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ABSTRACT

An improved human waste collection system was developed in 1985 using a piston and cylinder which collects, compacts, and stores in replaceable volumes human waste including cleaning material. Disposable pads on the piston face seal and clean the cylinder and occlusive air valves. Airflow provides waste entrainment and temporary retention. A series of prototypes including an automatic one-button operation unit was built and ground tested. A manually operated prototype with a number of test features including variable airflow was flown and evaluated on Shuttle flight STS-35. Performance was nominal. An airflow of 45 CFM (1.27 m^3 min^{-1}) was found to be adequate. Mean stowage volume of waste and hygienic material per use was 18.7 in^3 (306 cm^3). It now appears that such a unit can provide adequate collection of human waste and all associated hygienic material with minimum overhead of machine size, complexity, and power, and minimum logistical support including maintenance, cleaning, operating materials, and storage space for Shuttle or Space Station.

INTRODUCTION

COLLECTION OF HUMAN WASTES, especially solid wastes, remains a significant problem in spaceflight Methods used to date in the US program include plastic bags with adhesive attachment on Mercury, Gemini, and Apollo(1,2,3)*. a seat with airflow through a replaceable bag on Skylab(4), and currently a much modified system(5,6) consisting of a seat with airflow through a common collecting pot for only fecal material and which requires crew handling of hygienic waste separately. An improved waste collection system (IWCS) using seat, airflow, and compacted storage of feces and hygienic waste was developed and tested at the NASA Johnson Space Center (JSC) in 1985(7,8,9) and scheduled for flight test in 1986. A manual prototype was recently flown and its in-flight performance will be described.

DESIGN RATIONALE AND FEATURES

Mechanical compaction of all waste material produces a minimum volume for collection and storage; however, contact of fecal material with any unprotected mechanism results in rapid contamination and fouling. By placing a disposable paper and plastic pad over a fitted piston in a smooth cylinder, the mechanism is protected; the cylinder is cleaned by mechanical

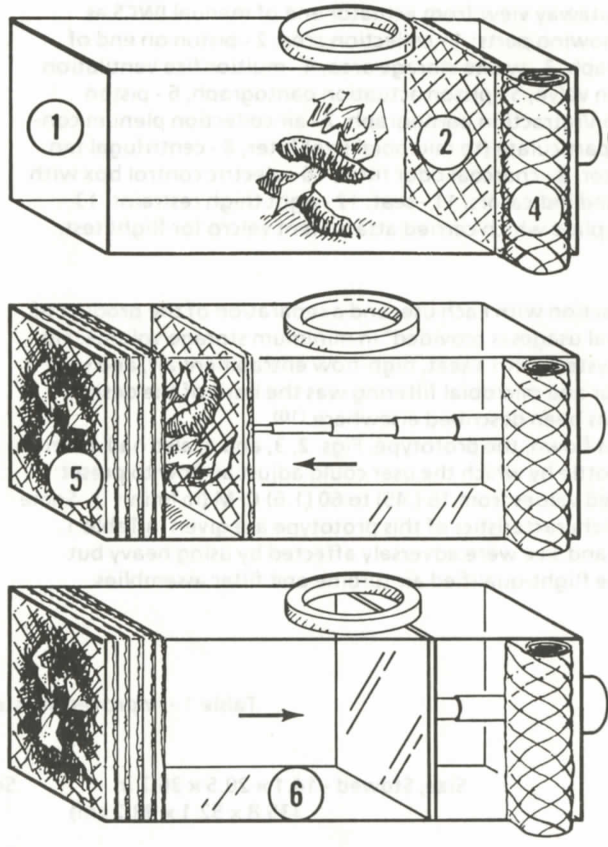

Fig. 1 Schematic of compaction system. Top; 1 - Collection stowage cylinder 2 - pad covering face of compaction piston 3 - piston actuator mechanism 4 - pad supply roll 5 - compacted waste and hygiene material 6 - cleaned collection volume. Top - Waste material is present in collection volume. Mid - Piston approaching stored material where constant pressure will be applied until next use cycle. Lower - piston being retracted prior to usage leaving the pad as part of the compacted mass. A fresh pad will be applied before each usage.

* Numbers in parentheses designate references at end of paper.

