Amine Swingbed Payload Technology Demonstration

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Amine Swingbed Technology

- The Amine Swingbed is an amine-based, vacuum-regenerated adsorption technology for removing carbon dioxide and humidity from a habitable spacecraft environment, and is the baseline technology for the Orion Program’s Multi-Purpose Crew Vehicle (MPCV)
  - Uses a pair of interleaved-layer beds filled with SA9T, the amine sorbent
  - A linear multiball valve rotates 270° back and forth to control the flow of air and vacuum to adsorbing and desorbing beds: one bed adsorbs CO2 and H2O from cabin air while the other bed is exposed to vacuum for regeneration by venting the CO2 and H2O
  - The two beds are thermally linked, so no additional heating or cooling is required
  - The technology can be applied to habitable environments where recycling CO2 and H2O is not required such as short duration missions
What is the Amine Swingbed Payload?

- The Amine Swingbed Payload consists of the swingbed itself, a desiccant wheel (to reduce water losses), an air-save tank and compressor (to reduce air losses), a blower, an air/liquid heat exchanger, a heater, various sensors, and a controller/power handler.

- Located in ExPRESS Rack 8 in the US Lab.

- Controlled from the ground at JSC’s Payload Operations Control Center (POCC).
Technology Maturation for Orion

- Ground tests of the Amine Swingbed technology provide for:
  - detailed performance data
  - reduces technology risk
  - integrated technology evaluations (multiple components together in one test)
Technology Maturation for Orion

Tests conducted at JSC are more complicated and more integrated with other ARS systems than previous tests.

- **2006/07/08**
  - unmanned tests
- **2008**: human test subjects
- **2009**: reduced pressure, elevated oxygen
- **2011**: suited test subjects

2006/07/08 unmanned tests

2008: human test subjects

2009: reduced pressure, elevated oxygen

2011: suited test subjects
Orion Technology Demonstration on ISS

Orion – Short Duration Missions

• Conserving resources like H2O is not critical
• Must maintain low levels of CO2 and humidity

ISS – Long Duration Missions

• Limits the amount of H2O and air vented overboard
• Resources are recycled

Amine Swingbed – Short & Long Duration Mission Technology

• Newly developed subsystems enable integration on ISS
  • Water Save subsystem and the Air Save subsystem
  • Using the ISS environment to test these subsystems integrated with the Amine Swingbed helps reduce risk for these technologies for potential future exploration missions and adds benefit to the ISS
On-Orbit Payload Integration

- Due to logistical constraints (mass, volume), the Payload was delivered to ISS in two Phases
  - Phase A delivered Feb 2011
  - Phase B delivered July 2011
- On orbit was the first time that the Phase A equipment physically mated with the Phase B equipment
  - Crew feedback stated there was less than 1 mm of clearance. (Whew!)
- But no payload experience is complete without having to troubleshoot something . . .
Anomaly and Troubleshooting History

楽しい GMT 2011/342: ISS Fire Alarm went off

楽しい GMT 2012/013: Amine Swingbed valve stopped moving. Incorrect wiring = blown fuse

楽しい GMT 2012/041: Initial on-orbit electrical measurements indicated motor was wired incorrect

楽しい GMT 2012/102: Motor rewire attempted, but visual indication and crewmember confirmed wiring was correct

楽しい GMT 2012/159, 160: Installed new fuse on control board, replaced motor/gearbox assembly
Anomaly and Troubleshooting History

😊 GMT 2012/172: Final installation of payload into Express Rack 8 – successful

😊 GMT 2012/175: Attempted Test Point 1. Proximity sensor failed to provide confirmation of complete rotation of valve. Mechanical cause: Set screws used to secure drive key inside gearbox were insufficiently torqued

😊 GMT 2013/030: Torqued the set screws on the drive key, but valve failed to rotate properly, then stopped altogether. Possible cause: rotary valve failure, gearbox failure, motor failure

😊 GMT 2013/059, 060: Evaluated valve torque resistance and replaced suspect gearbox with original gearbox – successful

😊 GMT 2013/079: Payload installed into Express Rack 8
Realities of Integrating Complex System

- Microgravity issues – assembly procedures
- Clear instructions – “Just-in-time” videos
- Direct communication with the crew
  - More efficient, and when talking directly with crewmembers the actions are more coherent
- More inflight anomaly resolutions
  - Do whatever can be done on orbit before bringing it home
- Engage the crew early
On-Orbit Installation in the US Lab

Payload controller:
- power and control
- data collection

Vacuum interface

Air inlet

Air return

Swingbed inside locker chassis
On-Orbit Operations

- The Amine Swingbed Payload is controlled by the Amine Swingbed team from the Payload Operations Control Center (POCC) at the Johnson Space Center in Houston by the Amine Swingbed team.

- Amine Swingbed Payload can run autonomously.

- Conducted 1000 hours of tests between May 2013 – February 2014:
  - typically 8 – 16 hours at a time

- Varied the air flow rate and rotary valve cycle period of the system.
CO2 Scrubbing Performance

![Graph showing CO2 scrubbing performance](image-url)
Case Study:
How much can Amine Swingbed impact ISS CO2 levels?
Benefits of the Payload Experience

- Buys down risk for Orion
  - Important lessons related to motor/gearbox
  - If the rotary valve was the problem, could have major impacts to Orion
- Going through the Safety Review Process helps expand your own knowledge of your payload
- Team is better because of the payload experience
  - Technology development experts caught a glimpse of the Ops world
Amine Swingbed as an ISS Resource

- ISS Program will maintain the capability to operate the Amine Swingbed Payload through at least 2015
  - Provide backup CO2 removal for contingency ops
  - Provide supplementary CO2 removal
- Recently supported Node 3 CDRA maintenance activity (April, 2014)
  - The Node 3 Carbon Dioxide Removal Assembly (CDRA) was taken offline for maintenance in April 2014. ISS program requested the Amine Swingbed Payload to provide supplemental and contingency CO2 removal during this period
# Acknowledgements

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Questions