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11. SKYLAB TRASH AIRLOCK*

By Larry R. Price

McDonnell Douglas Astronautics Company

SUMMARY

The Skylab Trash Airlock (TAL) was used throughout the Skylab mission to transfer trash materials that could support microbial growth from the pressurized cabin to the unpressurized waste tank. The TAL, which uses several basic mechanisms, was successfully operated daily for the 170 days of manned missions for a total of 637 cycles.

TRASH MANAGEMENT APPROACH

Trash management for Skylab was a challenging problem. The expected trash volume from three crewmen for a total of 140 days (actual duration of manned mission was approximately 170 days) was predicted to be 36.8 m³ (1300 cubic feet). This volume was more than could be conveniently stored in the cabin. Also, much of this trash (wet wipes, food containers, urine, etc.) could support microbial growth that could be a health hazard. In addition, to avoid contamination of experiments and minimize general pollution of space, trash could not be ejected into the spacecraft environment.

The resulting approach was to collect trash in bags at specified locations in the cabin. Trash was categorized and collected separately as biologically active or not biologically active. At appropriate times, usually daily, the biologically inactive trash bags were transferred to storage areas within the pressurized volume, and the biologically active trash was transferred to an unpressurized aft portion of the Orbital Workshop identified as the waste tank. This tank was internally screened and vented so that only vapor would escape from the Spacecraft. The general configuration is shown in Figure 1.

This approach required a highly reliable device that would allow convenient and safe transfer of biologically active trash in closed but vented bags from the pressurized cabin at 34.5 kPa (5 psi) to the unpressurized waste tank at a pressure of less than 0.607 kPa (0.088 psi).

The device designed and developed to meet those requirements was the Trash Airlock Assembly, McDonnell Douglas Astronautics Company part number 1B81491-1. The airlock is mounted on the bulkhead between the cabin and the waste tank at the centerline of the spacecraft. Figure 2 shows the TAL installed in the Skylab in its launch configuration.

*This work done under the sponsorship of NASA's Marshall Space Flight Center and Johnson Space Center, Contract NAS9-6555. NASA's U.S. Patent No. 3,807,656 on the Skylab Trash Airlock is available for licensing under NASA Patent Licensing Regulations 14 CFR 1245.2 by writing Patent Counsel, George C. Marshall Space Flight Center, Alabama 35812.