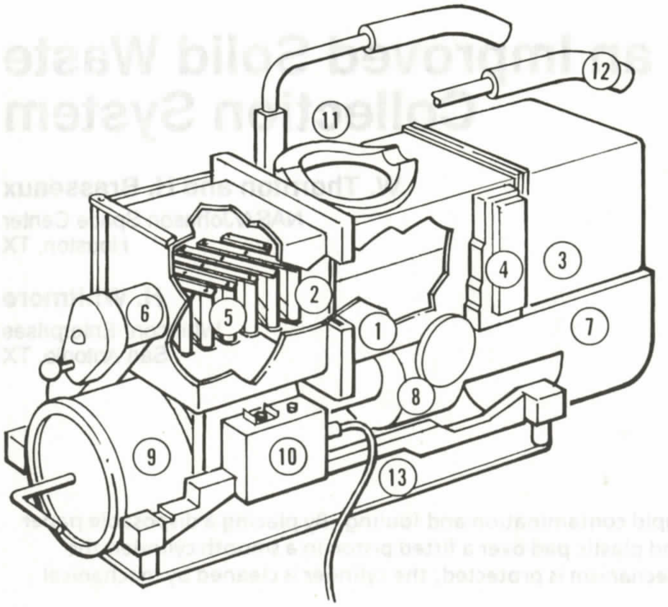

Fig. 2 Cutaway view from actuator end of manual IWCS as flown showing parts: 1 - collection area, 2 - piston on end of pantograph, 3 - waste storage area, 4 - multiorifice ventilation occlusion valve, 5 - piston actuation pantograph, 6 - piston extension/retraction pantograph, 7 - air collection plenum containing particulate (to microbial size) filter, 8 - centrifugal fan and motor, 9 - charcoal odor filter, 10 - electric control box with switch and indicators, 11 - seat, 12 - right thigh restraint, 13 - support plate which carried attachment velcro for flight test.

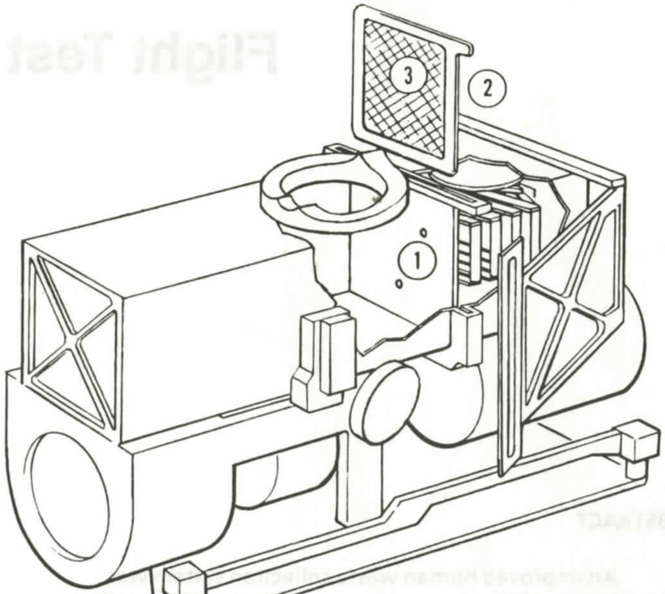

Fig. 3 Cutaway drawing viewed from storage end showing 1 - bare piston face, 2 - replaceable pad to cover piston carried by, 3 - a rigid frame which is slipped into a sealed holder in front of the piston.

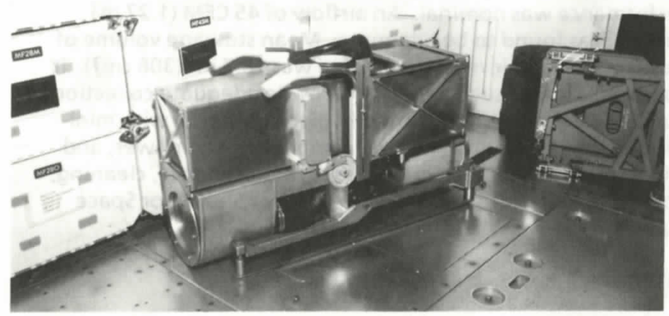

Fig. 4 Photo of IWCS on middeck viewed from actuator side. (Not in use location)

wiping action with each use, and a separation of the product of individual usages is provided* in minimum storage volume, Fig. 1. This system with a seat, high-flow entrapment air, and suitable odor and microbial filtering was the basis of the design which has been described elsewhere.[10]

As flown, the prototype, Figs. 2, 3, and 4, also had a variable throttle by which the user could adjust airflow to preset calibrated values from 16 (.45) to 60 (1.6) CFM (m^3min^{-1}). Some physical characteristics of this prototype are given in Table 1. Weight and size were adversely affected by using heavy but available flight-qualified air turbine and filter assemblies.

Table 1 - Improved Waste Collection System Characteristics

Size, Stowed - 14.1 × 20.5 × 36.7 in. (35.8 × 52.1 × 93.2 cm)	Seat Orifice 5 × 5.5 in. oval, (12.7 × 14 cm)
Weight - 110.4 lb (50.1 kg)	Compaction pressure - 55 ± 5 lbf (244.8 ± 22.3 N) total or .86 PSI ($55 \times 10^3 Nm^2$)
Power, Fan - 115 V 3-phase, 400 Hz, 357 Watts	Cylinder Size-square 8 × 8 in. (20.3 × 20.3 cm)
Waste Storage Vol. 640 in^3 (.01 m^3)	Max Air Flow - 60 ± 2 SCFM (1.7 ± .06 $m^3 min^{-1}$)

* This is significant for various investigations.

