

The Trash Compaction Processing System (TCPS) Technology Demonstration and Risk Reduction Updates FY23-FY24

Tra-My Justine Richardson, Steven A. Sepka, and Kevin R. Martin

National Aeronautics and Space Administration, Ames Research Center, Moffett Field, CA, 94035, USA

Michael K. Ewert, Melissa McKinley, Melissa Borrego

National Aeronautics and Space Administration, Johnson Space Center, Houston, TX 77058

Serena Trieu

Logyx LLC, Mountain View, CA 94043

Gregory S. Pace and Janine Young

KBR Wyle, Houston, TX, 77002

and

Douglas W. White

Stellar Solutions Inc., Chantilly, VA 20151

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Outline

Vocabulary

- PMW-Plastic Melt Processor
- HMC-Heat Melt Compactor: Gen 1 and Gen 2
- TCPS-Trash Compaction Processing System

- What is TCPS?
- The Four TCPS Subsystems
- Requirement Updates
- Risk Reduction Activities
- Flammability Testing
- Acknowledgement
- Reference

What TCPS does:

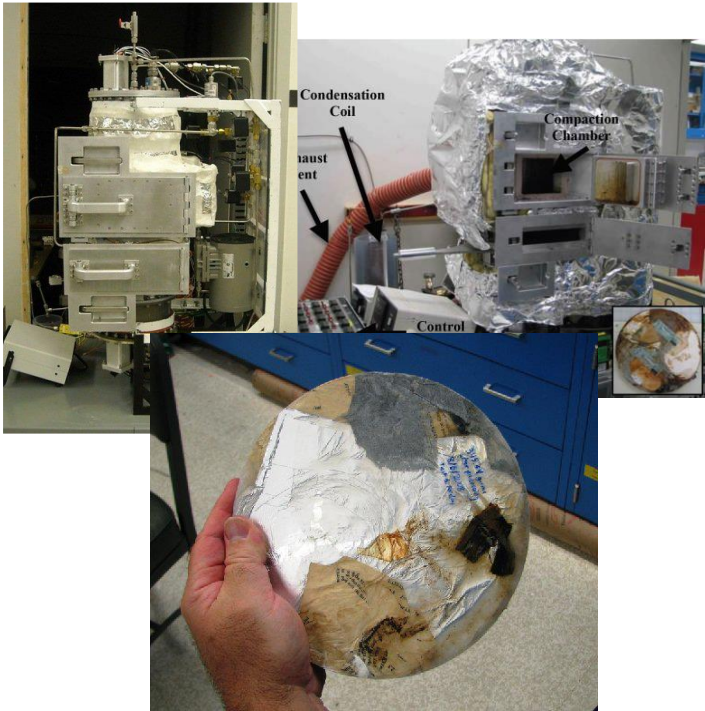
- Compact
- Safen
- Shape

Why?

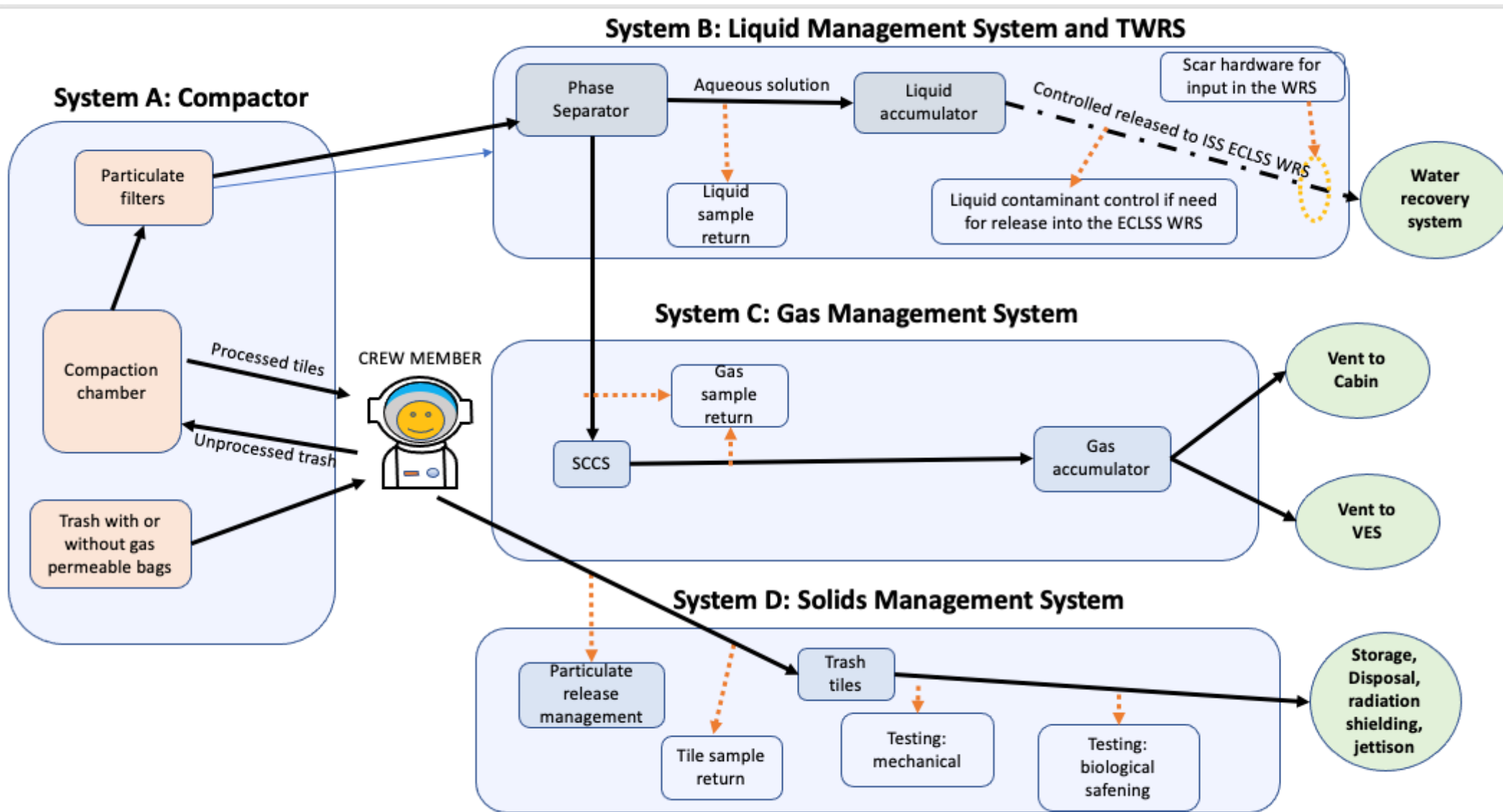
- Reduce the volume
- Handling/Storage/Jettison