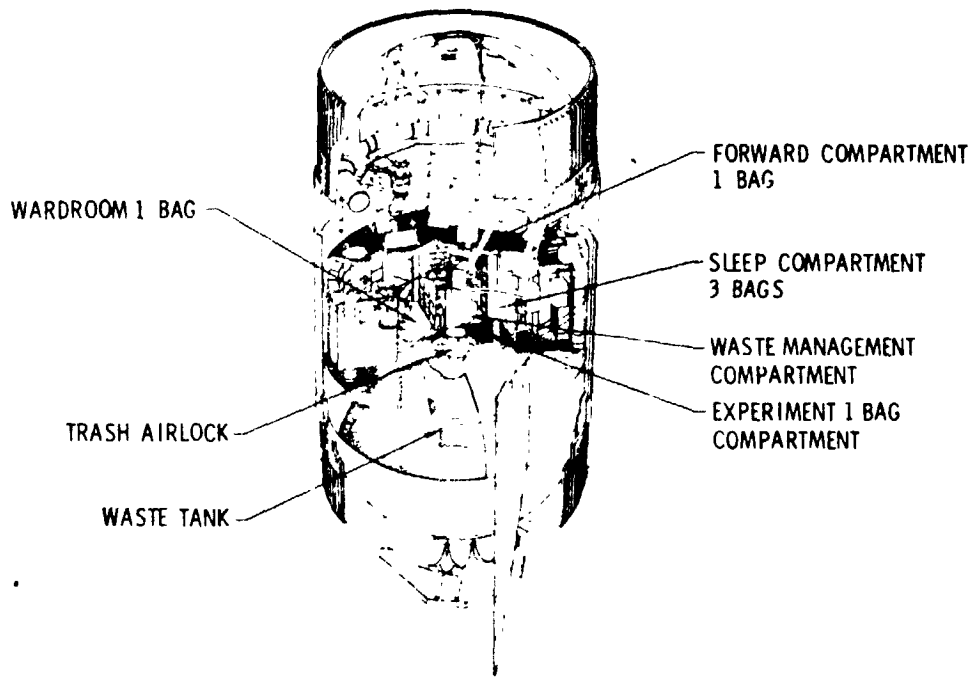


Figure 1. Trash Disposal Subsystem

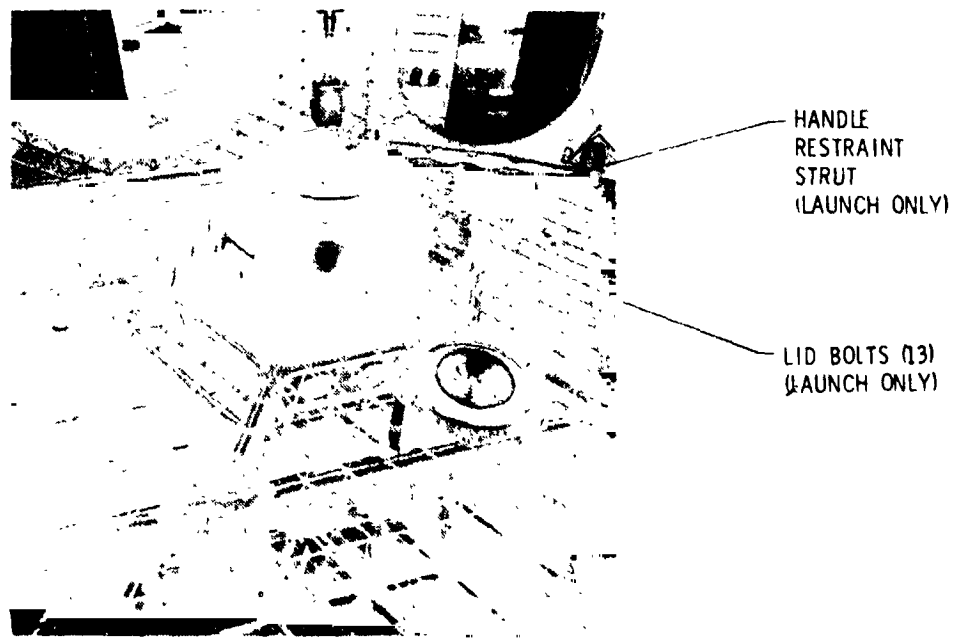


Figure 2. Launch Configuration Trash Airlock

GENERAL DESCRIPTION AND OPERATION

The trash disposal airlock assembly is a pass-through chamber built into the waste tank common bulkhead and extending through the floor into the cabin. Each side of the chamber is equipped with a hatch, forming an airlock (Figure 3). The airlock is equipped with a pressurization valve that ports the airlock to either the cabin or the waste tank, as required. On orbit, the trash disposal airlock is normally vented to the waste tank. The airlock body is spherical, approximately 610 mm (24 inches) in diameter, and has a pressure gage for viewing by the crew. It is equipped with a mechanical ejector to transfer the waste material to the waste tank. The functional steps of the operation cycle of trash disposal from the habitation area are as follows (see Figure 4):

1. Valve/outer door handle—pressure 34.5 kPa (5 psi) (verify).
2. Lid—unlock and open.
3. Insert trash bag.
4. Lid—close and lock.
5. Valve/outer door handle—close and vent [verify 3.45 kPa (0.5 psi)].
6. Valve/outer door handle—open.
7. Ejector handle—eject return to close.
8. Valve/outer door handle—close and vent.
9. Ejector handle—retract.

DESCRIPTION

The trash airlock is made up of the assemblies described below.

Lid Assembly (Figures 5 and 6)

The aluminum lid subassembly is the inboard door. It is a simple two-hinge door with a third friction hinge to maintain the lid in the open position. The lid contains a metal gasket with molded rubber seals on the top and bottom, which is removable and may be replaced with an on-orbit spare. The lid subassembly also houses the ejector mechanism.

