Improvement of Odor Control for the UWMS Hard-Sided Fecal Canister and the Alternate Fecal Canister

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On longer range exploration missions, the mass and volume of critical hardware and consumables required to support crew will pose a big stowage challenge. This includes the hardware for the collection and storage of human metabolic solid waste. The amount of stowage needed for this hardware both before (empty) and after (full) use will be a significant burden on the overall spacecraft habitable volume, layout, and design. To help with this challenge, the National Aeronautics and Space Administration (NASA) Mars Campaign Office (MCO) Logistics Reduction (LR) Portfolio has developed a collapsible canister for the collection and containment of fecal deposits. The Alternate Fecal Canister (AFC) is a collapsible alternative to the exploration toilet Hard-sided Fecal Canister (HFC). The AFC in its empty state has a volumetric benefit to smaller vehicles on longer missions. The current designs for HFC and AFC were tested with human fecal material for odor containment at White Sands Test Facility (WSTF) where the tests on both were unsuccessful. The source of the lack of

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containment was isolated to a gasket used on both HFC and AFC. The gasket used was found to be open cell in design. This paper provides a summary of the materials selection and testing process to identify a replacement gasket material with the intention to replace the gaskets on both existing units as well as incorporate it into the designs going forward for future builds for exploration. Details will be provided on the design of the canisters interface with the odor bacteria lid which led to the selection of the thickness of the desired replacement. Finally, the paper will provide an update on the testing in advance of a return to WSTF for final testing and detail plans to complete testing and perform a demonstration on ISS with UWMS.

Acronyms and Nomenclature

AFC = Alternate Fecal Canister
EPDM = Ethylene Propylene Diene Monomer
FKM = Fluoroelastomer
HFC = Hard-sided Fecal Canister
ISS = International Space Station
LR = Logistics Reduction
MCO = Mars Campaign Office
NASA = National Aeronautics and Space Administration
PVDF = Polyvinylidene Fluoride
UWMS = Universal Waste Management System
WSTF = White Sands Test Facility

I. Introduction

A major challenge of space travel is designing to minimize mass and volume for an optimal spacecraft design. For human exploration, the complexity increases with the additional hardware needed to keep the crew alive and the processes and systems needed. This includes the collection and storage of metabolic waste which is intrinsic in the human part of exploration. For longer duration missions, the sheer number of fecal material storage containers obviously becomes a factor based on crew size, length of mission and frequency of defecation. Both the stowed empty configuration and the final filled containers must be optimized for mass and volume. The containers must be robust enough to survive applicable launch and landing loads and be designed for efficient use by the crewmember. Size is optmimized for stowage of the fecal materal itself as well as consumables such as various wet/dry wipes and gloves for cleanup.

A. UWMS, AFC, HFC

The UWMS was initially designed by Collins Aerospace [1] [2] using a Hard-sided Fecal Canister (HFC) (see Figure 1) which is essentially a machined aluminum can which interfaces with the toilet itself as well as the venting, odor controlling lid. Because the body of the component is a single, machined piece it is very effective for odor control but is heavy and takes up space with an empty volume inside of the unfilled configuration. Although they partially nest, there is still a large stowage space allotment needed. The sizing of the canister requires replacement as often as every other day and for a Mars mission, a large quantity would be needed.

Figure 1. Orion's UWMS with HFC and Lifting Mechanism.

As part of the on-going work to optimize metabolic waste collection and storage, NASA developed an Alternate Fecal Canister (AFC) which utilizes a flexible material for the main body of the bag which when empty and compressed reduces the volume by 90% and provides a mass reduction of 45%. Reductions of mass and volume can be seen in Table 1 and Figure 2. [3]

Table 1. Fecal Canister – Volume and Mass Comparisons

Volume Comparison (cm^3)		
	Empty and Compressed	Full
AFC	1250	8193
HFC	13517	13517
Mass Comparison (kg)		
	W/ Lid*	W/o Lid
AFC	1.131	0.451
HFC	1.5	0.82
*Lid Mass 0.68kg		

Figure 2. AFC in full configuration, empty (stowed) configuration and Hard-sided Canister.

During WSTF odor testing of the AFC, an issue was found with the odor containment feature of the assembly which caused the assembly to fail odor testing. This was localized to the Bisco® gasket between the the AFC and the odor-controlling lid which is common to both the AFC and the HFC. Further review showed that the gasket material was an open cell foam which is ineffective for gas/liquid containment. This paper details the testing done with the original configurations, attempted fixes using tape external to the interface point, and finally selection of a replacement gasket material. See Figure 3 for details of gasket location on HFC.

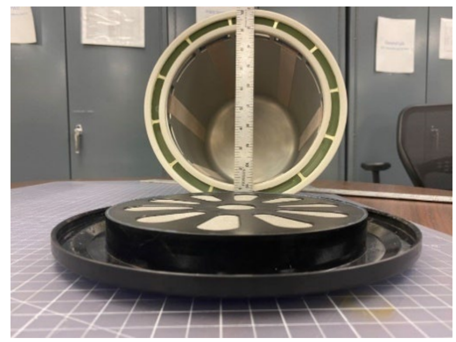


Figure 3. HFC with lid showing gasket locations.

The Orion program is flying the UWMS on Artemis missions. Artemis-II is using the HFC in the original configuration with the Bisco® gasket. Future missions plan to use to the AFC with the updated gasket material.