Plastic Waste Processor



The Four TCPS subsystems



OPERATION IN MICROGRAVITY

OBJECTIVES

User feedback on system interfaces, usability, servicing, maintenance, and operation needs to be obtained under μg spaceflight conditions for verifying TCPS system design and validating the Concept of Operations

SUCCESS CRITERIA

TCPS operation by ISS crew produced a minimum of 30 trash tiles.

TCPS was able to be cleaned and serviced within 5 minutes by ISS crewperson who recorded feedback on the processes.

PRODUCT QUALITY

OBJECTIVES

Test TCPS Wastewater Recovery System (TWRS) and liquid management system in μg

Process effluent gases to be ECLSS compatible; Vent compatible gases to ISS cabin

Process effluent gases to be compatible with ISS Vacuum Exhaust System (VES); vent compatible gases to VES

SUCCESS CRITERIA

At least 10 liquid effluent samples were collected for return to Earth. Each liquid sample shall come from a different trash model.

At least 5 trash batches were processed by TCPS with effluent gasses vented to the ISS cabin with no safety issues noted by ISS or ground crew. At least 5 gas effluent samples were collected for return to Earth, each sample coming from a different trash model.

At least 5 trash batches were processed by TCPS with effluent gasses vented to the ISS VES with no safety issues noted by onboard or ground crew. At least 5 gas effluent samples were collected for return to Earth, each sample coming from a different trash model.

EFFLUENT MANAGEMENT

OBJECTIVES

Tile quality and stability

Demonstrate volume reduction and safening of trash

SUCCESS CRITERIA

Breaking or crumbling of tiles and safety issues the tile removal are not reported by ISS crew

10 returned tiles are within 20% of flight hardware ground test measured values for tile density and water activity.

TCPS Requirement Updates

5.0 Safety The TCPS shall be safe during ground testing, launch, and operation on the ISS.

5.1 The TCPS shall meet the NASA safety requirements according to SSP 51721, SSP 50260, SSP 57000, and NASA-STD-3001, during all operating conditions.

5.1.1 Do not allow access to the compaction chamber during operation

5.1.2 do not open the chamber door when not at touch temperature

5.2.3 shall not exceed acoustic limits

2.0 Trash Processing The TCPS shall process trash into a compacted tile



2.1 375 g/L density (nominal)

2.2 simplified crew interaction

2.2.1 limit service to 15 minutes/15 cycle

2.2.2 limit to 2 crew hours/50 cycles

2.2.3 provide unique maintenance tools

2.2.4 limit to 5 minutes of crew time/cycle

2.2.5 reliability: test 20 cycle of each nominal, high liquid, foam trash model

2.3 one tile/12hours

2.4 biologically safe

2.4.1 $A_w < 0.5$

2.4.2 heat to 150°C for 3.5 hours

2.5 tile physical integrity

2.5.1 volume change $< 5\%$, mass change $< 1\%$



3.0 Output The TCPS shall allow for easy and safe removal of the tile by one astronaut.

3.1 solid particle release

3.2 odor, gas, condensate, liquid

3.3 crew interaction

4.0 Effluents-All effluents from processed trash shall be managed and be compatible with ISS systems.

4.1 85% water recovered

4.2 manage the water effluent

4.2.1 interface: system will not start without liquid container

4.2.2. scar the hardware for future liquid transfer to various water recycling system

4.2.3 Collect water sample to return to the ground for analysis

4.3 gas effluents management (ISS cabin/VES)

4.3.1 Do not initiate testing until the gas processing or storage system is ready

4.3.2 vent gas must meet VES requirements in SSP57000

4.3.3 gas sample collection and return to the ground for analysis

4.4 manage solids, gunk, and particulate

4.5 manage odor

4.6 venting to cabin (SMAC)

1.0 Trash Input The TCPS shall be able to accept trash inserted by an astronaut.

1.1 2.2Kg

1.1.1 Loaded by a single CM

1.2 Trash Model

1.3 Conserve the air

6.0 EXPRESS Rack The TCPS shall be certified to operate in an EXPRESS Rack on the ISS.

6.1 EXPRESS rack requirements

6.2 Volume

6.2.1 door protrusion

6.3 Power (500W average, 750W peak)

6.4 Cooling (AAA/MTL/ETL)

6.4.1 when using AAA, a minimum of one tile/ 24 hours

7.0 Operational Scenarios The TCPS shall implement prescribed operational scenarios for the purpose of demonstrating technology readiness.