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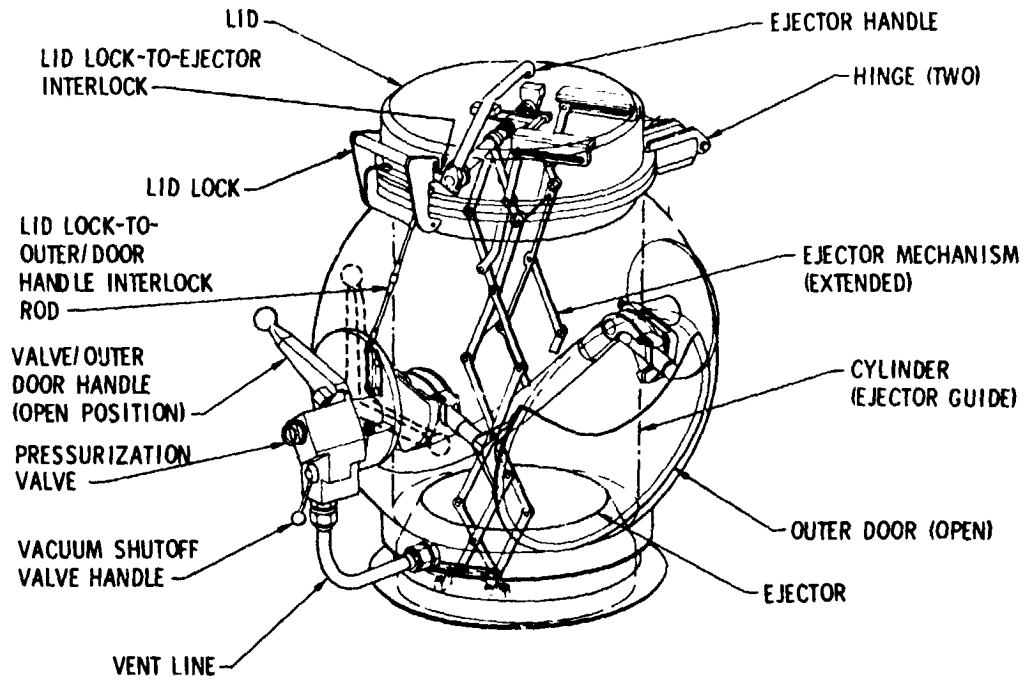