II. Interface Between Canister and Lid

The AFC Lid has a hook design feature integrated around its perimeter that snaps onto an extruded lip that is located around the outer edge of the canister as seen in a model view in Figure 4. An adhsesive backed circular shaped gasket is adhered to the top surface of the canister. The gasket has a nominal thickness of .188 in., and is used to fill a .110 in. nominal gap between the lid and canister. The gasket is compressed by roughly 41.5% of its nominal thickness once the lid is installed. For most foam gaskets, like the ones detailed in section V, the ideal compression range is between 25% and 50% of the original thickness.

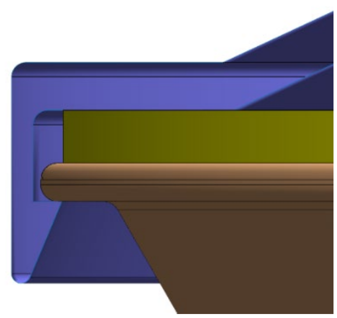
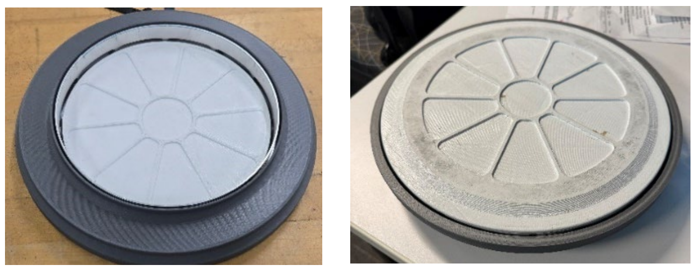


Figure 4. Model view cutaway of canister/lid interface

An outer ring (concept) was designed and 3D printed (Figures 5 and 6). The outer ring design intent was to provide an additional layer of odor control that would work in parallel with the lid gasket. The outer ring interior surfaces were lined with activated charcoal foam & fabric material to absorb and filter any additional odor leakage that bypassed the lid seal. The ring was attached to the bottom side of AFC Canister Ring with double-sided adhesive tape.
The outer ring concept was able to be incorporated without modification of the current design of the canister not of the canister ring. This outer ring design was ultimately not pursued beyond the prototype phase because it would add an objectionable amount of mass to the AFC assembly.

(a) (b)

Figure 5. AFC Outer Ring Concept, (a) Outer ring without charcoal fabric added, (b) Outer ring with charcoal fabric.

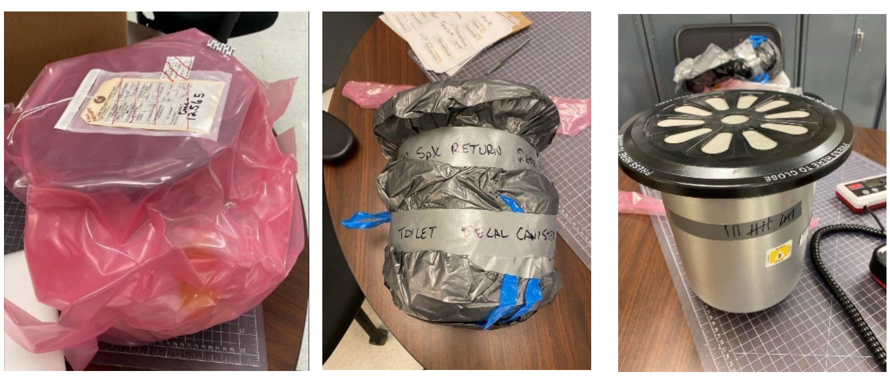


(a) (b)

Figure 6. AFC Outer Ring Concept with Charcoal, (a) Underside view, (b) Top view.

III. Returned Canister and Odor History

UWMS was demonstrated with limited use for 17 days on ISS. A single fecal canister was returned for evaluation. The HFC included the original BISCO® gasket. No odor complaints were noted by the ISS crewmembers but the HFC was wrapped in a trash bag and secured with grey tape. Upon arrival at the JSC lab, it was found to be enclosed in shipping materials of pink poly, bubble wrap, foam and a cardboard box as seen in Figure 7. An odor was noted upon arrival and before removal from the shipping materials. [4] Because of the noted odor with the returned HFC



(a) (b) (c)

Figure 7. Returned UWMS HFC (a) as received with shipping wrap, (b) as sent by crew and (c) unwrapped.

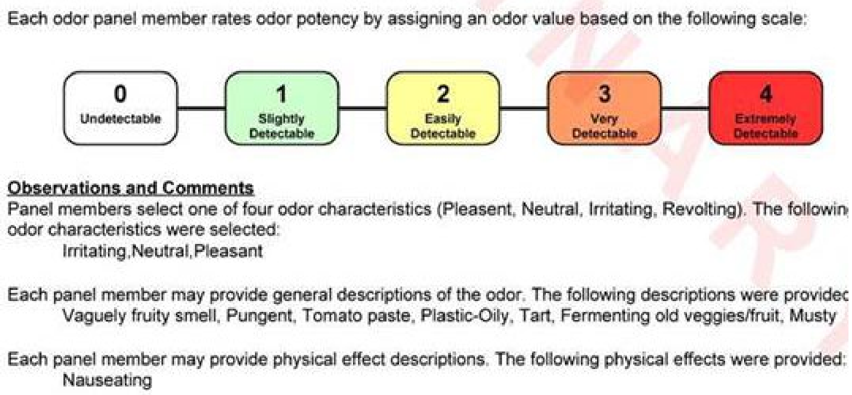
and the odor noted during testing of the AFC, an improvement to the gasket was sought.