7.1 Vent to VES

7.1.1 Ability to defer venting to VES

7.2 Bent to Cabin

7.3 Autonomous processing

7.3.1 autonomous pause operation if lost connection to subsystems such as cooling, effluent resources, anomaly, or failure

7.4 Manual operation from the front panel

7.5 Remote operation on the ground

7.5.1 adjustment of operating mode

7.5.2 Monitor and control the position of the ram in the compaction chamber

7.5.3 Allow control release of gaseous effluents to the VES

7.5.4 Allow for system interruptions and resumption

7.6 Arcturus telemetry for data transmission

7.6.1 Monitor, record, and transmit data

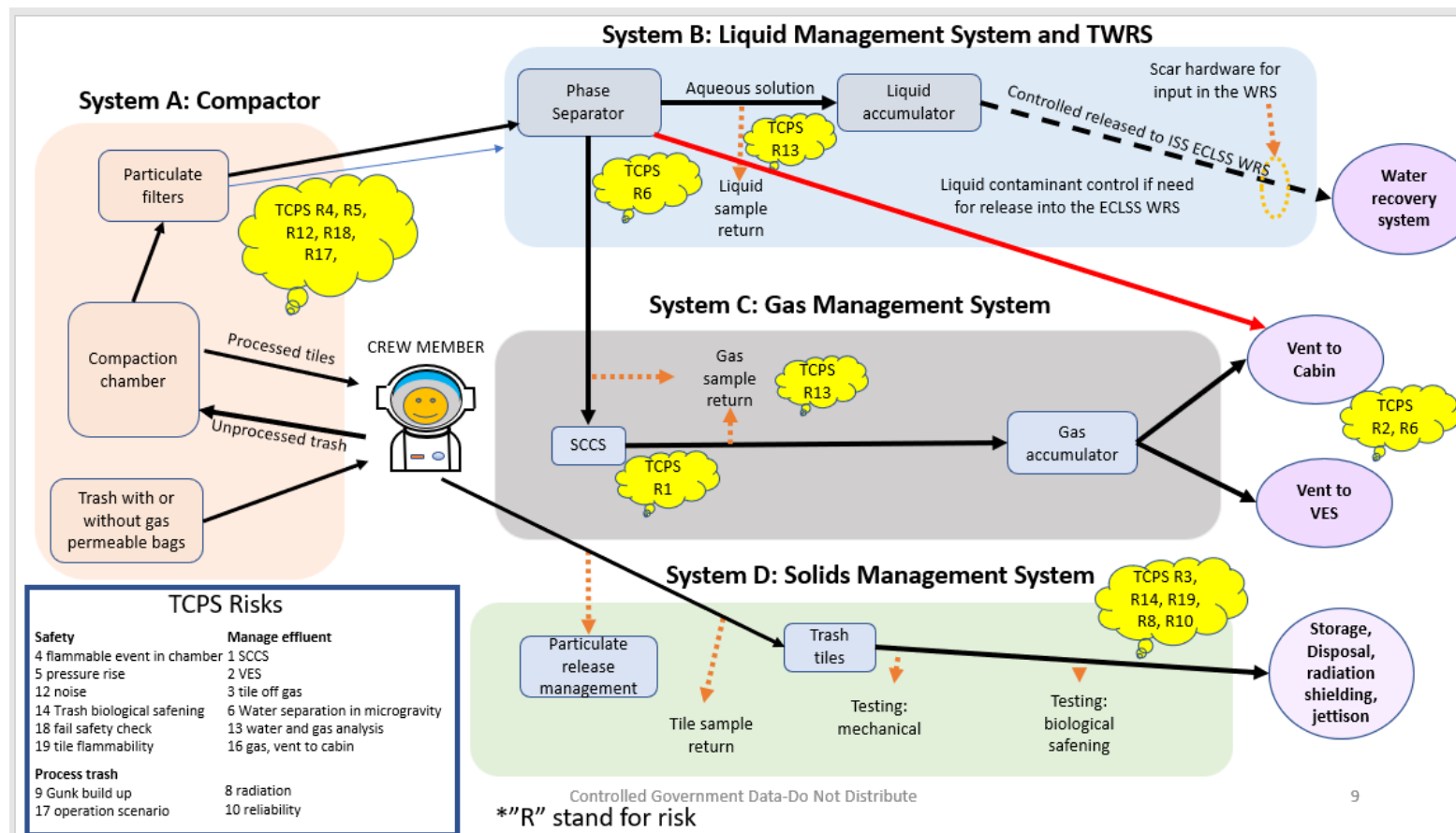
7.6.1 Transmit data the the DAN

7.6.2 Transmit data at 1Hz

Objective: of the TCPS risk reduction activities at ARC is to understand the various TCPS operations to minimize and troubleshoot operational issues on the flight demonstration units.

The risk reduction activity topics are:

- Different types of trash input types to include different trash batches (nominal, high liquids, high cloth, benign, hygiene, non-typical)
- Different processing parameters (e.g. temperature and pressure)
- The processing of the trash batches with and without trash bags
- The use of different trash bags
- Microbial studies of the processed tiles and of the hardware
- Tile densities, flammability, mechanical stability, water activity
- Trade studies to evaluate the equivalent system mass
- Processing of the gas effluents and methods for releasing them
- Processing of the recovered water and methods of recycling it
- Crew interaction
- Off-gassing of individual trash components



Objectives: To evaluate the processing of different trash batches

Trash batches = trash models

History

1. Nominal
2. High Liquid
3. High Clothes
4. Benign
5. Packing Foam

Additional trash batches

6. Hygiene Items
7. Non-typical Trash Batches

Non-Typical Items

Athletic Running shoe	Medium Binder clips
Nylon Running shorts	Rubber bands
Socks	HEPA filter
Men's leather belt with metal buckle	Plastic bags
Exercise Shirt	Hand Therapy Ball
Thermal protective gloves (deerskin)	Open End Wrench
Electric razor	2-Part Epoxy
Adjustable tether	Scientific calculator
Mini-Flashlight	Thread sealant/glue
Flight pen (ink)	Magnetic Strip Assembly
Mechanical Pencil	Nylon Brush for a drill
Highlighter pens	Oxygen Sensor
Permanent markers	pH strips
Black printer ink cartridge	Syringes
Label Maker Cartridge	First aid supplies