OPERATIONS

The unit was launched on Shuttle Flight STS-35 in an airlock, deck-mounted storage bag with accessories including a tray containing 40 piston pads, one for each usage. In use, the crew attached the IWCS to the floor middeck by velcro in the area between the existing waste collection system (WCS) and the galley. Urine collection was done with the hose assemblies from the existing WCS. An extension cord was connected to a middeck utility outlet for A.C. power. The IWCS was returned to airlock stowage for the return flight phase.

IWCS Operation consists of replacement of the empty pad frame with a filled unit, Fig. 3, air turbine activation, and retraction of the piston by turning the crank. This also automatically opens the seat slide and air collection chamber occlusion valves.

During usage, the subject employs one or two spring-loaded thigh bars for restraint to the seat. There is no restriction on volume of feces and hygienic waste material which may be deposited per usage. Cycle completion and compaction consists of reversing the handle rotation until actuation of an override mechanism occurs, and switching off the turbine. Between uses, collected waste material is compacted between alternating pads by a compressed spring's pressure on the piston, in this case, ~.8 PSI (55 × 10³ Nm²). This unit was designed to have evolved gas or vapors scavenged by a vent to space vacuum at an equivalent maximum flow of 1 5 lbs of air per day.

RESULTS

No difficulties were encountered in set up or stowage. Velcro attachment to the floor was marginal in strength. Operations precluded unstowing prior to mission day (MD) 7 when it was set up and then used by 7 crewmen for a total of 16 times through MD 9. In spite of the manual tasks, the crew found its operation acceptable. A clean receptacle, ability to discard waste hygiene material directly, and otherwise "feel at home" were considered major and desirable improvements. Seat and thigh restraints worked normally, and the large seat orifice produced favorable comment. The vent line was not connected* and all odors were denied. Various airflow rate settings were examined with the seat open and also in normal use. With the seat open, airflow of 16 SCFM (.453 m^3min^{-1}) was inadequate to entrain wipes and 30 SCFM (.85 m^3min^{-1}) entrained tissues while 45 CFM (1.27 m^3min^{-1}) was estimated to be "minimum" to "adequate" for entrainment/retention of feces. Flows up to 60 CFM (1.7 m^3min^{-1}) were not considered necessary. The nuisance of subject/bolus detachment remained.

UNLOADING AND INSPECTION - Following the flight, no leakage or other external problems were noted. Collected volume produced a linear piston displacement of 4.75 in. (12.1 cm) in the 8 in. by 8 in. (20.3 cm by 20.3 cm) collector for 16 recorded uses which gives a mean linear dimension per use of .29 in. (.74 cm) or mean volume of 18.7 in^3 (306 cm^3) versus mean dimensions of .25 in. (.64 cm) and 16.0 in^3 (262 cm^3) in use on Earth. Contents were ejected into a fitted plastic box for inspection by removing four screws and an end plate and actuating the piston requiring a total time of <5 min. It was obvious that voids, estimated to be 30% of volume, were present in the mass and that contents had collected in the inferior portion of the storage volume, Fig. 5. A quantitative examination of contents was not done but large volumes of wipes were present.

A thin, barely visible smear of feces was present on the inferior and lateral portions of the collection area.

* To conserve consumable air.

Fig. 5 Postflight removal of stored contents. A large volume of hygienic wipes are present and content distribution was toward bottom of volume. Contents have expanded with release of compaction pressure.

There was no contamination of piston or other mechanisms including the occlusion valves. The filter showed a very slight collection of lint only. Refurbishment for flight readiness consisted of cleaning which required less than 30 min.

SUMMARY

The unit met the design objective of providing a clean fecal collection volume with no more user involvement than in Earth toilets, except for manual cranking peculiar to this test which was well tolerated. An automated prototype with single actuation, push-button operation has been demonstrated.

The adjustable airflow provided unique data for collection flow requirements for this seat design, which would require modification for females. A flow of 40-50 CFM (1.1 - 1.4 m^3 min^{-1}) of air was adequate. All aspects of the airstream including valves, filter, and odor removal worked as designed. An optimized design could include reduction in size, weight, and power at the fan and filters and incorporation of urine collection methods. There was thin fecal smearing of the stainless steel surfaces as anticipated and, for extended operation, periodic usage of spray detergent with a "blank" pad or before normal use has been demonstrated to remove the film. Equivalent procedures in water toilets on Earth are required.

It is surprising that odors were not present without vacuum scavenging for only minimal O-ring sealing of shafts, etc. was done. More complete sealing is possible, and a constrained path through the charcoal should absorb odors and gases and eliminate any other requirement for scavenging.

Higher compaction pressure and, possibly, a directed airstream should improve packing efficiency. Larger storage volume and replaceable plastic film collection/storage packages which do not require crew interaction have been designed.

An automated version of the design with a simple urine collection system could be designed to interface with the existing Orbiter waste management compartment toilet area with significant improvement in utility, hygiene, and turnaround servicing over current techniques. For Space Station, it offers minimum supply overhead and maximum waste storage efficiency.

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