IV. Data Collected History

A. First Round Odor Testing

Odor testing was done in phases. Testing of the AFC concept was done at JSC essentially following the protocol as defined in NASA-STD-6001B, Test 6 but was not an official verification for the design. The test team performed the evaluations but were not certified as is done at the WSTF facility. More details on the testing methods can be found in other papers. [5] Rating scale shown below in Table 2.

Table 2. Odor rating scale from NASA-STD-6001B.



Each odor panel member rates odor potency by assigning an odor value based on the following scale:

0 Undetectable — 1 Slightly Detectable — 2 Easily Detectable — 3 Very Detectable — 4 Extremely Detectable

Observations and Comments

Panel members select one of four odor characteristics (Pleasent, Neutral, Irritating, Revolting). The followin odor characteristics were selected:

Irritating,Neutral,Pleasant

Each panel member may provide general descriptions of the odor. The following descriptions were providec

Vaguely fruity smell, Pungent, Tomato paste, Plastic-Oily, Tart, Fermenting old veggies/fruit, Musty

Each panel member may provide physical effect descriptions. The following physical effects were provided:

Nauseating

1. JSC Testing of AFC

Testing at JSC in 2021 utilized a custom-made testing apparatus, Figure 8, to enclose the AFC with odor containing materials. Early testing used banana oil as a substitute for fecal material. This material degraded the gasket material very quickly and was not suited for this type of testing. Additional testing was done with human fecal material donated from the test subject pool for this purpose. Testing included opening a valve to expose the gas which was surrounding the AFC with lid. Testers "sniffed" this gas and rated the odor using the scale defined in Test 6 and used at WSTF.

Figure 8. Odor Testing Apparatus for AFC.

2. WSTF for Qualification Testing

After successful screening testing at JSC, in 2022 an AFC test article (Figure 9) was filled with fecal material and driven to WSTF for official testing. The requirement was originally less than 1.5 based on the 0 to 4 odor testing scale (Table 2). This was found to be overly restrictive and not representative of other odor testing and was changed to less than 2.5 for the most recent testing. The first sample resulted in a failed test at 30 days with an average rating of 2.7. The test article was examined and it was determined that the source of the odor leak was at the gasket between the lid and the AFC. This gasket and interface are identical to the HFC used in the UWMS.

Figure 9. AFC filled for initial odor testing at WSTF.

B. Tape Solution – Kapton and Metal Tape Installations

The returned ISS canister was used to test alternate methods of odor control at the JSC lab. Testing was done in the open lab with the canister enclosed between "sniffs" in a larger insulated cooler. Three types of tape were applied and the canister was "sniffed" at various intervals. Grey duct tape was applied but did not adhere well. Odor was easily detected over a 5 day period. Aluminum metal tape was tested for an eight day period. Odor was not detected. Kapton tape was applied and odor was not detected for over two months, however this assessment was not per the rigorous testing protocol used at WSTF for official odor testing. Figure 10 shows the configurations.

(a) (b) (c)

Figure 10, (a) HFC with grey tape, (b) HFC with aluminum tape, (c) HFC with Kapton tape

This led to testing at WSTF with a similar test article. In 2022, an AFC was tested with Kapton tape filled with the fecal deposits. This test failed at the one month sample with an average rating of 2.8 however this test article was found to be compromised and this test was not relevant. A later test in 2023 with Kapton taped AFC and HFC units also failed with ratings on AFC of 3.2 and HFC at 2.9 at the 7 day odor test as seen in Table 3. There is variability in the odor results based on the original consistency, age and deterioration of the fecal deposits. It was concluded that taping the interface was not a successful mitigation for odor control and work started on a replacement gasket material.

Table 3 Results of Taped AFC and HFC Odor Testing at WSTF.

7 Day Odor Test	3.2	AFC Combined Average	2.9	HFC Combined Average
14 Day Odor Test	2.2	AFC Combined Average	2.6	HFC Combined Average
35 Day Odor Test	1.7	AFC Combined Average	2.0	HFC Combined Average

0	1	2	3	4
Undetectable	Slightly Detectable	Easily Detectable	Very Detectable	Extremely Detectable

V. Gasket Material and Design Updates

A. Gasket Thickness Impact on Positive Seals

The design of the filter lid and AFC interface ring introduced several challenges to the gasket selection process. Because the lid fits onto the canister like plastic food storage containers, where the dimensions of the lid and canister allow the lid to snap into place atop the canister without a locking mechanism, it is difficult to estimate the compressive force that the lid exerts on the gasket. The engineering drawing from Collins states that a maximum compressive force of 57 lbf can be applied between the lid and the gasket before the lid will pop off of the canister. This means that the lid could be pushing down on the gasket with a force anywhere from 0 to 57 lbf, and this number would change depending on the thickness and compressibility of the gasket material. Because of this uncertainty, the team aimed to find the thickest, most dense material possible that would approach this 57 lbf without exceeding it and causing the lid to pop off the canister, configuration seen in Figure 11.