Hygiene items

Aelita Kit ¹	Hygiene Towel, Wet Towel	Petroleum Jelly
Comfort Kits ²	ID Clips	Washcloths
Cotton Swab	Lipstick	Wet Napkins
Dental Floss	Makeup	Wet Wash Dispenser Assembly,
Deodorant	Mirror	Dry Towels
Dry Wipes	Nail Clippers	Dry Napkins
Emesis Bag Assembly	Nail Clippers	Soap and Plastic Bag
Facial Cleansing Wipes Assy	Nitrile gloves	Syptic Pencil
Gloves Dispenser Assembly	No-Rinse Shampoo	Toothbrush
Gloves Dispenser Pouch	Personal Hygiene Kit Container, PHK	Toothpaste
Hair Brush and/or Comb	Razor (Electric)	Towels
Hair Clipper	Razor (Manual) and Cartridge /	Tweezers
Hand Cream	Scissors	
Dry and Wet Wipes	Shaving Cream and Gel	
Hygiene Disposal Bag	Soap / Body Bath Pouch	

¹Aelita kit consist of shampoo and wipes for cleaning the hair

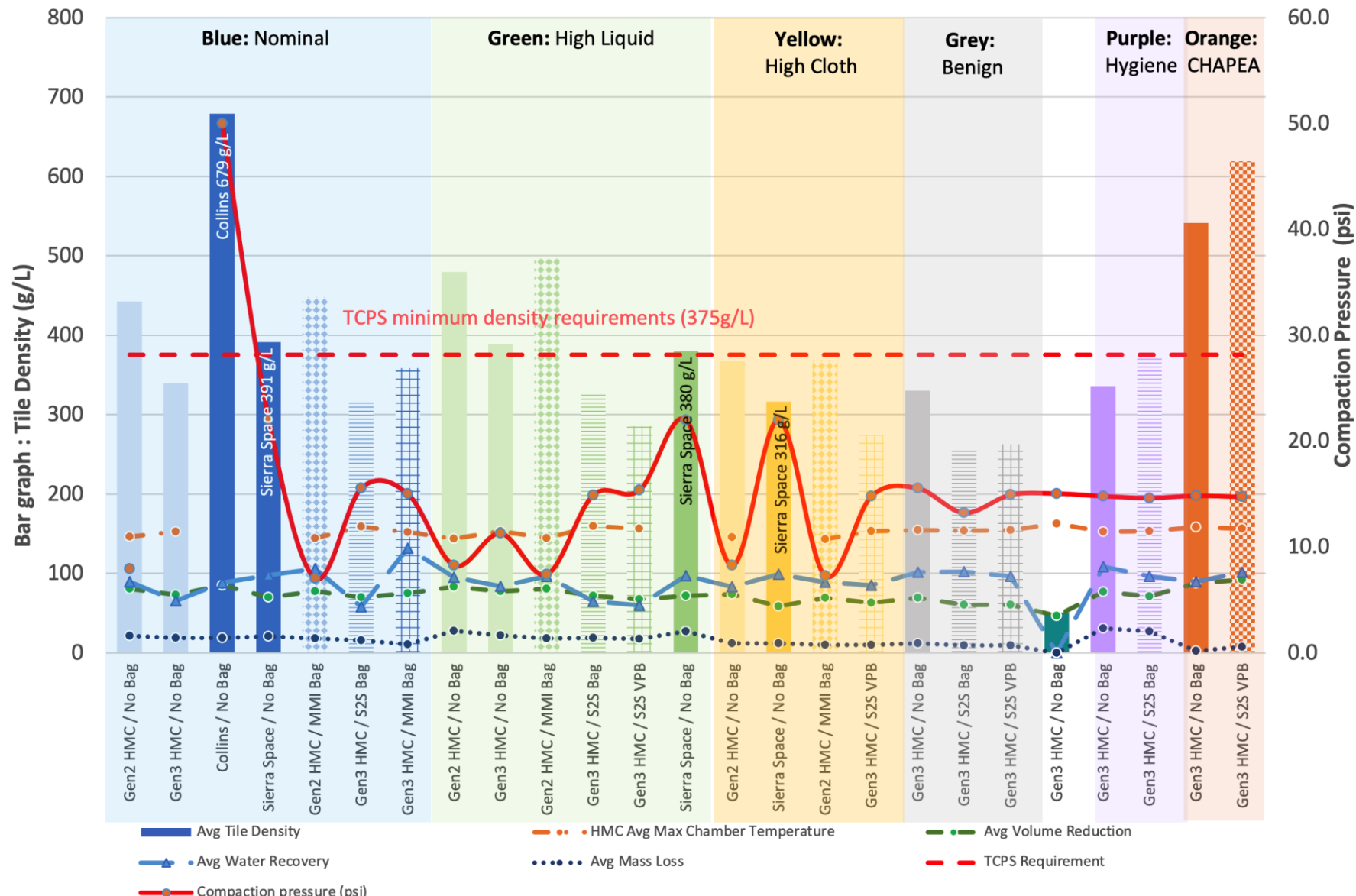
²Comfort kits is the hygiene kit with toothpaste

Risk Reduction Activities: Trash output (tile densities)