Figure 3. Trash Airlock

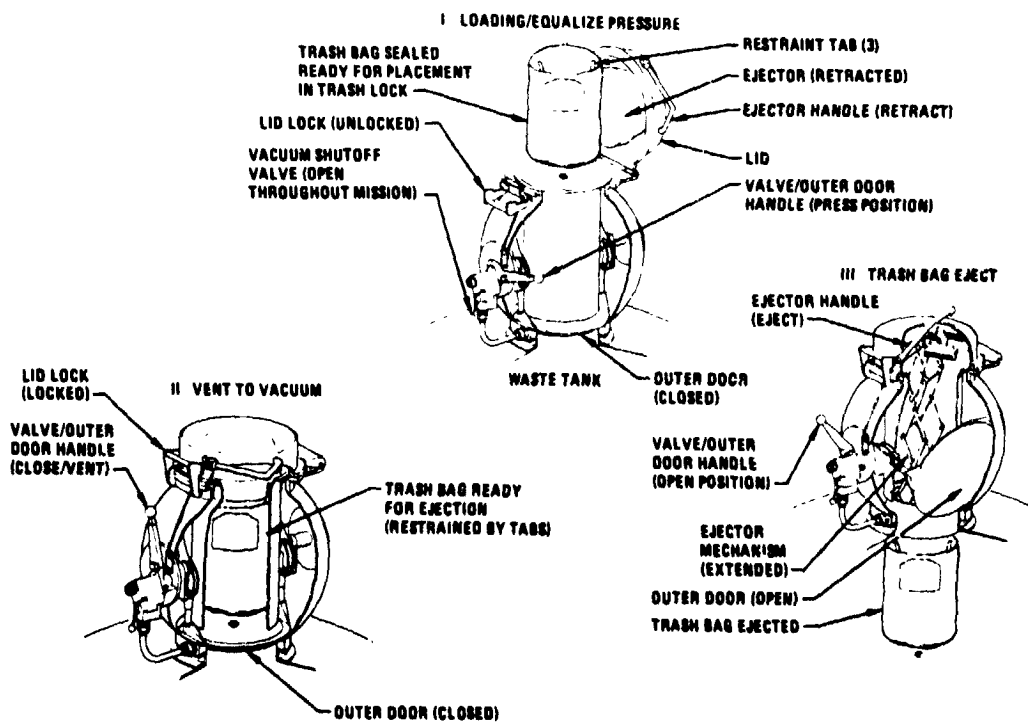


Figure 4. Operational Sequence

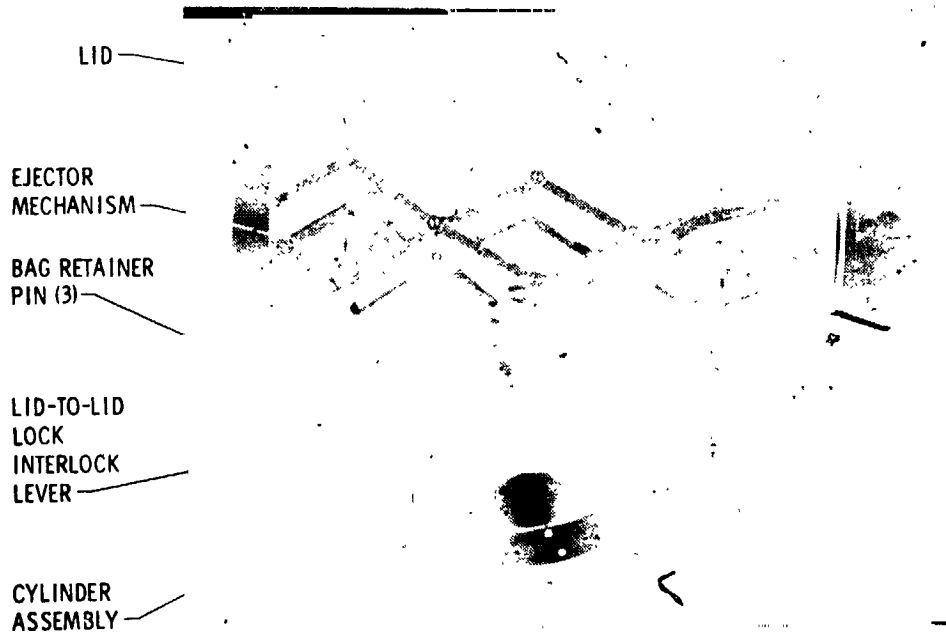


Figure 5. Lid and Ejector

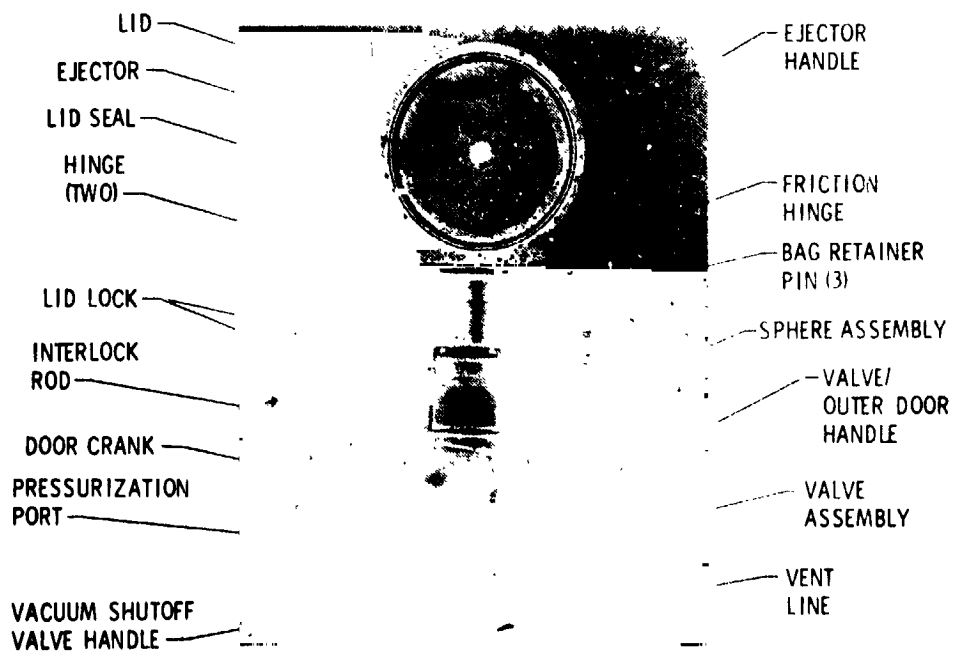


Figure 6. Trash Airlock Details

Trash Ejector Mechanism (Figure 5)

The trash ejector mechanism is a rigid scissors extension device operated by a crank arm with an overall mechanical advantage of 0.5. The mechanism is equipped with an ejection plate that pushes the trash bag into the waste tank when the ejection handle is raised. The ejector and scissors links are aluminum.

Sphere Assembly (Figure 6)

The aluminum sphere assembly is a weldment that serves as the pressure vessel and basic mounting structure for the mechanical system, which makes up the trash disposal operating system. The sphere itself is composed of six welded parts. The welds are made on an automatically programmed welding machine.

Cylinder Assembly (Figure 5)

The aluminum cylinder assembly is the compartment into which the trash bag is inserted before ejection into the waste tank. It is a smooth-walled cylinder 351.0 mm (13.81 inches) in diameter and approximately 559.0 mm (22 inches) long. Three steel pegs at the inboard circumference of the cylinder at 120 degrees hold the bag away from the outer door during opening.

Outer Door Assembly (Figure 7)

The aluminum outer door or "eyelid" forms the seal between the cabin environment and the waste tank vacuum when trash is being inserted into the airlock cylinder. Its seal is molded into the eyelid and cannot be replaced on-orbit. The eyelid is operated by the valve/outer door handle through a combination cam, crank, and over-center device that first retracts the eyelid 10.2 mm (0.4 inch) and then rotates the door on the inside of the airlock to clear the ejection port.

Valve/Outer Door Operator (Figures 8 and 9)

The door operator is a crank handle that operates both the valve and the outer door by direct attachment to the valve spool and by a cam and crank mechanism to the outer door operator. The parts are stainless steel.

Pressurization Valve Assembly (Figure 10)

The valve is a two-way, two-position valve using a rotating cylinder with O-rings to open and close ports. When the valve/outer door handle is in the PRESS position, the airlock is ported to the cabin. When the valve/outer door handle is in the VENT position, the airlock is ported to the waste