This greater force between the gasket and lid would eliminate any gaps between the gasket and the lid, or gasket and the canister, where air could slip through. This limited the material selection of gaskets, because the Collins lid drawing showed that the gap between the lip of the lid, where it attaches to the canister, and the top of the lid was 0.190" in depth. When factoring in the thickness of the lip of the canister that the lid interfaces, which is 0.080" thick, the remaining space that needed to be filled between the lid and canister was 0.110" thick. This meant that the gasket had to be thicker than 0.110" in order to fill the gap and create a compressive force between the gasket and the lid.

Because most vendors supply foam and rubber sheets in thicknesses of 0.125" (1/8"), 0.188" (3/16"), and 0.25" (1/4"), most of the tested gaskets were one of these three thicknesses. Any change in thickness to a value between these 3 standard values would need to be fulfilled by a custom order which would significantly increase fabrication costs. Two gaskets of a 0.375" thickness were ordered, but they were too thick to close the lid overtop of them. Several solid rubber gaskets were procured with the goal of creating a seal similar to a solid rubber O-ring. These materials, being solid, would be less permeable than a foam or sponge material. They were procured in thicknesses of 0.125", 0.188", and 0.25". Each of these gaskets was made of a different kind of rubber: Butyl, EPDM, Silicone, Neoprene, and Viton™ (FKM).

The 0.125" solid gaskets failed water testing (see section C. below for details on water testing), the team believes that their durometer was too high to form a seal that filled all of the small imperfections in the bottom of the lid, as well as the gasket being to thin to force the rubber into these small imperfections. The 0.188" and 0.25" thick rubbers were too thick to close the lid overtop of the canister. Their durometers were too high for them to be compressed into the 0.11" gap. For this reason, the team looked more into rubber foams and rubber sponge materials. These materials were much more compressible and had more room for error when selecting a thickness. After water testing with various rubber sponge and foam materials, there were passing materials of 0.125", 0.188", and 0.25" thicknesses. A final thickness of 0.188" was decided on for the foams for a few reasons:

- None of the foams tested at this thickness were too thick to lock the lid in place, like some of the 0.25" gaskets.
- This thickness was more successful during water tests than the 0.125" gaskets.

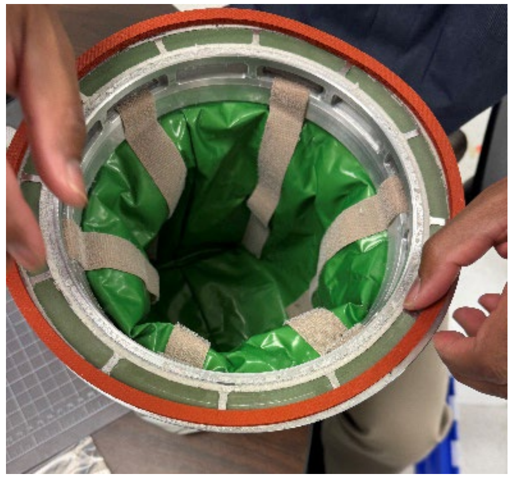


Figure 11. Gasket Images (a) Thinnest gasket candidate (1/8" thick HT-1240 solid silicone gasket) being applied to the AFC assembly.

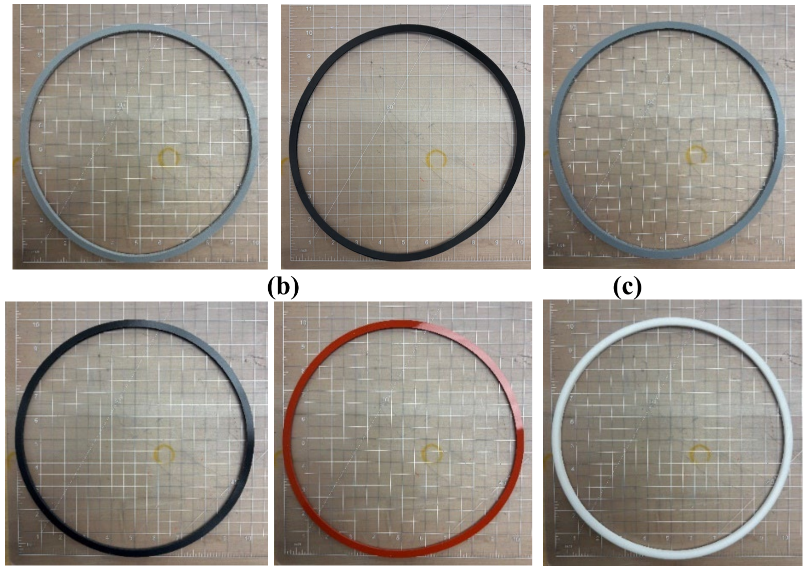
- 0.188" (3/16") is a common thickness that vendors offer their foam rubber sheets at, so prototypes could be easily and affordably ordered from vendors, or entire sheets of the foam could be bought off of sites like McMaster-Carr for engineering evaluations.

B. Candidate Gasket Materials

The first shipment of gaskets to be procured was an order from Rogers Corp of 5 BISCO® silicone materials. The following gasket materials and thicknesses were procured: R-SFO-206006 HT-800 hybrid closed/open-cell foam in 0.188", 0.25", and 0.375" thicknesses, R-SFO-206001 HT-870 in a 0.188", 0.25", and 0.375" thickness, R-SSD-125039 HT-1240 solid silicone rubber in a 0.125" thickness, RS-720 closed-cell sponge in 0.188" and 0.25" thicknesses, and RS-750 closed-cell sponge in 0.188" and 0.25" thicknesses. The gaskets were an assortment of open-cell foam, closed-cell sponge, and solid rubbers, all made of silicone. Silicone was selected for its flame-resistant properties, low outgassing properties, NASA flight heritage, affordability, ease of fabrication, and abundance of reputable vendors. Ultimately, every one of these gaskets failed to form a proper airtight seal between the filter lid and the canister. This is likely due to silicone being relatively porous compared to other rubbers, and the open-cell structure of several of the gaskets allowing air seep through the gasket. Candidate gasket materials are shown in Figure 12.