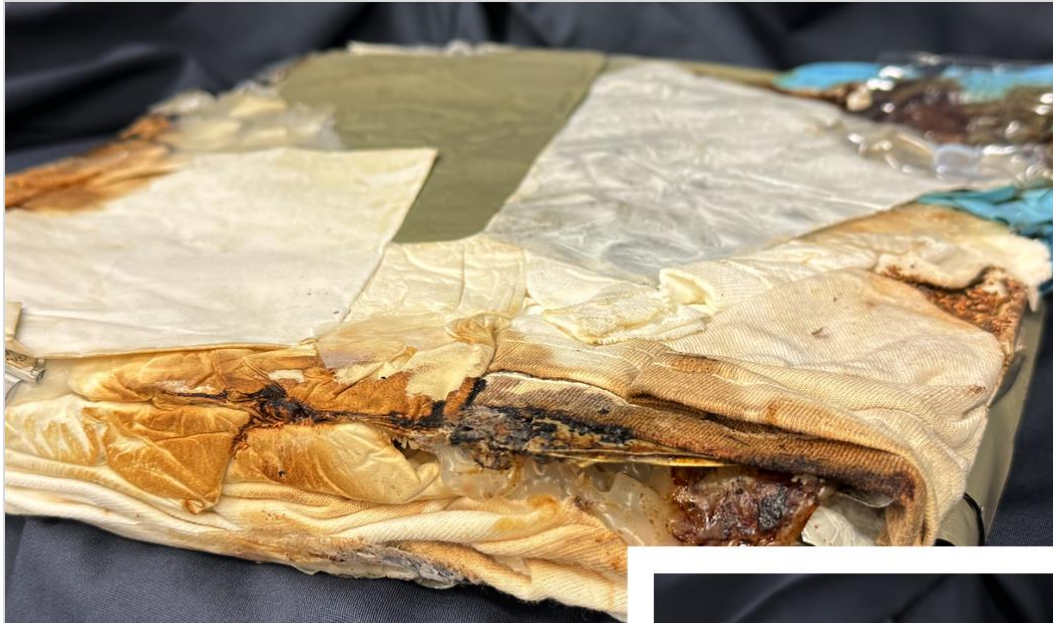
Take aways:

- Compression pressure and tile density
- Trash batches types and tile density

TCPS Processed Tile Densities (by Trash Model)



Risk Reduction Activities: Trash output (pictures)



A: high cloths



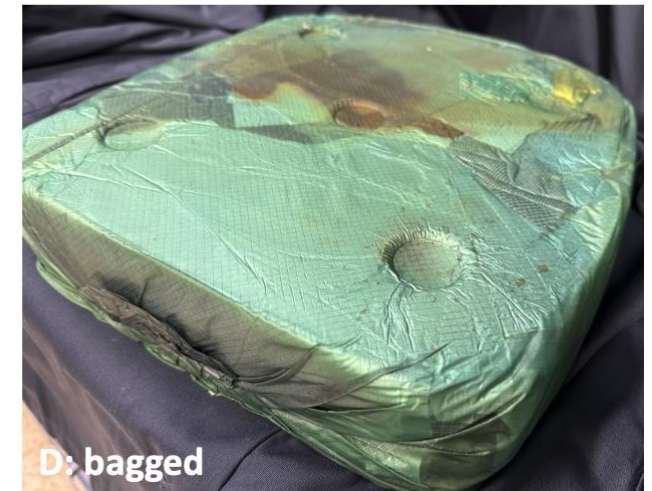
C: high cloths



B: HMC 1 cloths and plastic



E: high cloths



D: bagged

Risk Reduction Activities: Trash Processing (Moisture Content)

Theoretical values

Cloth	Cotton T-shirts	173.30	6.0%
	Towels	76.10	6.0%
Wipes	Huggies Simply Clean Wipes Fragrance Free	59.80	70.0%
	Dry lab. Chem Wipes	29.90	6.0%
	Disinfectant Wipes	4.60	70.0%
Personal Hygiene	Nitrile Gloves	23.50	0.0%
	Shampoo on Towels	7.30	70.0%
	Toothpaste on Towels	3.70	70.0%
	PET plastic	3.70	0.0%
	Chewing Gum	7.30	30.0%
	Deodorant	0.00	0.0%
Paper	Computer Paper, food and packaging paper	20.20	6.0%
Adhesives	Duct Tape	2.10	0.0%
	Kapton Tape	1.60	0.0%
	Velcro	5.00	0.0%

Food Packaging and storage (modified packaging materials are being evaluated. For example, alternate to BOB)	Bite size pouch	31.80	0.0%
	Thermo pouch	56.30	0.0%
	Beverage pouch	18.30	0.0%
	straw assembly	8.20	0.0%
	septum adapter assembly	6.20	0.0%
	rehydrateable pouch	64.00	0.0%
	overwrap, white laminate food packaging	69.30	0.0%
	dessicant	6.40	0.0%
	BOB	29.20	0.0%
Sweat Solids	Sodium Chloride	18.00	4.0%

Food (do a residual food test by taking the foods out of the bags and measure residue) and compare to model here.	Beef Patty	8.94	70.0%
	Scrambled Eggs	8.34	80.0%
	Beef Franks	8.54	80.0%
	Macaroni	10.63	10.0%
	Tortilla	10.36	20.0%
	Rice pilaf	9.55	80.0%
	Sweet & Sour Chicken	16.82	80.0%
	Cream Spinach	5.19	80.0%
	Orange-Pineapple Drink	16.06	97.0%
	Apple Cider Drink	15.88	97.0%
	Pineapple Drink	16.35	97.0%
	Dried Apricots	4.17	50.0%
	Peaches	9.55	75.0%
	Macadamia Nuts	6.06	2.5%
Packaging Materials - Flight	Strawberries	0.61	90.0%
	Vanilla Pudding	6.67	80.0%
Foam	Ziploc Bag	75.60	0.0%
	Bubble Wrap	75.60	0.0%
	Zotek F30	0.00	0.0%

ASTM 599-15 Total Evaporable Moisture Content of Aggregate by Drying

4. Significance and Use

4.1 This test method is sufficiently accurate for usual purposes, such as adjusting batch quantities of ingredients for concrete. It will generally measure the moisture in the test sample more reliably than the sample can be made to represent the aggregate supply. In cases where the aggregate itself is altered by heat, or where more refined measurement is required, the test should be conducted using a ventilated, controlled temperature oven.