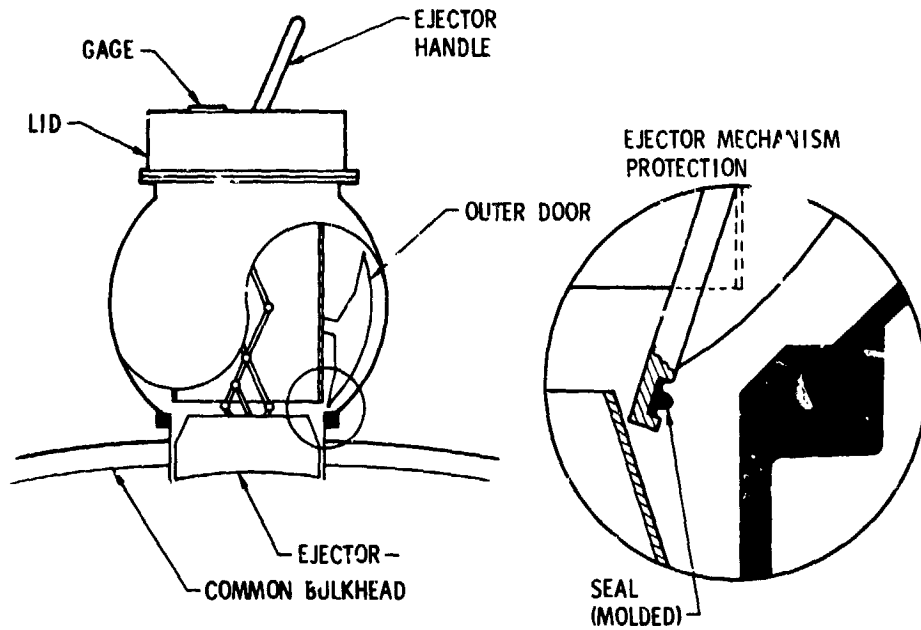


Figure 7. Outer Door and Ejector

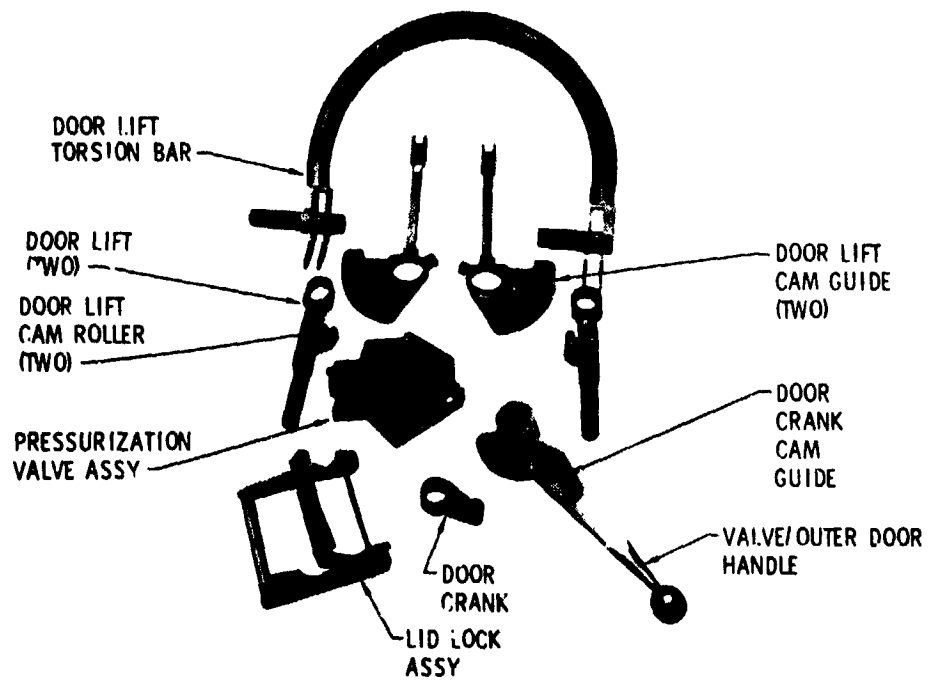


Figure 8. Trash Airtight Mechanisms

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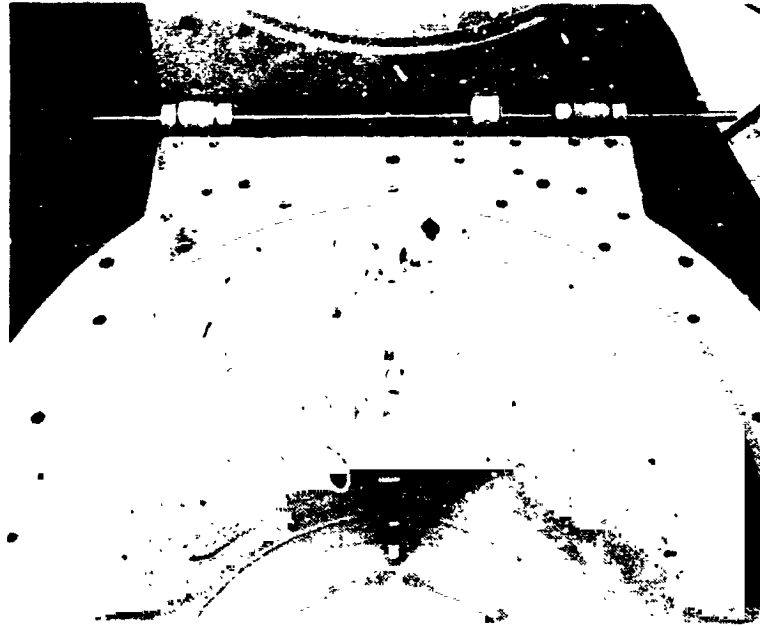


