排向室外大气,另外为了模拟人体在航天器内的 CO_2 代谢,真空热试验期间需向航天器密封舱内注入纯 CO_2 气体。为保障真空热试验期间废气排放和 CO_2 气体注入等功能的实现,需研制热试验设备。

收稿日期:2023-04-19

作者简介:冯红旗(1971-),男,陕西省泾阳县人,研究员。

*基金项目:中国载人航天工程基金资助项目。