4.2 Large particles of coarse aggregate, especially those larger than 50 mm, will require greater time for the moisture to travel from the interior of the particle to the surface. The user of this test method should determine by trial if rapid drying methods provide sufficient accuracy for the intended use when drying large size particles.

8. Calculation

8.1 Calculate total evaporable moisture content as follows:

$$p = 100 (W - D)/D \quad (1)$$

where:

p = total evaporable moisture content of sample, percent,
 W = mass of original sample, g, and
 D = mass of dried sample, g.

8.2 Surface moisture content is equal to the difference between the total evaporable moisture content and the absorption, with all values based on the mass of a dry sample. Absorption may be determined in accordance with Test Method C127 or Test Method C128.

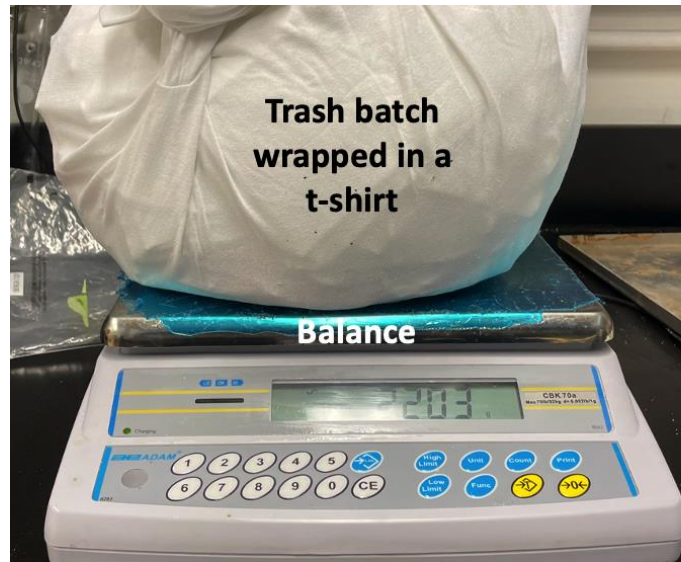
TCPS Moisture Analysis Calculation

$$\text{percent moisture} = 100 \frac{*(Wet\ mass - Dry\ mass)}{Wet\ mass} \quad \text{Equation 1}$$

Procedure:

Heat the trash batches in the vacuum oven at 10mmHg as follows:

- Record the mass
- Ramp to 50C for 5 hours
- Ramp to 100C for 24 hours
- Ramp to 150C for 24 hours.
- Record the mass after drying.
- Repeat the heating cycle until the mass is constant



Trash model example used for moisture analysis using heat and vacuum *(photo credit NASA ARC)*

TCPS Risk Reduction Activity: Moisture Analysis Results

Trash Model	Mass of the trash		Moisture contents ³		Average moisture contents			Estimated amount of water in the trash batch ⁵		% difference ⁶
	Initial ¹ g	Final ² g	g	%	%			g	%	
Nominal	2190	1761	429	24.4	24.1	±	0.2	431.8	24.4	1.3
Nominal	2206	1781	425	23.9						
High Cloth	2207	1970	237	12.0	12.2	±	0.2	264.3	13.7	10.9
High Cloth	2203	1959	244	12.5						
High Liquid	2206	1643	563	34.3	34.5	±	0.2	563.9	34.5	0.0
High Liquid	2198	1632	566	34.7						
Benign	2200	1948	252	12.9	12.3	±	0.6	223.3	11.3	8.8
Benign	2210	1978	232	11.7						
Hygiene B ⁷	1150	831	319	38.4	38.4	na ⁸	na ⁸	333.3	40.8	6.1
Hygiene A	1311	829	482	58.1	58.1	na ¹	na ¹	492.5	60.2	3.4

¹ Both the wet and dry trash items

² Mass loss after oven dried

³ According to ASTM C566-19. The moisture content is equal to the $100 \times (\text{wet mass} - \text{dry mass}) / \text{dry mass}$

⁴ The average moisture content is equal to the mass loss divided by the initial mass $\times 100$

⁵ The estimated amount of water in the trash batch is calculated based on the individual moisture contents of the trash items