Figure 9. Door Lift Mechanism (Without Door)

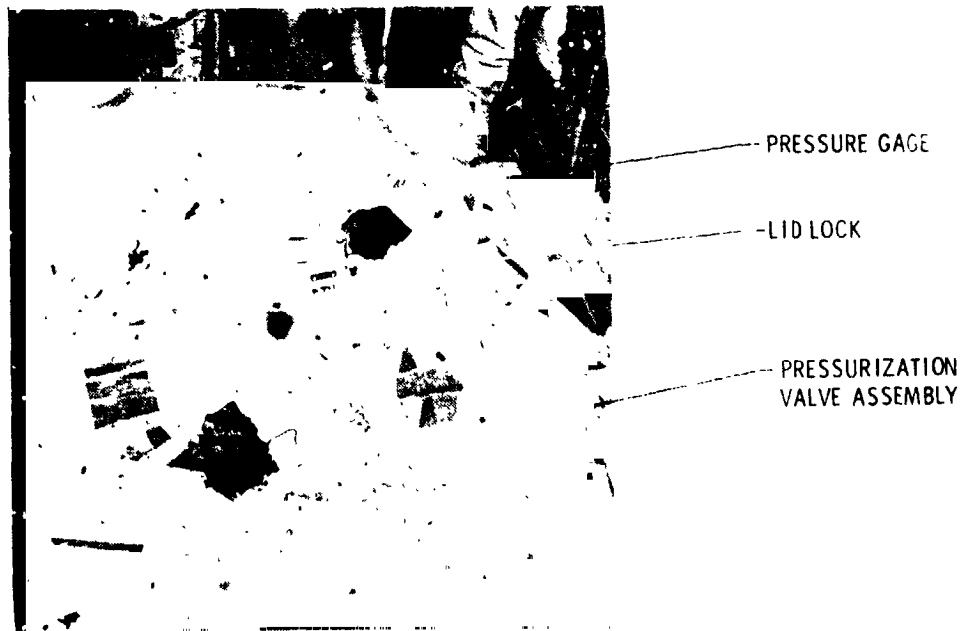


Figure 10. Operational Trash Airlock

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tank. When the valve/outer door handle is rotated to the OPEN position, the airlock is still ported to the waste tank, although partially closed relative to the VENT position. The valve metal parts are stainless steel.

Absolute Pressure Gage (Figure 10)

The absolute pressure gage contains a bourdon tube pressure sensor housed in a sealed stainless steel container evacuated to provide the reference vacuum. The bourdon tube drives the needle through an amplifying linkage mechanism. The gage reads from zero to 103.4 kPa (15 psi) but will take pressures up to 310.2 kPa (45 psi) without degradation. The gage indicates when the airlock has completed pressurization or depressurization. The gage may also be used for trouble shooting for leaks by indicating pressure decay or vacuum degradation.

Lid Lock (Figures 6, 8, and 10)

The stainless steel lid lock is an over-center cam device with a large mechanical advantage. It performs the following:

1. Unlatches the lid, making it possible to raise the lid for inserting trash.
2. Provides an over-center latch to compress the lid seal to ensure a pressure seal when the airlock is exposed to the waste tank vacuum. Cabin pressure aids in compressing the seal further when the airlock is depressurized.

DESIGN FEATURES

The trash airlock is designed to perform normally in the 34.5 kPa (5 psi) cabin environment. Its life is based on five operations a day for 140 days at cabin ambient temperatures. Its proof pressure is approximately 68.9 kPa (10 psi) differential and is capable of withstanding a launch malfunction differential pressure of 179.2 kPa (26 psi) in either direction without damage.