Because the silicone foams and sponges had failed odor testing, the next shipment that was ordered consisted of all solid rubbers to hopefully eliminate the possibility of air seeping through the gasket. The second shipment procured were gaskets made of solid EPDM, Viton™ (FKM), Neoprene, and Butyl respectively, and were procured from Buffalo Seal & Gasket. Each material was ordered in 0.188" and 0.25" thicknesses. These thicknesses were selected because the only solid rubber gasket in the first shipment, the HT-1240, failed the water test and was 0.125" thick. The team believed that the reason this gasket failed to form a water-tight seal was because the gasket was not thick enough to properly fill the gap between the lid and the canister and create adequate compression to form a seal. So thicker solid gaskets were ordered, and because most vendors don't supply a thickness between 0.125" and 0.188", 0.188" was the closest increase that could be obtained. This extra thickness proved to be too much of an increase, as none of these solid gaskets fit properly with the canister, as they were too thick and too dense for the lid to close overtop of them.

After the failure of the solid rubber gaskets, it was decided that any materials selected going forward would need to be compressible to allow for greater margins of error in the thickness of the gaskets. Gasket thicknesses of 0.188" and 0.25" would now be preferred, and closed-cell sponge materials were prioritized because they offered compressibility with less permeability than an open-cell foam. A few sheets of closed-cell Viton™ (FKM) sponge were ordered from McMaster-Carr in 0.125" and 0.188" thicknesses for water testing, and once they had passed, additional 0.125" and 0.188" Viton™ (FKM) sponge gaskets were procured to perform odor testing. A closed-cell silicone sponge material, R10480S, was provided by Stockwell Elastomerics in 0.188" and 0.25" thicknesses as free samples. Zotek F30 Kynar® (PVDF) closed-cell foam gaskets were ordered in 0.188" and 0.25" thicknesses. These were the most successful trials by far, with the 0.188" Viton™ (FKM) sponge lasting about a month with no odor during fecal odor testing and the 0.188” Kynar® (PVDF) gasket lasting about 3 months with no detectible odor during it’s first round of fecal odor testing in the Hab Lab. This Kynar® (PVDF) gasket was tested further in Building 33’s



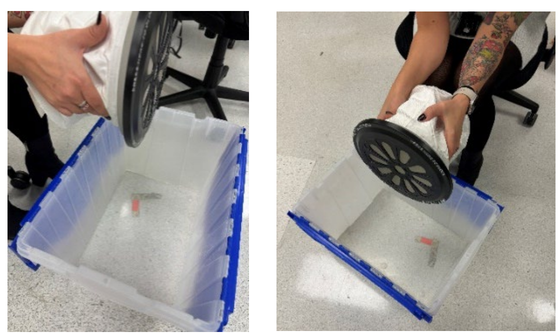
(a) (b) (c)

(d) (e) (f)

Figure 12. Examples of some gasket materials tested. (a) 0.188” thick, RS-750 closed cell silicone foam, (b) 0.188” thick, closed cell Viton™ (FKM) sponge, (c) 0.25” thick, HT-800 open celled silicone foam, (d) 0.188” thick, HT-870 open celled silicone foam, (e) 0.125” thick, HT-1240 solid silicone foam, (f) 0.188” thick, closed cell F30 PVDF sponge.

test chamber and passed odor testing for nearly a month.

C. Water Testing



(a) **(b)**

Figure 13. Water test being performed on an AFC gasket (a) Side View, (b) Top View.

The process of odor testing the various gaskets is one of the most significant bottlenecks in the schedule of this project, because for most of the first 8 months of tests were performed with only one test chamber. An odor test could last anywhere from 2 weeks (the quickest documented failure) to 3 months or more. To ensure that the best gasket candidates were being tested in the test chamber, all procured gaskets had their water sealing ability tested, see Figure 13. The gasket would be installed on an AFC or HFC, and the lid would be fixed over top after filling the canister with 2 cups of water. The canister would then be held horizontally and rotated slowly for 2 minutes to determine whether water would seep out of the gasket at any point along its perimeter. Care was taken to ensure that the canister was not tilted to the point that water would saturate the charcoal filter within the lid and leak through. The idea being that if a gasket did not form a watertight seal, there were significant gaps between the gasket and the lid where droplets could seep through, which would surely let foul smelling air through that same gap in the case of an odor test. Using this method, ill-fitting or porous gaskets were discovered and discarded before they had the chance to fail an odor test, leaving the test chamber open for better performing gaskets. If a gasket formed a watertight seal, it might also form an airtight seal with further testing, but if a gasket could not form a watertight seal it would surely not form an airtight seal.