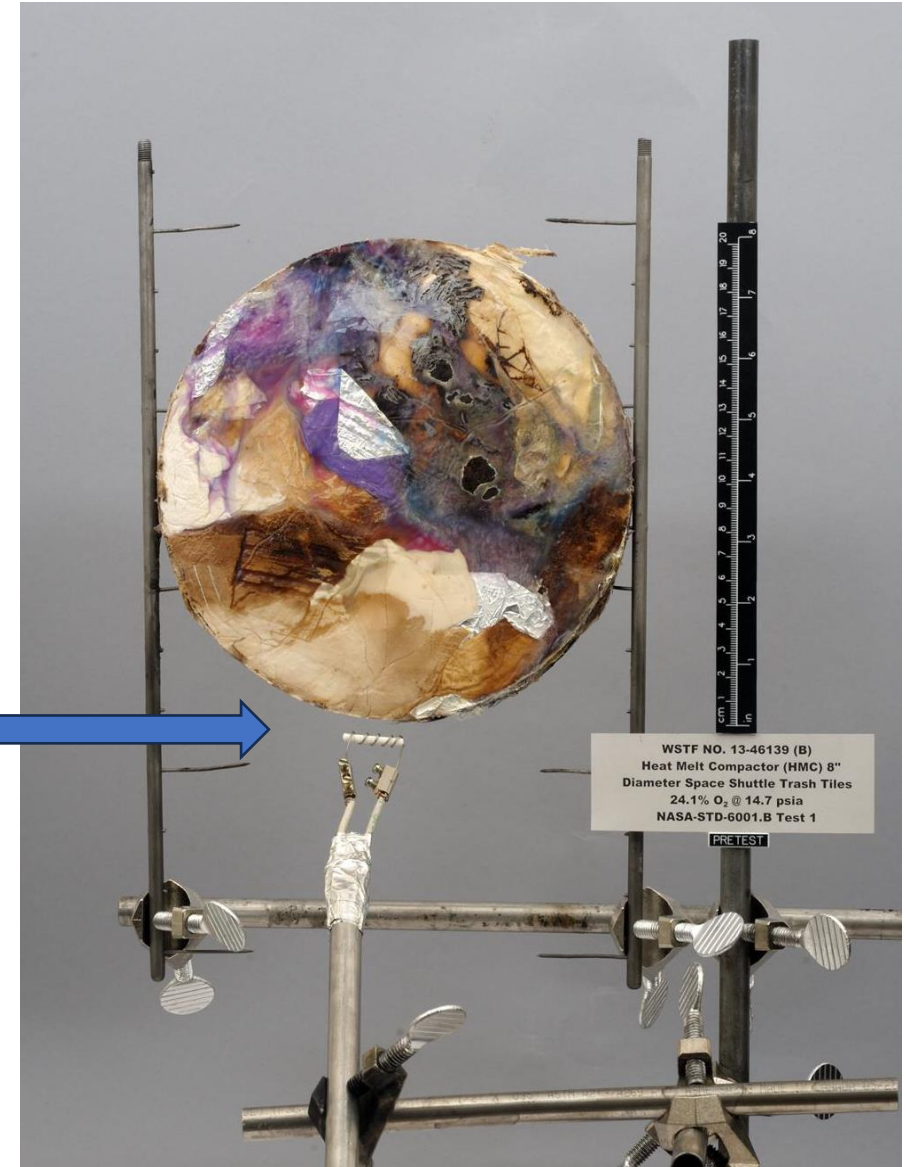
⁶ The percent difference is the $(\text{estimated value} - \text{the average}) / \text{estimated value} \times 100$

⁷ The trash model was made up where 150mL of water was added to the towel and allow to air dried in the lab, a typical use case on ISS.