The TAL includes the following safety interlocks:

1. Lid Lock-to-Valve/Outer Door Handle (Figure 3) — The valve/outer door handle must be in the PRESS position before the lid lock can be unlocked. This prevents opening the lid with the valve in the VENT position or with the outer door open.
2. Lid-to-Lid Lock (Figure 5) — The lid must be closed before the lid lock can be retracted. This prevents closing the lid lock with the lid open, which would allow overriding the lid lock-to-valve/outer door interlock.

3. Ejector Handle-to-Lid Lock (Figure 3) – The ejector must be retracted before the lid lock can be unlocked. This prevents unlocking and opening the lid with the ejector extended.

The following summarizes other significant features.

1. Total Gas Volume: 0.1218 m³ (4.3 ft³).
2. Transfer Tube Size: 350 mm (13.8 inches).
3. Trash Capacity: 350 mm dia. by 457 mm (13.8 inches dia. by 18 inches).
4. Overall Size: See Figure 11.
5. Weight: 71.7 Kgm (158 lb).
6. Microbial Control: May be evacuated between operations.

FLIGHT EXPERIENCE

The trash airlock was used successfully throughout the three missions. Although there were no malfunctions of the airlock, there were several operational difficulties that were successfully resolved. Figure 12 shows astronaut Gerald Carr operating the TAL in space.

There were two incidents of near jamming, which were attributed to overfilled trash bags. Further problems were avoided by better control of trash combinations during disposal.

It was noted during the first manned mission that the valve handle could be inadvertently kicked into or left in an intermediate position between the pressurize and vent positions, which caused a cabin atmosphere leakage of as much as 1.5 Kgm/hr (3.3 lb/hr). This problem was overcome by strapping the handle in the PRESS position between operations.

During the second manned mission, an operating characteristic of the airlock was highlighted. The manual force required to squeeze the lid during the initial portion of the latching operation is high. This high force characteristic is more significant in weightlessness because body restraint is difficult. It was found that the high force of latching could be overcome by proper technique or use of two crewmen.

Although the trash airlock was used to approximately 80% of the expected on-orbit operation with no malfunction, there are two improvements recommended for future use. First, a detent device should be added to the valve handle to positively maintain the valve handle in the PRESS or VENT positions between operations. Second, the squeeze force during latching should be reduced. This could be done by refining the hinge gap adjustment by shimming or changing to a softer rubber for the lid seal.

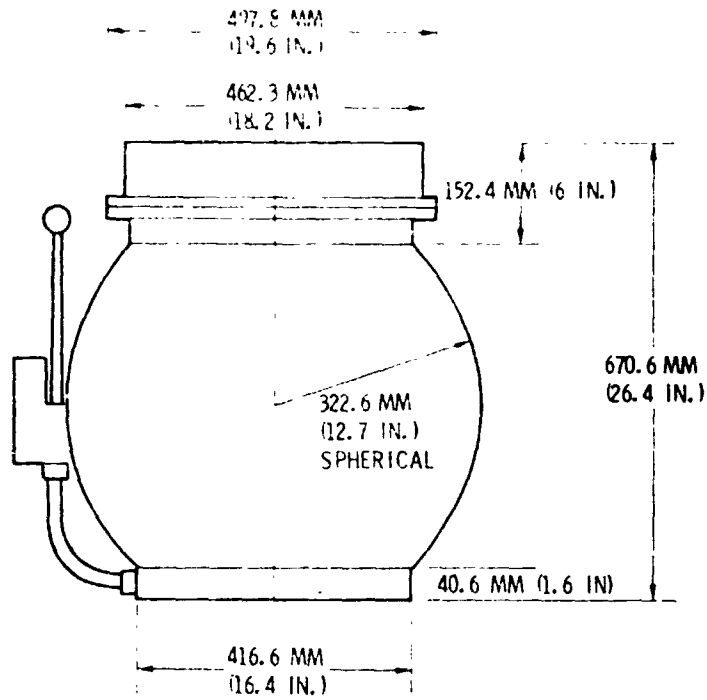


Figure 11. Overall Dimensions



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Figure 12. Astronaut Gerald Carr Operates Trash Airlock in Space