D. Odor Testing in Small Test Chamber

Once a gasket passed it's water test, that gasket would be removed from the AFC and a spare of the same type would be added in its place. This was done to avoid using a potentially saturated gasket during odor testing, as the water may occupy space that odor would normally escape through under normal use conditions (assuming the gasket was a foam or sponge material). From there, the gasket would undergo its first odor containment test in a small test chamber shown in figure 14. For all of the odor tests at JSC, project team used the protocol and scale from NASA-STD-6001B but are not certified as are the WSTF team. The first odor tests performed in this chamber began in July

(a) **(b)** **(c)**

Figure 14. HFC gasket testing in small chamber (a) Top view, (b) AFC opened upon onion test conclusion (c) chamber opened under Hab Lab fume hood for fecal testing.

of 2024 using onions as the odor media, which was switched to fecal samples in November of 2024 to more closely represent the AFC use conditions. The goal of this initial round of odor testing in the small chamber was for the assembly to contain odor below an average smell rating of 1.5 for two months. Nearly all of the gaskets tested failed this requirement, with most gaskets lasting about two weeks before a strong odor could be detected. The only gasket to conclusively pass this requirement was the Kynar® (PVDF) gasket, which lasted about 2.5 months in the small test chamber with no detectable smell. One inconclusive result was the Viton™ (FKM) gasket, as it released an unpleasant odor from the chamber and was initially deemed a failure, but upon opening the chamber and inspecting the assembly it was found that the smell was seeping through the lid filter media and no smell could be detected around the gasket interface. It's unknown whether this lid filter had become saturated with odor after multiple odor tests, or if this was the only time it failed. The potential failure of the filter media was not noticed until the conclusion of the building 33 odor testing detailed below. It also raised concerns that previous gaskets may have been deemed failing because of the failure of the filter lid media. But in most cases of gasket failure the odor was detected around the gasket's interface with the canister. This initial testing in the small test chamber was concluded in December of 2025 when the Kynar® (PVDF) gasket and AFC/HFC assembly were taken to WSTF for final odor testing.

The results of each initial odor test are as follows:

- From July 16*th* 2024 to August 5*th* 2024, a ¼ inch thick, HT-870 (an open-cell silicone foam) gasket was tested on an HFC containing onions with a 3D printed lid. After 20 days, the test ended resulting in a failure with 3's and 4's recorded.
- From August 6*th* 2024 to October 9*th* 2024, this test was restared after swapping the 3D printed lid with a canister filter lid due to concerns that the canister had failed the odor test because the ill-fitting 3D printed lid had popped off of the canister. After 36 days, the test ended when the highest odor rating up to that point had been a 0.5. The gasket was initially deemed a success, but it was later determined that it should be retested with fecal samples for a more accurate representation of use conditions.
- From October 17*th* 2024 to November 4*th* 2024 a ¼ inch thick, RS-720 (a closed-cell silicone foam) gasket was tested on an HFC containing onions with a canister filter lid. After 18 days, the test ended resulting in a failure with 3's and 4's recorded.
- From November 4*th* 2024 to November 18*th* 2024 a ¼ inch thick, HT-870 (open-cell silicone foam) gasket was tested on an HFC containing fecal material with a canister filter lid. After 14 days, the test ended resulting in a failure with 4's recorded. Prior to the next test, the lid was replaced but the HFC and inner and outer

gaskets were used again. From November 19*th* 2024 to December 4*th* 2024 a ¼ inch HT-870 (hybrid foam gasket) was tested on an HFC containing fecal material with a canister filter lid. After 16 days, the test ended resulting in a failure with 4's recorded.

- From December 4*th* 2024 to December 17*th* 2024 a ¼ inch RS-750 (closed-cell silicone foam) gasket was tested on an HFC containing fecal material with a canister filter lid. After 13 days, the test ended resulting in a failure with 3's and 4's recorded.
- From March 31*st* 2025 to May 13*th* 2025 an external charcoal fixture was added to the test article including a ¼ inch RS-750 gasket tested on an HFC containing fecal material with a canister filter lid. After 43 days, the test ended resulting in success with no smell detected and a 0 recorded by all sample testers.
- From May 13*th* 2025 to July 22*nd* 2025 a 3/16*th* inch Kynar® (PVDF) gasket was tested on an HFC containing fecal material with a canister filter lid. After 70 days, the test ended resulting in a success with no smell detected and a 0 recorded by all sample testers.

E. Odor Testing in 50 gallon drum

Because the AFC team started gasket odor testing with only one test chamber, this caused considerable bottlenecks in the testing process, as even the worst performing gaskets took about 2 weeks to fail the odor test. More successful gaskets could go a month or more before failing, meaning that testing a shipment of 4 gasket types could take anywhere from 2 to 6 months. In March of 2025, the team decided that another test chamber was needed to expedite the testing process. The original test chamber's volume was only about 1 cubic foot in volume, making it substantially smaller than the test chamber used at WSTF for odor testing. To more accurately represent the size of the WSTF chamber, the new test chamber was made using a 50-gallon steel drum (~6.7 cubic feet), see Figure 15. The drum had a removable lid that could be fastened to the drum with a bolted drum ring and a rubber gasket to form an airtight seal. Pipe fittings with a pressure gauge and ball valve were fixed to the top of the lid to allow the AFC team to extract odor samples for testing. Because the pressure gauge on the 1 cubic foot chamber never read above 1 psi during testing, a pressure relief valve was deemed unnecessary for the much larger volume, as the pressure would not rise significantly. When performing odor evaluations, the chamber would occasionally let out a small puff of air when opened, indicating that the filter lid of the canister was allowing pressure buildup to escape from the AFC as intended. At the time of writing, only one odor evaluation had been performed using this new chamber. A gasket made from 3/16" thick closed cell Viton™ (FKM) foam was tested for 5 months in 2025, from April 21^{st} to September 16^{th}. The team first reported a slight smell, similar to slightly spoiled milk or a slight rotten fruity smell, about two weeks after the start of the test. The smell was not deemed noticeable enough to be considered a failure, and testing continued. The smell remained relatively constant until around July/August, when the smell was observed to be noticeably stronger. The test was considered a failure, but the test was allowed to continue since the Kynar® (PVDF) gasket tested in the other chamber had been successful in its testing and the team would move forward with that design. The Viton™ (FKM) gasket was left in the test chamber to collect more data and observe any long-term changes in smell. When the test was ended and the chamber was opened to remove the canister, the team sniffed around the canister to see if the source of the leak could be identified. It was noted that no smell could be detected around the rim of the lid, which would be expected if the gasket failed. Instead, the team only noticed that a fecal odor could be detected when sniffing the very center of the filter lid, indicating that the lid had failed to sufficiently screen the odor coming through the charcoal filter. This raised questions about the efficacy of the lid and whether it's use life was shorter than 30 days, as the ongoing Kynar® (PVDF) gasket test in building 7 started to release odor after about 28 days, causing the team

(a) (b) (c)

Figure 15. Odor Testing in Barrel (a) 50 gallon barrel used as test chamber, (b) ball valve setup used for sample extraction, (c) rusting on inside of barrel after odor test (Light uncorroded spots on the bottom are where the test stand legs met the barrel floor)

to investigate the Viton™ (FKM) test chamber as well. The team also observed that a layer of rust had formed along nearly the entire interior surface of the barrel, with only the metal beneath the feet of the aluminum test stand being free of rust. This indicated that the filter lid was allowing not only outgassing products to escape the canister, but water vapor from the fecal samples as well. The amount of water vapor released is unknown, but it was enough to rust the entire interior surface of the 50-gallon steel drum. This was the third time the AFC team had observed signs of water vapor being released from the canister, as two previous odor tests had developed wispy, thin strands of mold on the exterior of the filter lid during testing.

F. Odor Testing in JSC Building 33

To increase the likelihood of successful testing at WSTF, a screening test was done at JSC in a similar chamber as that used at WSTF. Testing was done with the F30 Kynar® (PVDF) gasket in JSC Building 33 Chamber N. After 30 days the project team's evaluation of odor detectability was essentially "0." A test setup very similar (but not officially meeting the NASA standard as defined in NASA-STD-6001B.) was used. The test was continued past 30 days when a slight odor increase was noted around the 30 day mark. The odor ratings continued to increase until the test was halted after 60 days, when the odor rating ranged between a 1 and a 2. Results are shown in Figure 16 below and the test setup in Figure 17. When removing the assembly from the test chamber, the project team noted an odor similar to spoiled milk could be detected when sniffing near the mesh openings in the filter lid. The odor was noticeably only detectable when sniffing the center of the filter lid, not when sniffing around the gasket interface. This raised concerns that the odor detected in previous testing may have been the result of the filter lid media failing and not the gasket. To confirm this suspicion, the project team removed an AFC from an ongoing fecal odor test in the barrel test chamber in Building 29. This AFC also had a noticeable spoiled milk odor coming only from the center of the filter lid. These two examples point to a few possibilities. The filter lids may become saturated with odor constituents. The filter may not block all constituent odor producing gases and particles from exiting the canister, and is only able to capture a select few constituent gases resulting in a foul odor but not necessarily a fecal odor. The lid filter media will likely need to be revisited to improve fecal odor containment methods in future missions.

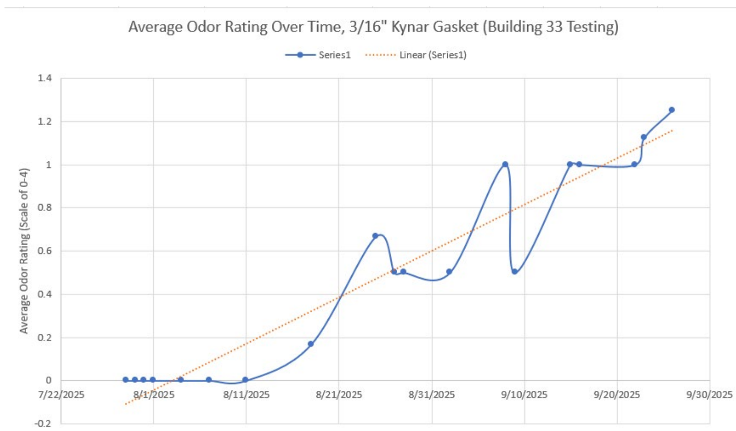


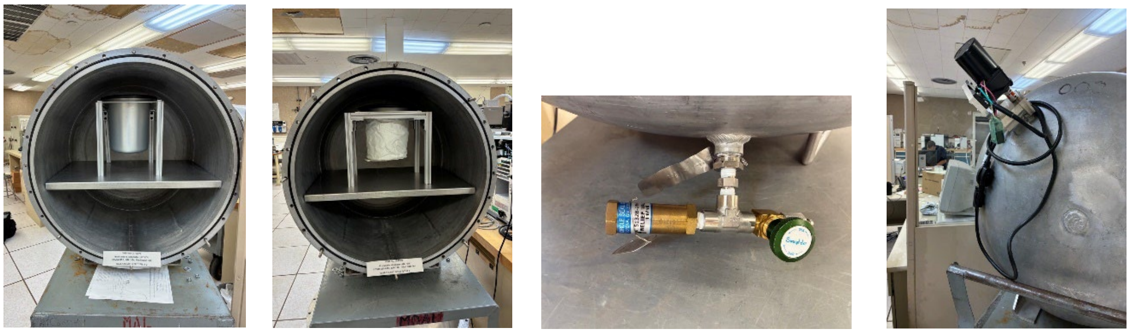
Figure 16. Building 33 Testing – Average Odor Rating Over Time for the 3/16" Kynar Gasket.

(a) **(b)** **(c)**

Figure 17. Odor Screening testing at JSC (a) test article in chamber, (b) Chamber N with door closed, (c) "sniff" testing.

G. WSTF Odor Test Results, Summary and Material Selection

Multiple tests were done at JSC with increasingly representative test methods and apparatus to increase the likelihood of a susscuful test at WSTF. AFC and HFC test articles with fecal material and the Kynar® (PVDF) gasket



(a) (b) (c) (d)

Figure 18. AFC and HFC odor testing at WSTF with Kapton Gasket, (a) HFC in test chamber, (b) AFC in test chamber, (c) gas sample port, (d) fan for circulation in chamber.

(Figure 18) were tested at WSTF and passed 30 days at 1.5 levels in 2026. Because the Kynar® (PVDF) gasket passed all tests, is readily available and cost effective, this material was selected to update the flight design in both the HFC and AFC. See Table 4 for details of the testing.

Table 4. AFC Gasket Testing Results

			AFC Test Passes and Failures					
Gasket	Thickness	Material	Gasket Fit Check	Water Test	Onion Test	Initial Fecal Test	Pre-White Sands Fecal Test	WSTF Fecal Test
HT-800	0.188"	Open-Cell Silicone Foam	✓	X				
HT-800	0.25"	Open-Cell Silicone Foam	✓	X				
HT-870	0.188"	Open-Cell Silicone Foam	✓	✓	N/A	Not tested due to 0.25" failure		
HT-870	0.25"	Open-Cell Silicone Foam	✓	✓	✓	X		
HT-1240	0.125"	Solid Silicone Rubber	✓	X				
RS-720	0.25"	Closed-Cell Silicone Foam	✓	✓	X			
RS-750	0.25"	Closed-Cell Silicone Foam	✓	✓	N/A	X		
Viton	0.188"	Solid Viton	X					
Viton	0.25"	Solid Viton	X					
Neoprene	0.188"	Solid Neoprene	X					
Neoprene	0.25"	Solid Neoprene	X					
EPDM	0.188"	Solid EPDM	X					
EPDM	0.25"	Solid EPDM	X					
Butyl	0.188"	Solid Butyl	X					
Butyl	0.25"	Solid Butyl	X					
Viton	0.188"	Closed-Cell Viton Sponge	✓	✓	N/A	Inconclusive, possible lid failure, promising results for 1 month		
Viton	0.25"	Closed-Cell Viton Sponge	✓	✓	N/A	Put on hold to test Kynar		
R10480S Silicone	0.188"	Closed-Cell Silicone Sponge	✓	✓	N/A	Put on hold to test Kynar		
PVDF (Kynar)	0.188"	Closed Cell Kynar Foam	✓	✓	✓	✓	✓	✓
F30 PVDF (Kynar)	0.25"	Closed Cell Kynar Foam	Some Gaskets too thick, some fit					

H. Requirements Update

The original AFC functional requirement was meant to mimic an ISS increment and required odor testing for 270 days with no greater than 1.5 on the 0-4 odor scale as defined in NASA-STD-6001B. This was determined to be unrealistic and not representative of the actual use case. The updated requirement for the AFC has been changed to odor testing for 30 days with no greater than 2.5 on the 0-4 odor scale as defined in NASA-STD-6001B. This is aligned with other component odor testing requirements and fits the Artemis mission profile for stowage of filled fecal containers with a crewed presence on the vehicle.

VI. Other Design Options and Future Work

The gasket replacement objective is considered to be successfully met. However, it appears that there is a point that the odor controlling lid media becomes saturated. Based on the results, this is not an issue for near term missions but additional work is needed for longer durations on an odor containment system for metabolic waste.

VII. Conclusion

Accurate odor testing requires the use of human fecal material rather than other odor producing substances or ersatz materials and is also dependent on the test apparatus and method. Odor constituents which are produced by fecal material as it degrades while stored in a closed container are varied and behave unlike other ersatz that may be used in testing. Saturation of odor controlling media is an issue to be addressed. A balance of odor control efficiency, mass and volume, and venting vs. not venting containers creates a design challenge for additional study. Work in this area continues and is of value to all missions which include crewed elements. A significant effort has been made to find an odor containment gasket material with Kynar emerging as the best choice based on performance, availability, cost. This material will be used on the AFC in future missions such as Orion's Artemis-3. It is hoped that work will continue in this area for exploration missions.

Acknowledgments

Thanks to the various teams who work with the human element that includes all areas that generate odor. Teams within NASA and contractors are working on odor control methods for metabolic waste including urine and fecal material as well as non-metabolic waste storage for trash. Sharing of this data helps further development of successful odor control methods.

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