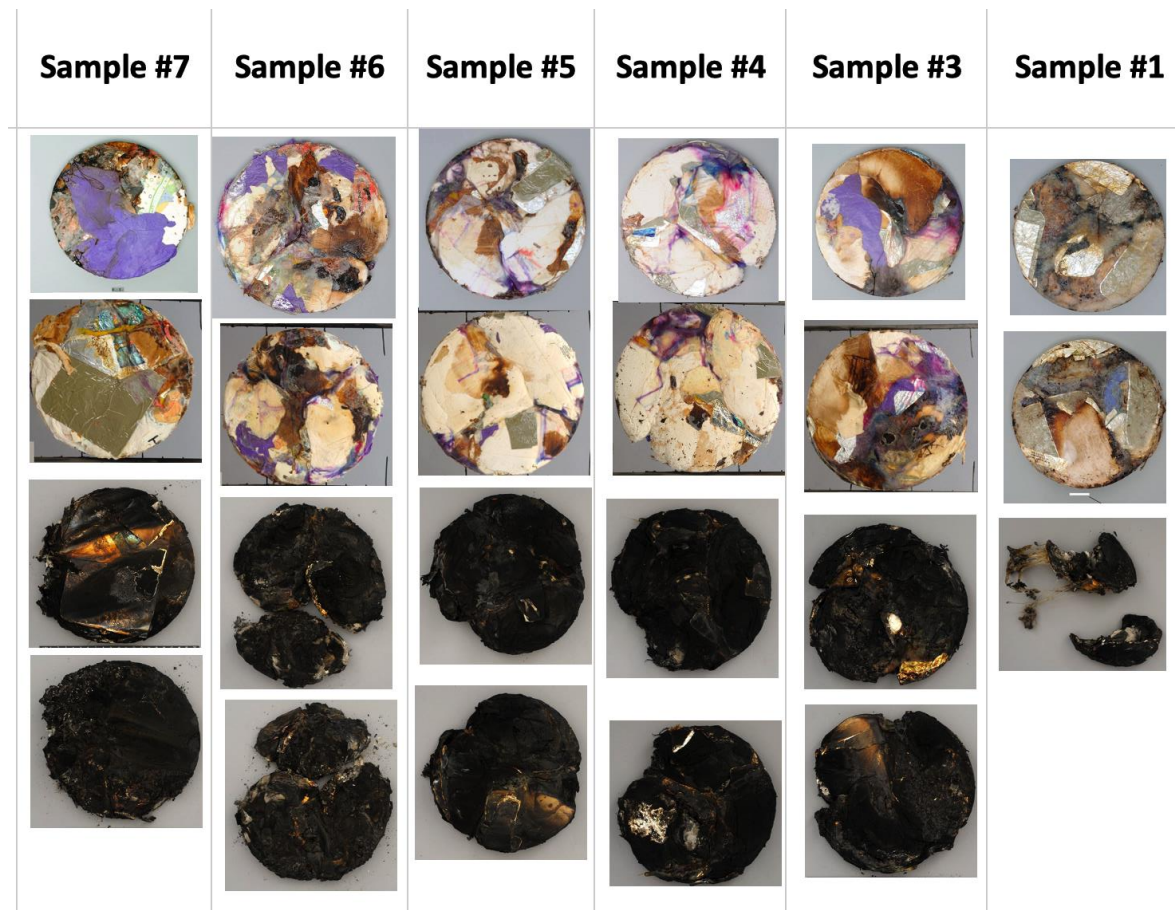
⁸ only one test run was completed

White Sand Test Facility (WSTF) Off-gassing and Flammability Testing

Ignition
source



TCPS Risk Reduction Activity: WSTF Flammability Test Results



Test #	Diameter	thickness	Weight	burn Length	Propagation time	Burn time	Weight Loss	Relative O2 Consumption	% weight loss	Quantify of Sparks	Quantify of Cinders	Quantify of Flame Jets	Quantify of burning Material	Effect on K-10 paper
	cm	cm	g	cm	sec		g	%	%	none	none	none	large	Ignition
1	20.3	2.4	358.96	20.3	137		158.873	36.1	44.3	none	none	none	large	Ignition
3	20.4	1.8	438.21	20.3	269		113.49	35.5	25.9	none	none	small	large	Ignition
4	20.4	2.5	458.93	20.3	274		128.56	35.4	28.0	none	none	none	large	Ignition
5	20.4	2.4	450.15	20.3	114		109.44	31	24.3	none	none	none	large	Ignition
6	20.4	1.6	376.89	20.3	183		121.04	34.4	32.1	none	none	none	large	Ignition
8	20.4	2.1	374.64	20.3	148		72	17	19.2	none	none	none	large	Ignition

White Sands Off gas Test Results on HMC Gen 1 Tiles

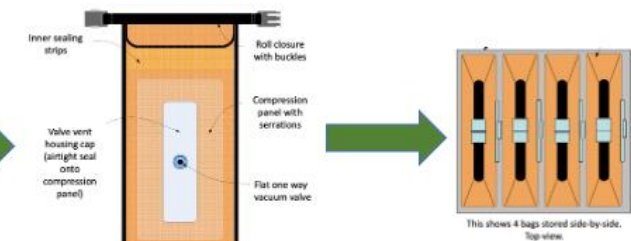
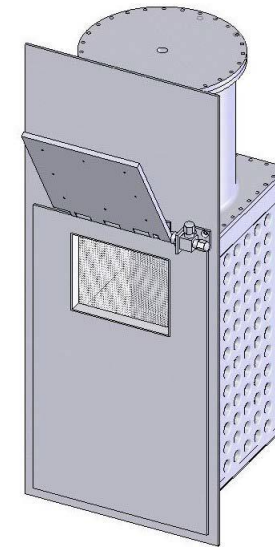
Components	SMAC mg/m3	Measured ug/g
2-Furfural	7.89	0.02
2-Heptanone	23.35	0.005
2-Methylbutanal	21.1	0.02
2-Methylfuran	0.13	0.009
2-Methylpropenal	0.14	0.007
2-Pentanone	70.2	0.007
3-Methylbutanal	21.1	0.03
Acetaldehyde	7	0.28
Acetic acid	7.4	0.005
Acetone	52	0.29
Acrylonitrile	2.9	0.002
Benzaldehyde	17.3	0.01
Benzene	1.5	0.008
Butene	57	0.005
Butyraldehyde	17.1	0.01
C10-C11 Saturated and unsaturated aliphatic hydrocarbons	131	0.12
C6 Saturated aliphatic hydrocarbon	211	0.005
C7 Unsaturated aliphatic hydrocarbon	200.28	0.006
C8 Saturated and unsaturated aliphatic hydrocarbons	35	0.07
C9 Saturated aliphatic hydrocarbons	314	0.06
Carbon disulfide	3.1	0.02
Carbon monoxide	63	1.3
Carbonyl sulfide	4.9	0.009
Chloromethane	41.17	0.007
Dimethyl disulfide	0.1	0.005
Ethyl acetate	179.34	0.04
Ethyl alcohol	2000	1.6
Ethyl formate	90.72	0.06

Components	SMAC mg/m3	Measured ug/g
Ethylbenzene	130	0.005
Furan	0.07	0.06
Heptanal	28	0.006
Heptane	204.47	0.005
Hexamethylcyclotrisiloxane	90	0.48
Hexane	176	0.005
Isobutyraldehyde	17.7	0.01
Isopropyl alcohol	150	0.08
Methane	3500	0.003
Methyl acetate	120.73	0.1
Methyl alcohol	90	0.19
Methyl ethyl ketone	30	0.03
Methyl formate	12.3	0.03
Methyl isobutyl ketone	140	0.005
n-Butyl acetate	189.11	0.02
n-Butyl alcohol	80	0.02
n-Hexanal	24.6	0.25
Octamethylcyclotetrasiloxane	280	0.31
Octane	348.92	0.02
Pentanal	21.1	0.07
Pentane	588.28	0.01
Propane	898.81	0.005
Propionaldehyde	14.3	0.02
Propylene	857.64	0.005
Styrene	42.5	0.005
Toluene	15	0.005
Trimethyl silanol	4	0.01
Vinyl acetate	10.5	0.03

Additional Work needed on TCPS tiles

- Higher compaction pressure yield denser tiles
- Different trash batch types directly relates to tile densities
- Flammability test on HMC Gen 1 tiles requires tiles to be stored in Nomex bag
- Continue working on Risk Reduction Activities

- Tailor trash management technologies, in particular, trash compaction to the various space missions



Acknowledgement

This project is funded both by the Exploration Capability Logistic Reduction and the Life Support System programs. We appreciate the program managers for their continued support: