General Disclaimer

One or more of the Following Statements may affect this Document

- This document has been reproduced from the best copy furnished by the organizational source. It is being released in the interest of making available as much information as possible.

- This document may contain data, which exceeds the sheet parameters. It was furnished in this condition by the organizational source and is the best copy available.

- This document may contain tone-on-tone or color graphs, charts and/or pictures, which have been reproduced in black and white.

- This document is paginated as submitted by the original source.

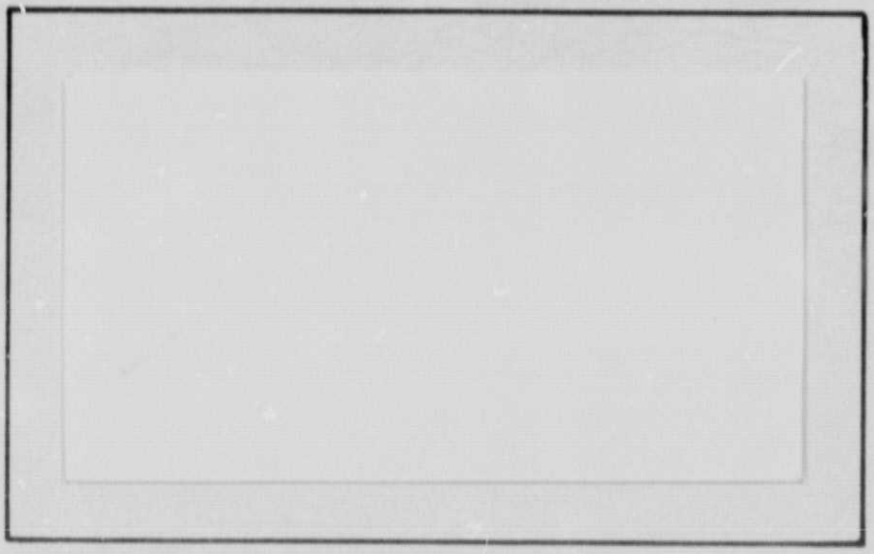
- Portions of this document are not fully legible due to the historical nature of some of the material. However, it is the best reproduction available from the original submission.

(NASA-CR-151628) SPACECRAFT DISINFECTANT/CLEANSING AGENT DEVELOPMENT Final Report (Fairchild Republic Co.) 48 p HC A03/MF A01 CSCL 11K

N78-18212

Unclas
G3/27 05958

NASA CR-
151628



FAIRCHILD
REPUBLIC COMPANY

RD177R4001
30 December 1977

Final Report

Spacecraft Disinfectant/Cleansing Agent Development

Prepared for
National Aeronautics and Space Administration
Lyndon B. Johnson Space Center
Houston, Texas 77058

Contract NAS 9-14769
DRL Line Item No. 1

FAIRCHILD

Fairchild Republic Company Farmingdale, L.I. New York 11735

Prepared by :
M. Abbate

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

TABLE

1.0 INTRODUCTION

Sanitation requirements in space do not present any unusual problems and are in many respects much the same as those on Earth. Previous sanitation methods, although adequate, have been somewhat cumbersome and not always completely satisfactory. In the Shuttle era, with a high frequency of flights, it is highly desirable to have efficient sanitation agents which are simple to use. These agents should be formulated for specific tasks such as personal hygiene, system equipment, and for the special requirements of life science payloads. The agents must have no adverse impacts on the rest of the space ship but should enhance mission effectiveness by providing a clean and healthy environment.

In 1972, Fairchild Republic Co. completed a study under Contract NAS9-12205 on Spacecraft Sanitation Agent Development for space station use. This effort defined sanitation requirements for personal hygiene and crew systems, and selected sanitation agents and techniques for their use. The final report, document number MS142Y0004, included a recommendation for further development effort in the design and fabrication of pressure-packed formulations. This current study was undertaken to implement this recommendation for use on the Shuttle. The program was to define spacecraft sanitation requirements for Shuttle payloads and to select sanitation agents on the basis of a trade-off study of missions versus requirements. Prototype products were to be developed and tested, including concept verification at zero-gravity.

2.0 SUMMARY

This program was initiated to develope prototype sanitation agents and dispenser for use on the Shuttle Orbiter. Following the recommendation of a previous study, the sanitation agent was to be dispensed as a foam from pressure packed containers. Foams are easily applied and spread over the surface to be cleaned with a minimum of water. The foam entrains the soil and can be readily removed with wipes. In addition it is expected that cleansing can be accomplished without loss of material to the cabin environment.

For the Shuttle Orbiter, the following requirements were identified: a personal hygiene agent, a general system maintenance agent; and a sanitation agent for life science payloads.

The sanitation agent container, which was selected in a trade-off study, employs two chambers, a rigid outer container and an inner flexible bladder. The bladder contains the sanitation agent formulation and its release is controlled by a manually operated valve. The outer container holds a high pressure vapor. There is no void in the bladder which makes the package operation independent of orientation and therefore usable in zero gravity. Foam is developed by a low boiling point fluid or dissolved gas in the product. When the product is dispensed at atmospheric pressure, the evolved gas or vapor whips up a foam in the valve. The sanitation agents were initially formulated with freons which produces an excellent foam. However freon is uncompatible with the life support system and was replaced with carbon dioxide dissolved at high pressure. The CO_2 system may limit high temperature exposure to prevent leakage or package distortion.

The sanitation agents have been shown to be effective in cleaning soils from personnel and material. The use of the agents result in a significant reduction of microbial contamination. No problems were encountered with valve clogging with repeated usage and there is very little over-run. To verify the package concept, the products were flight tested in null gravity in a KC-135 aircraft. The products functioned as expected.

3.0 STATEMENT OF WORK

The work statement for sanitation agent includes the following tasks:

3.1 PREDEVELOPMENT REVIEW

FRC shall define spacecraft sanitation requirements based on current Shuttle Orbiter, Shuttle Payloads, and future long range manned space projects. For purposes of establishing requirements, FRC shall consider supporting up to a 180 day mission on a spacecraft containing seven people (males and females). In addition, FRC shall include consideration of sanitation requirements associated with laboratory work (animals, microbiology, etc.). Experience with previous spacecraft sanitation equipment and characteristics of sanitation equipment from previous research and development efforts shall be reviewed.

3.2 SELECTION OF SANITATION AGENTS

FRC's previous effort resulted in the selection of two sanitation agent formulations: one for personal hygiene use and the other for equipment maintenance. Subsequent experience and/or requirements may dictate the need for additional formulations. The predevelopment review should serve to identify whether or not additional agent formulations are required. FRC shall perform trade-off analyses as required to select the sanitation agents of choice for the sanitation requirements defined in the predevelopment review. The trade-off criteria shall include considerations of disinfecting power, safety and toxicity, product stability, performance, reliability, size, weight and cost. Results of the trade-off study shall be summarized along with recommendations and shall be submitted to the technical monitor for review and approval.

3.3 DEVELOPMENT OF PROTOTYPE PRODUCTS

FRC shall develop appropriate configurations of pressure packaged dispensers for the sanitation agents selected in the trade-off study. For each agent formulation, there will be a two-step process:

1) a brief definition of the product requirements; and
2) a development of formulation and package.

The formulations to be used shall be compatible with the Shuttle environmental control system. The use of freon in the formulations is not acceptable because the freon tends to overload the Shuttle environmental control system. The use of carbon

dioxide as a pressurant is considered acceptable as long as the total daily amount expended does not exceed 20 gm.

It is anticipated that the process of prototype development is in reality a process of selecting the appropriate propellant, valve, container, and formulation. FRC shall conduct feasibility tests to evaluate various packaging combinations. From the results of the tests, optimum packaging combinations shall be identified. In addition to the packaging/dispenser development, FRC shall select related material to be used with the dispensing agent (tissues, wipes, cloth, etc.).

3.4 FEASIBILITY TESTS

FRC shall conduct feasibility tests with the selected combinations to:

1) determine stability of the agent;
2) evaluate functional performance;
3) determine ease of agent removal; and
4) identify problems due to residual buildup.

3.5 ZERO-G EVALUATION OF PRESSURE PACKAGED SANITATION AGENTS

FRC shall conduct zero-g evaluation tests on the selected prototype agent pressure package dispensers. The purpose of the zero-g tests will be to verify that the hardware will perform as predicted in a null gravity environment. Functional performance, ease of agent removal, and residual buildup problems will be investigated in the zero-g tests.

4.0 RESULTS AND DISCUSSION

Phase I of this study comprises Task 3.1, 3.2, and 3.3. A detailed report of these tasks was released in 30 September 1976 as document RD177R4000, "Interim Report, Spacecraft Disinfectant/Cleansing Agent Development." The results of Task 3.1 and 3.2 will only be summarized in this report. Task 3.3, Development of Prototype Products has been redone inasmuch as the original product formulations included freons which have since been determined to be incompatible with the operation of the life support system.

4.1 PREDEVELOPMENT REVIEW, TASK 3.1

The application of spacecraft disinfectant/cleansing agents was defined for two broad categories of development:

a) Sanitation and Personal Hygiene, and
b) Maintenance

The general need for crew hygiene determines the type of cleansing agent required and is basically unrelated to mission type or length with the obvious exception of quantity and to a lesser degree, packaging. It is in the area of maintenance that more complex requirements impact the agent formulations, in that various payload types dictate a spectrum of possible alternate needs.

4.1.1 Personal Hygiene

The personal hygiene requirements are based upon a body cleaning protocol utilizing wet and dry wipes, and a personal hygiene station, (PHS), providing a hand washer and wet sponges or washcloths.

4.1.1.1 Whole Body. Minimum Frequency: Twice Weekly, to daily. The sanitation requirement is for a detergent that would remove surface sebum, desquamated keratin, scales of epidermis, excess bacteria, and foreign solids and liquids (soil, grease and oil, food, etc.). In Shuttle, the procedure will be accomplished with a wet wipe (washcloth) moistened with a suitable agent, followed by dry wipes.

4.1.1.2 Hands (and face as required). Minimum Frequency: Approximately 10 times daily following use of the Waste Collector System (WCS), work and maintenance activity, and before and after meals. For normal use, the same cleanser as used for the whole body washing is satisfactory.

For maximum efficiency, it should be applied directly to the hands, worked in, and removed with a dry wipe. Optionally, the agent may be used with water at the PHS.

4.1.2 System Maintenance

4.1.2.1 Waste Collector System

a. Fecal System

The fecal collector utilizes air flow to entrain feces which are directed into motor-driven rotating blades. The feces are thrown onto the collector walls creating a large exposed area for subsequent vacuum processing. The entrainment air is filtered to remove all particles including bacteria, and odors. Regular maintenance requires the wiping of the seat to prevent accumulation of human bacteria, hair and epithelium in normal usage, and possible diarrhetic feces or urine.

Irregular maintenance could be required for the replacement of odor control filters during extended missions. This would require an agent to sanitize the canister and related handling items during the change.

In the event of system failure, the back-up system used, would be the Apollo paste-on bags. Without air flow to separate and entrain the fecal bolus, the possibility of personal fecal contamination is greatly increased. Odors also present an additional problem.

b. Vomitus System

A portable disposal collector in the form of a flexible plastic bag and closure device is used. The bag is hand held over the face enclosing the mouth and nose. It is sealed after use and discarded in the fecal collector or vented trash storage. Sanitation may require an area rinse-down in the event of poor aim. Personal clean-up is effected at the PHS.

c. Urine System

The urine is collected by air entrainment in a urinal suitable for male and female use. For female collection, intimate contact is required to avoid spilling. A biocide is used to stabilize urine in the storage tanks. The sanitation requirements for the urinal are similar to those of the fecal collector. The possibility of urine spillage is somewhat greater than for feces.

On long missions, maintenance of the urine/air separator may be required if the filter becomes obstructed.

4.1.2.2 Food Preparation System

a. Galley

The galley or food preparation area is used to rehydrate and warm the food. As all of the food is processed in closed containers, normal sanitation is restricted to the interfaces between the equipment and the food packages. This nominally is a needle which injects a

measured amount of water into the packages. Regular maintenance is only the cleansing and disinfecting of the needles. The hot air oven used to warm food containers would not need regular maintenance.

Special maintenance would be required in the event of system failure. Food container rupture due to improper handling or faulty fabrication is the most probable failure. This could result in contamination of the galley components with food.

b. Food Service

The food is served in the containers in which it was rehydrated and heated, placed in reusable compartmentalized trays. These trays also have holders for utensils, condiments, and wipes. Following eating, the food containers are returned to bags for storage in the lockers, the waste paper and condiments are disposed into trash storage, and the trays and utensils are wiped and returned to storage. The sanitation requirement is to remove spilled food from the tray and adhered food from the utensils, and destroy any contaminating microbes. The sanitation agent should leave the trays and utensils aesthetically pleasing, i.e. clean, shining, "sweet smelling," and tasteless.

4.1.2.3 Sleep Area. The sleep area normally generates little need for sanitation. However, depending upon the integrity of the other cabin systems and efficiency of housekeeping elsewhere and personal hygiene, the walls of the sleep area could become contaminated with organic material of human and food origin. In time, this would support microbial growth with associated odors. In the event of respiratory disease, or vomiting or diarrhea in a bunk, the area would need disinfecting.

The need for aesthetically pleasing odors in space vehicles has been stressed by flight crews. It is important that regular sanitation procedures in the relaxation area leave the area appearing clean and "sweet smelling."

4.1.2.4 Cabin Work Areas. The cabin work areas are subject to the same contamination as the sleep area. The need for sanitation is likewise dependent mainly upon housekeeping elsewhere and personal hygiene.

4.1.3 Shuttle Payloads

Of all the potential payloads considered in RD177R4000 only life science payloads had requirements for specialized cleansing agents.

It is in the area of life sciences that one can anticipate a wide variety of dedicated agents and pressure packages. The research areas will include specimen sampling, autopsy, histology and preservation, chemical and physical analysis, and the cleaning, repair, checkout, lubrication and sterilization of test equipment. Specialized

research will be performed using human surrogates and cells and tissues. Equipment will be required to house vertebrates, invertebrates, and plants and to incubate and grow cells and tissues. Various carry-on laboratories will be devoted to biomedicine and biology to perform human research.

4.2 SELECTION OF SANITATION AGENTS, TASK 3.2

Based upon the assessment of Shuttle crew systems and payloads, the potential applications of pressure packaged sanitation agents are personal hygiene, systems maintenance, and life science payloads. A trade-off analysis was performed to provide recommendations for selection of the most promising agents for the required sanitation tasks. The report was issued 7 June 1976 as document No. RD177N2004, "Trade-Off Analysis Report, Spacecraft Disinfectant/Cleansing Agent Development."

Five agents were selected at that time for futher development. These were personal hygiene agents PH1, and PH2; system maintenance agents SM1 and SM2, and life science payload agent LSP2. PH1 is a strong cleanser for use following dirty work and contained a solvent for removing grease. At a meeting at NASA/Houston on 2 June 1977, this product was dropped for consideration for Shuttle since heavy soiling would not normally be encountered during a mission. This also simplifies the logistics of sanitation agent supply. At the same time SM2 was dropped because of the banning of freon use at that time. SM2 had the special property of being an expanding foam, designed to get into crevices, and hard to reach places. The formulation replacing freon with a compressed gas could not duplicate this effect.

The alternatives to be evaluated include selection of germicidal agent and packaging characteristics including propellant container, valve, and actuator.

4.2.1 Germicidal Agents

The agents selected in the trade-off study are:

a. PH-2

   Hexachlorophane, moderate antimicrobial effects with detergent properties.

b. SM-1

   Saponated cresols (Lysol), markedly germicidal, fungicidal, and virucidal; excellent detergent properties. Originally the active ingredient in SM-2 which was dropped.

c. LSP-2

Phenolics (Amphyl). Widest range of antimicrobial activity; compatible with soaps for detergent action.

4.2.2 Packaging

4.2.2.1 Propellant. Fluorocarbons are the most desirable materials for use as the propellant. They produce an excellent foam and maintain a constant pressure in the container. However after initial formulation with freons, they were later banned because of incompatibility with the life support system. Hydrocarbons have the same characteristics as the fluorocarbons, but are a fire hazard. Of the potential compressed gases candidates, carbon dioxide was chosen because of its greater solubility in the product than nitrogen. Foams produced with carbon dioxide have a more watery consistency and do not expand as much as freon produced foams. There is some change in property as the product is dispensed. However an acceptable product can be produced.

4.2.2.2 Container. Since these products will be used in space, aerosol systems holding the product freely in the container cannot be used, since one cannot ensure that the product is always in contact with the dip tube or the dispensing valve of the system. Therefore, those containers with a built-in bladder or piston will be used. The Sepro type container is commercially available from the Continental Can Company, and consists of a rigid plastic bag fitted into a standard three-piece tin plate container. Additionally, since the internal bag is made of a rigid plastic, there is no danger of the outer pressure causing a "pinching" of the bag resulting in an inoperative container.

4.2.2.3 Valves. A continuous spray valve was selected since it was determined that there was no need for a metered valve. Automatic metering of the product is unnecessary since the user would automatically release the valve activator when a sufficient amount of product was dispensed. Since the area to be covered would vary depending upon the use, a metered valve could prove to be a disadvantage. Preliminary studies were carried out in order to determine the proper valve dimensions for each product so as to obtain a suitable delivery rate.

4.2.2.4 Actuator. A variety of nozzles are available so as to optimize the dispensing characteristics. For example, wide cones are available for products to be applied to the body, long capiliary tubes are available for hard to reach places, etc.

4.3 DEVELOPMENT OF PROTOTYPE PRODUCTS, TASK 3.3

This task was initially accomplished with freons as the framing agent and later redone with CO_2 based formulations.

4.3.1 Selection of Components

4.3.1.1 Germicidal Agents. These agents were selected in the trade-off study reported in RD177N2004 and include the following:

PH2 - Hexachlorophene

SM1 - Phenolic (Lysol).

The original germicidal agent in SM1 was Povidone/Iodine. In preliminary development evaluation some of the product permeated the plastic bladder at elevated temperatures causing detining of the container wall. Iodine is not satisfactory for use with commercially available package materials. The phenolic agent in SM2 was used in SM1 since without freon the physical characteristics desired with SM2 were not obtainable.

LSP2 - Cresol (Amphyl)

4.3.1.2 Containers. A two chamber container is used to give gravity-independent operation. The product is contained in a plastic bladder which is gas free. The space between the bladder and the rigid container wall is pressurized. Figure 1 is a cross-section of the "Sepro" type container commercially available from the Continental Can Company. The plastic bladder is fitted into the three-piece tin plate container and is crimped in place by the valve assembly.

4.3.1.3 Valves. A continuous spray valve was selected and sized to obtain a suitable delivery rate. The valve assembly is the only component besides the plastic bladder in contact with the product. The plated mounting cup used in earlier packages interacted with the hexachlorophene to produce a brownish tint on some packages. The current valve assembly uses a stainless steel mounting cup and spring to avoid discoloration. The valve is produced by the Precision Valve Corp. of Yonkers, N.Y. The valve stem is 0.016 inch Nylon and the stem gasket is Buna N. The dry weight of the container and valve is less than 90 grams.

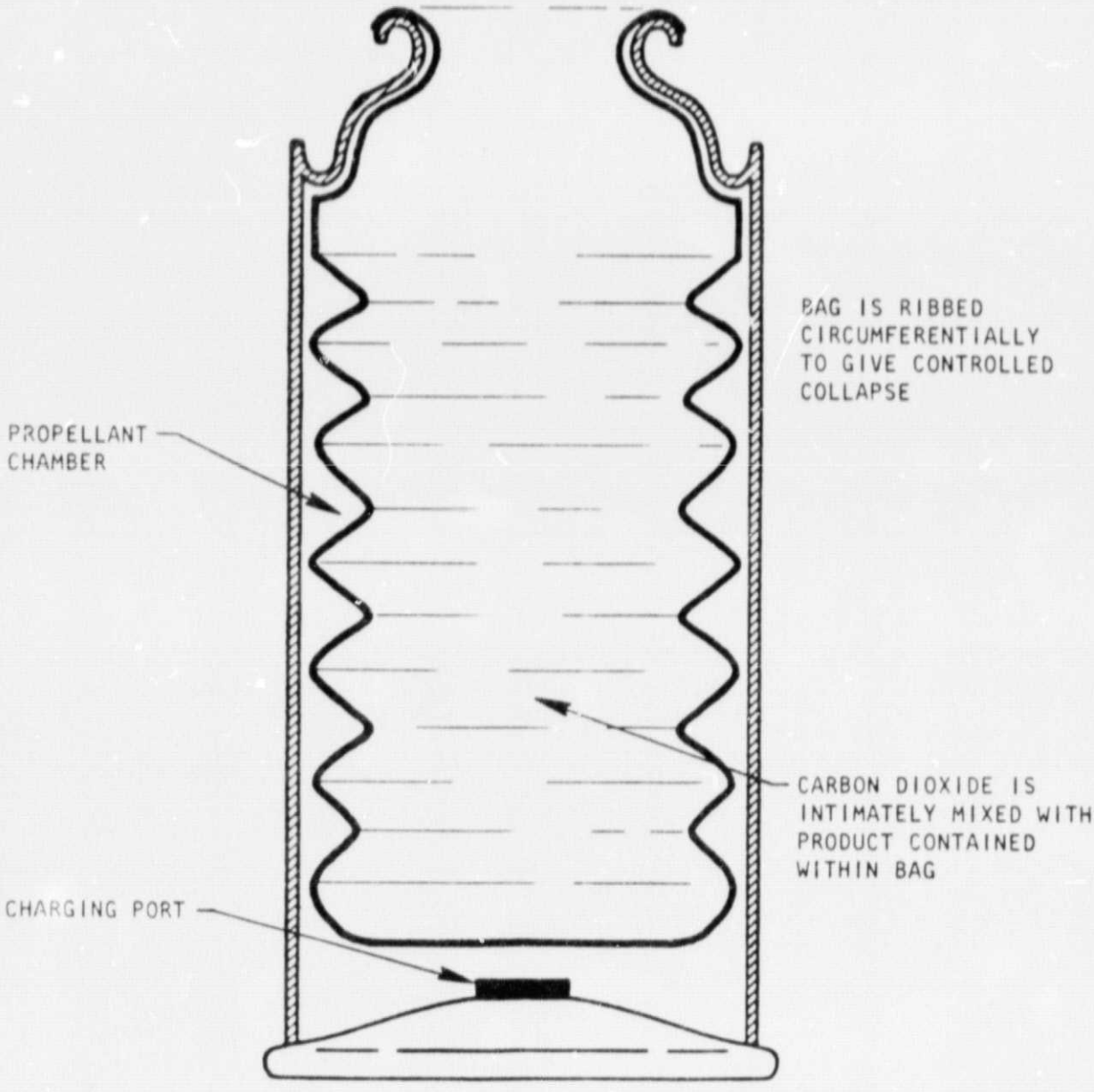


Figure 1. Cross-Section of "Sepro" Container

There are a variety of actuator/nozzles available which affect the size or shape of the extruded foam. Figure 2 shows three types all of which can be easily removed and interchanged. The two round nozzles have inside diameters of 1/16 and 1/8 inch. The wide mouth nozzle has a 1/4 inch flat and is 1/8 inch high.

4.3.1.4 Pressurant. Freon 12 is used as a pressurant between the container and bladder. It is sealed with rubber plug and in normal operation cannot be released to the cabin atmosphere.

4.3.2 Formulations

The formulations were finally revised in October 1977 to take into consideration the use of CO_2 as the foaming agent. They also reflect changes as a result of the zero-g flight program and the Space lab ground test in May 1977.

4.3.2.1 PH-2 - Cleanser, Body and Face

	wt. %
pHIsoHex*	75.00
Hexachlorophene	0.75
Distilled Water	24.25
	100.00%

Directions for Manufacture

Dissolve the hexachlorophene in the water and add this solution to the pHIsoHex. Stir and mix until a homogeneous mixture is formed.

To Pressurize

Above concentrate 100%
Carbon Dioxide to
saturate the concentrate

To Package

Place about 135 grams of concentrate into a 202 x 509 Sepro container. Crimp a Precision Valve in place. Add 16 grams of Propellant 12 to the outer container using special Sepro Can filling device and seal the rubber plug into place. Check pressure with a pressure gauge. Pressure should be about 85-90 psig. Pressurize

*pHIsoHex contains 3% Hexachlorophene in a soap base.

the inner bag to about 5 psi greater than above using carbon dioxide. Repeat several times. Continue with shaking until a saturated solution of carbon dioxide in the concentrate is formed. (Approximately 2.0 to 2.5 grams of carbon dioxide will be taken up by the product.) Depress valve to allow all air to escape so that the bag is collapsed and no vapor is present. Since the bag will be completely filled, there will be no effective pressure within the bag.

4.3.2.2 SM-1 - Cleanser, General Cleaning

	Wt. %
Polawax A-31*	1.39
Anhydrous Ethanol	28.76
Lysol Liquid**	5.00
Propylene Glycol U.S.P.	3.00
Boric Acid, N.F.	0.90
Distilled Water	60.95
	100.00%

Directions for Manufacture:

Heat the Polawax A-31 and the ethanol to 45°C. Heat until dissolved. Heat Lysol, Propylene Glycol, Boric Acid and water to 45°C, and when dissolved add the solution of Polawax in ethanol to this mixture. Continue stirring until a homogeneous mixture is formed.

To Pressurize

Above concentrate 100%
Carbon Dioxide to
saturate the concentrate

To Package

Place 135 grams of concentrate into a 202 x 509 Sepro container. Crimp a Precision Valve in place. Add 16 grams of Propellant 12 to the outer container using special Sepro Can filling device and seal the rubber plug into place. Check pressure with a

*Polawax A-31 is a self-emulsifying, non-ionic wax.

**Lysol Liquid contains o-phenylphenol (2.80%), o-benzyl-P chlorophenol (2.70%), Ethyl Alcohol (1.80%), Xylenolas (1.50%), Isopropyl alcohol (0.90%), Tetrasodium Ethylene Diamine tetraacetate (0.76%), Soap (16.50%), Inert (73.04%).

pressure gauge. Pressure should be about 85-90 psig. Pressurize the inner bag to about 5 psi greater than above using carbon dioxide. Repeat several times. Continue with shaking until a saturated solution of carbon dioxide in the concentrate is formed. (Approximately 2.0 to 2.5 grams of carbon dioxide will be taken up by the product.) Since the bag will be completely filled, there will be no effective pressure within the bag.

4.3.2.3 LSP-2 - Sterilization Agent

	Wt. %
Amphyl*	5.00
Sodium Lauroyl Sarcosinate-95%	4.00
Sodium Lauryl Sulfate, U.S. P.	6.00
Cocoyl Sarcosine	3.00
Distilled Water	82.00
	100.00%

Directions for Manufacture:

Add the sodium lauryl sulfate, sodium lauroyl sarcosinate-95% and cocoyl sarcosine to water and stir until dissolved. Add the Amphyl and stir until a smooth homogeneous mixture is formed.

To Pressurize

Above concentrate 100%
Carbon Dioxide to
saturate the concentrate

To Package

Place 135 grams of concentrate into a 202 x 509 Sepro container. Crimp a Precision Valve in place. Add 16 grams of Propellant 12 to the outer container using special Sepro Can filling device and seal the rubber plug into place. Check pressure with a pressure gauge. Pressure should be about 80-85 psig. Pressurize the inner bag to about 5 psi greater than above using carbon dioxide. Repeat several times. Continue with shaking until a saturated solution of carbon dioxide in the concentrate

*Amphyl contains o-phenylphenol (15%), p-tert-amylphenol (6.3%), Ethyl Alcohol (4.7%), Soap (44.0%), Inert (30.0%).

is formed. (Approximately 2.0 to 2.5 grams of carbon dioxide will be taken up by the product). Depress valve to allow all air to escape so that the bag is collapsed and no vapor is present. Since the bag will be completely filled, there will be no effective pressure within the bag.

4.3.3 Product Specifications.

4.3.3.1 PH2, Body and Face

a) Delivery Rate - 2.6 ±0.5 g/sec
b) pH - 5.6 ±0.2
c) Dispensing Pressure - 75 ±10 psig at 70°F
d) Color - White

4.3.3.2 SM1, Cleanser, General Cleaning

a) Delivery Rate - 2.8 ±0.5 g/sec
b) pH - 7.6 ±0.2 (sample diluted with equal weight of water)
c) Dispensing Pressure - 75 ±10 psig at 70°F
d) Color - Slightly Pink

4.3.3.3 LSP2 - Sterilization Agent

a) Delivery Rate - 2.2 ±0.5 g/sec
b) pH - 5.6 ±0.2
c) Dispensing Pressure - 75 ±10 psig at 70°F
d) Color - Slightly Pink

4.3.4 Stability Studies.

4.3.4.1 Test Plan. The prototype products developed were subjected to stability studies covering a period of one month. The evaluation was in accord with Document No. RD177T3000 "Test Plan".

4.3.4.1.1 Number of Units. Four units of each product stored at

1. Ambient room temperature (approximately 21°C or 70°F)
2. 37°C or 100°F
3. 47°C or 116°F

One unit of each product cycled through 0°F (-17°C) for not less than four hours.

4.3.4.1.2 Time Interval. The units were evaluated according to the following time schedule:

1. One unit - 2 days after filling
2. One unit - 1 week after filling
3. One unit - 2 weeks after filling
4. One unit - 4 weeks after filling
5. The recycled unit (0°F to R. T.) - 2 weeks after filling

4.3.4.1.3 Filled Container Evaluation. Products shall stabilize at 72°±2°F (22° ±1°C) prior to evaluation. Observe and evaluate for these criteria:

a) Distortion of Container — No distortion shall be tolerated. If seamed, no stretching of seam shall be tolerated.

b) Valve Operation — Valve shall operate easily and products shall be dispensed with no sputtering.

c) Leakage — When immersed in water for 15 minutes, no gas bubbles shall appear.

d) Valve Clogging — The valve shall not clog after ten repeated operations and drying. Residue shall not accumulate around the orifice.

4.3.4.1.4 Formulation Evaluation. For the container and valve combination, observe and evaluate for these criteria.

a) Dispensing Character — The product shall be assessed for:

1. Smoothness
2. Feel
3. Foam stability
4. Viscosity
5. Surface tension
6. Foam wetness
7. Overrun (ratio of foam volume to weight)
8. Esthetics (color, odor, appearance)
9. Other properties special to the intended use

b) pH — The pH shall deviate from the intended pH by not more than 0.2 pH units.

c) The pressure shall not deviate from the intended pressure by more than 10 psi. When the product has been exhausted to 10 grams, the pressure shall not deviate more than 15 psi from the intended pressure.

d) Delivery Rate — The delivery rate shall not vary more than 25%.

4.3.4.1.5 Evaluation of Evacuated Container.

After evacuation, cut open container and inspect for:

a) Effect on internal coating, lacquer, plate or metal

b) Effect on seam component

c) Effect on valve mechanism (metal components, elastomeric seals, plastic components)

d) Effect on internal bladder, dip tubes, etc.

No visible degradation shall be tolerated.

4.3.4.2 Results

The results of exposure of the products to the four temperature regimes are discussed below. Some properties including delivery rate and pressure vary from the product specification even at ambient room temperature exposure. This is due to variations inherent with manual fabrication of the packages. Components, particularly the freon pressurant are not at thermal equilibrium and cause variations in fill. In an automatic process, where large numbers of packages are processed, equilibrium exists and component quantities can be closely controlled. In addition, the mechanical operations of sealing the valve assembly and pressure chamber plug are more reliable. However it is not practical to produce a small number of packages on automatic machinery, and these variations do not seriously impact the performance of the packages.

4.3.4.2.1 Package Component Evaluation

There are no significant effects on the package components by any of the products over the period of the test. This includes the internal coating of the can, the seam component, the valve assembly, and the bladder. The use of stainless steel in the valve assembly has eliminated all traces of the discoloration reaction which had been encountered with PH2 with the standard plated assembly. The replacement of providone/iodine by lysol liquid in SM1 has eliminated the detining of the internal coating of the can and the discoloration of the bladder.

4.3.4.2.2 Functional Evaluation

The results of the time-temperature test on the package function are shown in the following evaluation matrix, Table 1.

ITEM NO.	FILLED CONTAINER EVALUATION (RATE BY ACCEPTABLE/NOT ACCEPTABLE)				FORMULATION EVALUATION												
					QUALITATIVE TESTS (RATE BY ACCEPTABLE/NOT ACCEPTABLE)										QUANTITATIVE TESTS (RATE BY SPECIFICATION)		
	DISTORTION	VALVE OPERATION	LEAKAGE	VALVE CLOGGING	SMOOTHNESS	FEEL	FOAM STABILITY	VISCOSITY	SURFACE TENSION	FOAM WETNESS	OVERRUN	COLOR	ODOR	APPEARANCE	DELIVERY RATE (gms/sec)	pH (± 0.2)	PRESSURE CO_2
PH 2	A	A	A	A	A	A	A	A	A	A	A	WHITE	A	A	2.8	5.5	97
SM 1	A	A	A	A	A	A	A	A	A	A	A	SL. PINK	A	A	3.0	7.1	94
LSP2	A	A	A	A	A	A	A	A	A	A	A	SL. PINK	A	A	2.6	5.7	92

TABLE 1a. EVALUATION MATRIX, 2 DAY 21°C

ITEM NO.	FILLED CONTAINER EVALUATION RATE BY ACCEPTABLE/NOT ACCEPTABLE				FORMULATION EVALUATION												
					QUALITATIVE TESTS RATE BY ACCEPTABLE/NOT ACCEPTABLE										QUANTITATIVE TESTS RATE BY SPECIFICATION		
	DISTORTION	VALVE OPERATION	LEAKAGE	VALVE CLOGGING	SMOOTHNESS	FEEL	FOAM STABILITY	VISCOSITY	SURFACE TENSION	FOAM WETNESS	OVERRUN	COLOR	ODOR	APPEARANCE	DELIVERY RATE (gms/sec)	pH (± 0.2)	PRESSURE CO_2
PH 2	A	A	A	A	A	A	A	A	A	A	A	WHITE	A	A	2.5	5.4	75
SM 1	A	A	A	A	A	A	A	A	A	A	A	SL. PINK	A	A	3.2	7.2	100
LSP2	A	A	A	A	A	A	A	A	A	A	A	SL. PINK	A	A	2.4	5.8	90

TABLE 1b. EVALUATION MATRIX, 1 WEEK 21°C

ITEM NO.	FILLED CONTAINER EVALUATION RATE BY ACCEPTABLE/NOT ACCEPTABLE				FORMULATION EVALUATION QUALITATIVE TESTS RATE BY ACCEPTABLE/NOT ACCEPTABLE										QUANTITATIVE TESTS RATE BY SPECIFICATION		
	DISTORTION	VALVE OPERATION	LEAKAGE	VALVE CLOGGING	SMOOTHNESS	FEEL	FOAM STABILITY	VISCOSITY	SURFACE TENSION	FOAM WETNESS	OVERRUN	COLOR	ODOR	APPEARANCE	DELIVERY RATE (gms/sec)	pH (± 0.2)	PRESSURE CO_2
PH 2	A	A	A	A	A	A	A	A	A	A	A	WHITE	A	A	2.9	5.1	100
SM 1	A	A	A	A	A	A	A	A	A	A	A	SL. PINK	A	A	3.0	6.7	90
LSP2	A	A	A	A	A	A	A	A	A	A	A	SL. PINK	A	A	2.8	5.5	100

TABLE 1c. EVALUATION MATRIX, 2 WEEK 21°C

ITEM NO.	FILLED CONTAINER EVALUATION RATE BY ACCEPTABLE/NOT ACCEPTABLE				FORMULATION EVALUATION QUALITATIVE TESTS RATE BY ACCEPTABLE/NOT ACCEPTABLE										QUANTITATIVE TESTS RATE BY SPECIFICATION		
	DISTORTION	VALVE OPERATION	LEAKAGE	VALVE CLOGGING	SMOOTHNESS	FEEL	FOAM STABILITY	VISCOSITY	SURFACE TENSION	FOAM WETNESS	OVERRUN	COLOR	ODOR	APPEARANCE	DELIVERY RATE (gms/sec)	pH (± 0.2)	PRESSURE CO_2
PH 2	A	A	A	A	A	A	A	A	A	A	A	WHITE	A	A	3.3	5.6	92
SM 1	A	A	A	A	A	A	A	A	A	A	A	SL. PINK	A	A	2.4	7.0	92
LSP2	A	A	A	A	A	A	A	A	A	A	A	SL. PINK	A	A	2.3	5.6	75

TABLE 1d. EVALUATION MATRIX, 4 WEEK 21 °C

ITEM NO.	FILLED CONTAINER EVALUATION (RATE BY ACCEPTABLE/NOT ACCEPTABLE)				FORMULATION EVALUATION												
					QUALITATIVE TESTS (RATE BY ACCEPTABLE/NOT ACCEPTABLE)										QUANTITATIVE TESTS (RATE BY SPECIFICATION)		
	DISTORTION	VALVE OPERATION	LEAKAGE	VALVE CLOGGING	SMOOTHNESS	FEEL	FOAM STABILITY	VISCOSITY	SURFACE TENSION	FOAM WETNESS	OVERRUN	COLOR	ODOR	APPEARANCE	DELIVERY RATE (gms/sec)	pH (± 0.2)	PRESSURE CO_2
PH 2	A	A	A	A	A	A	A	A	A	A	A	WHITE	A	A	2.7	5.4	97
SM 1	A	A	A	A	A	A	A	A	A	A	A	SL. PINK	A	A	2.3	7.2	75
LSP2	A	A	A	A	A	A	A	A	A	A	A	SL. PINK	A	A	2.3	5.7	55

TABLE 1e. EVALUATION MATRIX, 1 WEEK 37°C

ITEM NO.	FILLED CONTAINER EVALUATION RATE BY ACCEPTABLE/NOT ACCEPTABLE				FORMULATION EVALUATION												
					QUALITATIVE TESTS RATE BY ACCEPTABLE/NOT ACCEPTABLE										QUANTITATIVE TESTS RATE BY SPECIFICATION		
	DISTORTION	VALVE OPERATION	LEAKAGE	VALVE CLOGGING	SMOOTHNESS	FEEL	FOAM STABILITY	VISCOSITY	SURFACE TENSION	FOAM WETNESS	OVERRUN	COLOR	ODOR	APPEARANCE	DELIVERY RATE (gms/sec)	pH (± 0.2)	PRESSURE CO_2
PH 2	A	A	A	A	A	A	A	A	A	A	A	WHITE	A	A	2.6	5.5	90
SM 1	A	A	A	A	A	A	A	A	A	A	A	SL. PINK	A	A	2.7	7.2	95
LSP2	A	A	A	A	A	A	A	A	A	A	A	SL. PINK	A	A	2.5	5.5	88

TABLE 1f. EVALUATION MATRIX, 2 WEEK 37°C

ITEM NO.	FILLED CONTAINER EVALUATION RATE BY ACCEPTABLE/NOT ACCEPTABLE				FORMULATION EVALUATION QUALITATIVE TESTS RATE BY ACCEPTABLE/NOT ACCEPTABLE										QUANTITATIVE TESTS RATE BY SPECIFICATION		
	DISTORTION	VALVE OPERATION	LEAKAGE	VALVE CLOGGING	SMOOTHNESS	FEEL	FOAM STABILITY	VISCOSITY	SURFACE TENSION	FOAM WETNESS	OVERRUN	COLOR	ODOR	APPEARANCE	DELIVERY RATE (gms/sec)	pH (± 0.2)	PRESSURE CO_2
PH 2	A	A	A	A	A	A	A	A	A	A	A	WHITE	A	A	2.4	5.7	85
SM 1	A	A	A	A	A	A	A	A	A	A	A	SL. PINK	A	A	2.8	7.1	90
LSP2	A	A	A	A	A	A	A	A	A	A	A	SL. PINK	A	A	1.9	5.5	80

TABLE 1g. EVALUATION MATRIX, 4 WEEK 37°C

ITEM NO.	FILLED CONTAINER EVALUATION (RATE BY ACCEPTABLE/NOT ACCEPTABLE)				FORMULATION EVALUATION												
					QUALITATIVE TESTS (RATE BY ACCEPTABLE/NOT ACCEPTABLE)										QUANTITATIVE TESTS (RATE BY SPECIFICATION)		
	DISTORTION	VALVE OPERATION	LEAKAGE	VALVE CLOGGING	SMOOTHNESS	FEEL	FOAM STABILITY	VISCOSITY	SURFACE TENSION	FOAM WETNESS	OVERRUN	COLOR	ODOR	APPEARANCE	DELIVERY RATE (gms/sec)	pH (± 0.2)	PRESSURE CO_2
PH 2	A	A	NA	A	A	A	A	A	A	A	A	WHITE	A	A	2.8	5.5	100
SM 1	NA	A	NA	A	A	A	A	A	A	A	A	SL. PINK	A	A	2.3	6.9	75
LSP2	A	—	NA	—	CAN INOPERATIVE										—	—	0

TABLE 1h. EVALUATION MATRIX, 1 WEEK 47°C

ITEM NO.	FILLED CONTAINER EVALUATION RATE BY ACCEPTABLE/NOT ACCEPTABLE				FORMULATION EVALUATION QUALITATIVE TESTS RATE BY ACCEPTABLE/NOT ACCEPTABLE										QUANTITATIVE TESTS RATE BY SPECIFICATION		
	DISTORTION	VALVE OPERATION	LEAKAGE	VALVE CLOGGING	SMOOTHNESS	FEEL	FOAM STABILITY	VISCOSITY	SURFACE TENSION	FOAM WETNESS	OVERRUN	COLOR	ODOR	APPEARANCE	DELIVERY RATE (gms/sec)	pH (± 0.2)	PRESSURE CO_2
PH 2	A	A	NA	A	A	A	A	A	A	A	A	WHITE	A	A	1.9	5.4	80
SM 1	A	A	NA	A	A	A	A	A	A	A	A	SL. PINK	A	A	2.6	7.2	85
LSP2	A	A	NA	A	A	A	A	A	A	A	A	SL. PINK	A	A	2.9	5.6	100

TABLE 1i. EVALUATION MATRIX, 2 WEEK 47°C

ITEM NO.	FILLED CONTAINER EVALUATION (RATE BY ACCEPTABLE/NOT ACCEPTABLE)				FORMULATION EVALUATION												
					QUALITATIVE TESTS (RATE BY ACCEPTABLE/NOT ACCEPTABLE)										QUANTITATIVE TESTS (RATE BY SPECIFICATION)		
	DISTORTION	VALVE OPERATION	LEAKAGE	VALVE CLOGGING	SMOOTHNESS	FEEL	FOAM STABILITY	VISCOSITY	SURFACE TENSION	FOAM WETNESS	OVERRUN	COLOR	ODOR	APPEARANCE	DELIVERY RATE (gms/sec)	pH (± 0.2)	PRESSURE CO_2
PH 2	A	A	NA	A	A	A	A	A	A	A	A	WHITE	A	A	2.7	5.7	90
SM 1	NA	—	NA	—	CAN INOPERATIVE										—	—	0
LSP2	NA	—	NA	—	CAN INOPERATIVE										—	—	0

TABLE 1j. EVALUATION MATRIX, 4 WEEK 47°C

ITEM NO.	FILLED CONTAINER EVALUATION (RATE BY ACCEPTABLE/NOT ACCEPTABLE)				FORMULATION EVALUATION												
					QUALITATIVE TESTS (RATE BY ACCEPTABLE/NOT ACCEPTABLE)										QUANTITATIVE TESTS (RATE BY SPECIFICATION)		
	DISTORTION	VALVE OPERATION	LEAKAGE	VALVE CLOGGING	SMOOTHNESS	FEEL	FOAM STABILITY	VISCOSITY	SURFACE TENSION	FOAM WETNESS	LVERRUN	COLOR	ODOR	APPEARANCE	DELIVERY RATE (gms/sec)	pH (± 0.2)	PRESSURE CO_2
PH 2	A	A	A	A	A	A	A	A	A	A	A	WHITE	A	A	2.7	5.5	95
SM 1	A	A	A	A	A	A	A	A	A	A	A	SL. PINK	A	A	3.0	7.2	92
LSP2	A	A	A	A	A	A	A	A	A	A	A	SL. PINK	A	A	2.6	5.6	90

TABLE 1k. EVALUATION MATRIX RECYCLED 0°F TO AMBIENT, 2 WEEK

The results up to 37°C exposure are satisfactory. There are somewhat high package pressures, but these can be better controlled in an automatic packager or by altering the manual procedure. At 47°C, while the product properties were completely satisfactory, the packages all leaked some freon causing most of them to become inoperative. As long as there is some liquid freon in the can the package operates normally when returned to ambient room temperature. When the leak continues long enough the product is no longer expelled in the normal manner.

This result differs from that of the original products formulated with freon. Depending on the freon type used, the ambient temperature pressures varied from 35-45 psig for some products to 65-75 psig for others. At elevated temperatures, the internal package pressures did not become excessive. In addition the pressure in the outer container always exceeded the pressure in the bladder. With the freon formulations, storage at 47°C did not present a problem.

With the replacement of the freons with the soluble gas CO_2, pressure problems occur if the quantity of CO_2 dissolved at ambient temperature is high enough. In an attempt to produce the best possible foam, a nearly saturated concentration was used. Two problems occur. First, the bladder pressure exceeds the freon pressure of approximately 70-75 psig, and consequently the bladder expands. In so doing it would contact the plug in the outer container which seals the freon in the can. If the plug is distorted leakage may occur.

The second problem occurs in the excessive pressure developed at elevated temperature as the CO_2 solubility decreases. This can be illustrated by a calculation of the pressure/temperature relationship of CO_2 dissolved in water. (The solubility/temperature relationship of CO_2 in the complex formulations is not known but since water is the major component, this example may be appropriate.) Figure 3 shows the pressure at 47°C for varying masses of CO_2 dissolved in 135 grams of ambient temperature water, with the potential void volume as a parameter. If the container volume is only about 135 cc, the void is essentially zero. But if the container can expand a void can form and the CO_2 will be partitioned between free gas and dissolved gas. The larger the void the lower the pressure. As can be seen, except for large voids and low CO_2 concentration, the CO_2 pressure exceeds the freon pressure at 47°C. Such a mechanism may account for the freon leakage in the new formulations. It is not practical to use a gas as a pressurant in the outer container since the pressure would be greatly reduced as the product is expanded.

The use of stronger package materials was not considered since they are not standard in the Sepro container and would not be economically practical. There is some chance that the batch of cans employed may have been sub-standard or improperly assembled, but this is not too likely.

There are two ways to cope with this problem. One is to limit the allowable storage temperature of the package. Preliminary tests indicate that the package will survive at least 42°C. Commercially, aerosol cans are stored at cool temperatures. The temperatures to be encountered on Shuttle itself present no problems. A second approach to the problem is to limit the quantity of CO_2 to the point where the pressures are acceptable. This would make the foam somewhat more moist and approach a cream consistency.

The recommended approach is to reduce the CO_2 pressure somewhat as is reflected in the revised product specification of 75 psig, and also to limit storage temperatures to about 40 - 42°C. If this temperature is exceeded, the package should be checked for operability before use.

4.4 FEASIBILITY TESTS, TASK 3.4

Feasibility tests were designed to evaluate the performance of the formulations under space conditions as regards limitations of water and materials, and methods of application.

4.4.1 Functional Evaluation

4.4.1.1 Microbiological Evaluation

The efficacy of the three formulations in controlling bacterial growth on personnel and equipment was evaluated.

4.4.1.1.1 Personal Hygiene Agent PH2

The following tests were carried out. Areas of the subjects armpits were marked out for testing. One side was sampled with moist sterile swabs which were used to inoculate nutrient agar plates. The side to be treated was washed with a small amount of PH2 and wiped clean with a sterile moist wash cloth. Samples were taken as before. Two samples of each area were taken for each of two incubation temperatures, 21°C and 37.5°C. The plates were incubated for 48 hours after which colonies were counted. The results were as follows:

	Colony Count	
Incubation Temp.	Untreated Side	Treated Side
21°C	2, 3	1, 0
37.5°C	6, 12	1, 4

In a second test, hands were intentionally soiled by anal region contact. Soil of one hand was eluted with 100 cc sterile water of which 0.5 cc was plated on nutrient agar. The hands were then washed with PH2, using a damp wash cloth for rinsing. The other hand was then eluted with 100 cc sterile water of which 0.5 cc was plated on agar. Colonies were counted after 48 hours with the following results.

	Colony Count	
Incubation Temp.	Untreated Hand	Treated Hand
21°C	TNTC* (both plates)	120, 97
37.5°C	TNTC (both plates)	140, 126

*TNTC = too numerous to count; greater than approximately 300

The conclusion of these tests is that a significant reduction of bacteria occurred.

4.4.1.1.2 System Maintenance Agent, SM1

Four locations in the building were treated as follows. In each location four comparable areas were marked out. Two areas were sampled by rolling moist sterile cotton swabs across the surface and then rolling the swabs over the surface of the agar plates. Two samples were taken for two incubation temperatures. The two areas to be treated were washed with a small amount of sterile water and dried with a sterile cloth. Samples were taken and plated as before. Plates were incubated for 48 hours at 21°C and 37.5°C. The following colony count resulted.

		Colony Count	
Area	Incubation Temp.	Untreated	Treated
Labcounter top, Bacteriology	21°C	4, 6	4, 2
	37.5°C	4, 7	0, 0
Edge, BOD Sink	21°C	45, 57	0, 0
	37.5°C	12, 17	1, 0
Toilet Bowl	21°C	2, 5	0, 0
	37.5°C	8, 13	1, 3
Doorknob, Hallway	21°C	0, 0	0, 0
	37.5°C	2, 2	2, 3

The conclusion is that SM1 is effective in controlling bacteria.

To assess if SM1 exhibited any residual activity, an area of a laboratory bench top was cleaned and then sampled 2 hours and 24 hours later with a sterile moist swab. A contiguous not cleaned area was similarly sampled. Colonies were counted after 48 hours incubation at 37.5°C with the following results.

	Colony Count	
Time After Cleaning	Untreated	Treated
2 hours	18	13
24 hours	12	8
24 hours	7	10

These results are not very conclusive. The agent in the dry state would not be expected to be bacteriocidal.

4.4.1.1.3 Life Science Payload, LSP2

Tests were made of very contaminated environments. Samples were taken of the inside of cubitainers of sewage and industrial waste after the liquid was removed.

Areas were selected and treated in the same way as the previous SM1 tests. The results were as follows.

Sample Area	Incubation Temp.	Colony Count Untreated	Colony Count Treated
Domestic waste	21°C	CM*	3, 6
	37.5°C	CM	0, 0
Industrial waste	21°C	CM	0, 0
	37.5°C	CM	2, 0

*CM = Confluent matte of colonies in swabbed area; individual colonies could not be distinguished or counted.

The conclusion is that LSP2 is very effective in controlling microbial contamination.

To check residual activity, a laboratory counter top was cleaned with LSP2. After 2 hours this area and a contiguous area were sampled. After incubation the untreated surface sample had 40 colonies and the treated surface 25 colonies. There may be residual activity which is manifest when the surface is moistened with the sampling swab.

4.4.1.2 Cleaning Effectiveness

There apparently are no official procedures for evaluating the effectiveness of sanitation agents. The following organizations were contacted in this attempt: Federal Drug Administration, Consumers Union, Consumers Research, Good Housekeeping, Revlon, and Colgate-Palmolive. Subjective tests were therefore employed to assess each product's effectiveness.

4.4.1.2.1 PH2

Based on earlier evaluations during Spacelab tests, the soap content of PH2 was reduced to minimize residual stickiness experienced by some subjects. This goal is essentially accomplished for all test subjects when a moist wash cl[illegible] is used for rinsing. The sanitation agent is easily applied to the skin surface or to a wash cloth and spread over the surface. After working-in, removal of the agent is easy if care is taken between toes and fingers or in body folds. On completion, when the surface is dry, the user feels subjectively clean and refreshed. The appearance of the soiled skin surfaces that are washed are acceptably clean.

The recommended procedure is as follows:

> Apply a small amount to the hand, or preferably to a damp wash cloth. Wipe body surfaces as needed. i.e., face, hands, crotch or whole body. Remove with several damp wash cloths, being sure to cleanse well in body folds.
>
> If adequate water is present, hands may be rinsed under flowing water stream.

4.4.1.2.2 SM1

Surfaces representative of spacecraft systems, including plastic, metal, and painted surfaces were cleaned with SM1. These surfaces are acceptably clean in appearance with the use of a minimum of water. Care must be taken not to apply excessive agent. The agent is easily applied to the surface and removed, although extra care is required in crevices. In these cases, breaking down the foam in the applicator before spreading is effective. When dry, the surface feels clean and is not sticky. The recommended procedure is as follows:

> Use on all habitability surfaces for general cleansing and disinfection.
>
> Apply a small amount of the cleansing agent to the surface, spread with a moist or dry wipe, remove thoroughly with a dry wipe, covering the entire surface and all crevices.

4.4.1.2.3 LSP2

The physical properties of LSP2 are essentially the same as SM1. The surface appearance is acceptable after cleaning soil. The recommended procedure is as follows:

> A strong cleanse and biocidal agent for use on surfaces contaminated with body fluids and solids.
>
> Apply a small amount of the cleansing agent to the surface, spread with a moist or dry wipe, remove thoroughly with a dry wipe, covering the entire surface and all crevices.

4.4.2 Residual Buildup

No problems of residual buildup were identified in either the use of the personal hygiene agent on the skin or in the use of SM1 or LSP2 on typical surfaces. In proper application, small quantities of agent are required and when rinsed or wiped clean, only a small residual remains. Repeated cleaning does not noticeably affect this residual as determined by appearance or feel.

4.5 ZERO-G EVALUATION OF PRESSURE PACKAGED SANITATION AGENTS, TASK 3.5

Zero-G evaluation tests were conducted in November 1976 to verify that the sanitation agent and its dispenser would perform as required at null gravity. These tests were carried out as a "piggy-back" program during scheduled KC-135 flights.

4.5.1 Test Program.

The flight test plan was submitted as Document No. RD177N3001. The test sanitation agents consisted of 15 packages each of PH1, PH2, SM1, SM2, and LSP2. For each agent there were variations of valve, nozzle and fill pressure. The valve size, which affects delivery rate, were either 0.018 or 0.020 inches. The nozzle types were as shown in Figure 2 (section 4.3.1.3). These products, except for PH2, were formulated with freon rather than CO_2. The results however are felt to be applicable to either foam.

Because of the relative brevity (20-30 seconds) of the attainable zero-g interval, testing was confined to short term aspects. Sanitation agent buildup, personnel and material interactions with the agent, and other longer term aspects were determined in ground testing. The flight test investigated the following parameters.

4.5.1.1 Dispensing. The flight test investigated the ability of the pressure packaged sanitation agents to be dispensed to personnel, equipment, or an application agent in a controlled manner. Of concern was the ability to deliver the required quantity of the agent to the surface without losses to the cabin, and without a significant residue at the package aperature.

4.5.1.2 Application. The application of the sanitation agent over the surfaces to be cleaned was studied. Human test subjects included a variety of skin types represented by six male and one female. Equipment surfaces included flat sheets of plastic and aluminum, panels with rivets, heads, cutouts and corners, and screens. The tests were designed to verify that the agents at zero-g could be readily applied and that it could be spread to make proper surface contact for effective cleaning.

4.5.1.3 Removal. Ease of removal of the sanitation agent from the various surfaces was investigated. Complete removal is not necessarily required or desirable. Continuing biostatic action by residual agent is useful, for example, in life science payloads.

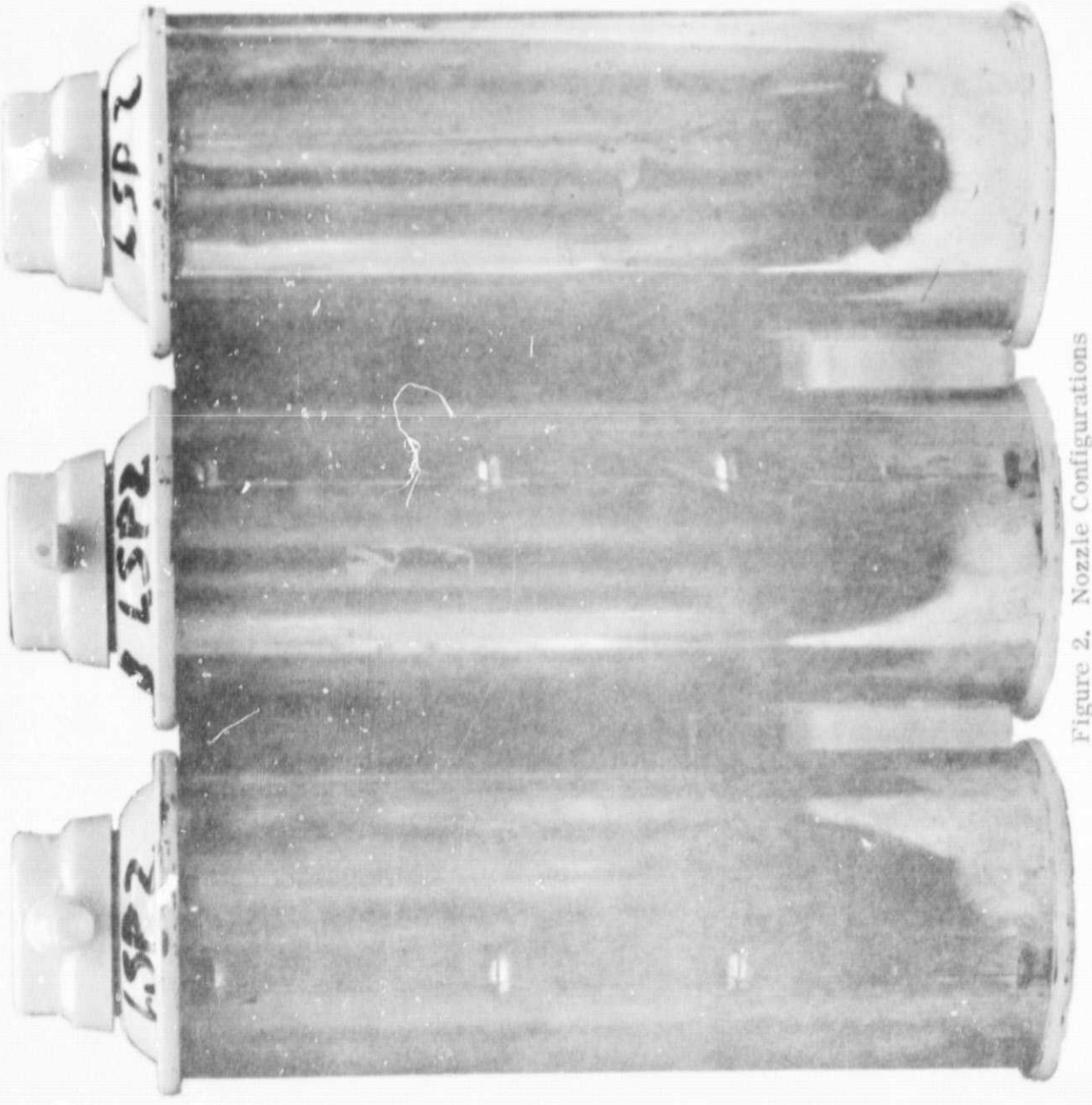


Figure 2. Nozzle Configurations

4.5.1.1 Efficacy. The efficiency of soil removal was subjectively evaluated. In addition various methods of application and removal as well as product acceptability of the personal hygiene agent was evaluated. Microbial samples of surfaces were not collected but were deferred to ground testing.

4.5.2 Test Results.

The zero-g test program was accomplished during three flights. The number of useful parabolas was sufficient to achieve the test objectives. Figure 3 shows part of the test set-up with test subjects restrained in the three front seats while observers assist and record results.

4.5.2.1 Dispensing. Dispensing sanitation agents at zero-g proved to be straightforward and simply controlled. With most packages the product exited the nozzle in a smooth stream with no loss to the cabin environment. In one or two packages, free gas in the package caused some splattering of the foam at the nozzle. The splatter was contained within a small cone and impacted and adhered to the surface at which it was directed without loss to the cabin.

When a stationary package was directed onto a surface, a ball of foam was formed and remained on the surface. If the package is moved along a surface, a line of foam is formed. When directed into space, a straight string of foam was formed which, after travelling several feet, broke up into a series of small foam balls.

With the valve fully open, the delivery rate of the product was about 8.5 grams in 3 seconds for the 0.020 inch valve and 6.5 grams in 3 seconds for the 0.018 inch valve. From the user's point of view there is no significant difference between these. It is slow enough for adequate volume control and fast enough for convenience. In practice, the user modulates the valve opening controlling the rate and delivered volume through visual feedback.

When the valve was closed, foaming action continued so that even after wiping the nozzle orifice clean after valve actuation, the residual volume of product from the valve to the orifice continued to expand and over-run. For freon-based products the expansion continued for 3-4 seconds. With CO_2 products, expansion is complete within one second. Foam is extruded up to about 3/8 inches in length for the wide mouth nozzle and about 1/16 inch for the smallest nozzle.

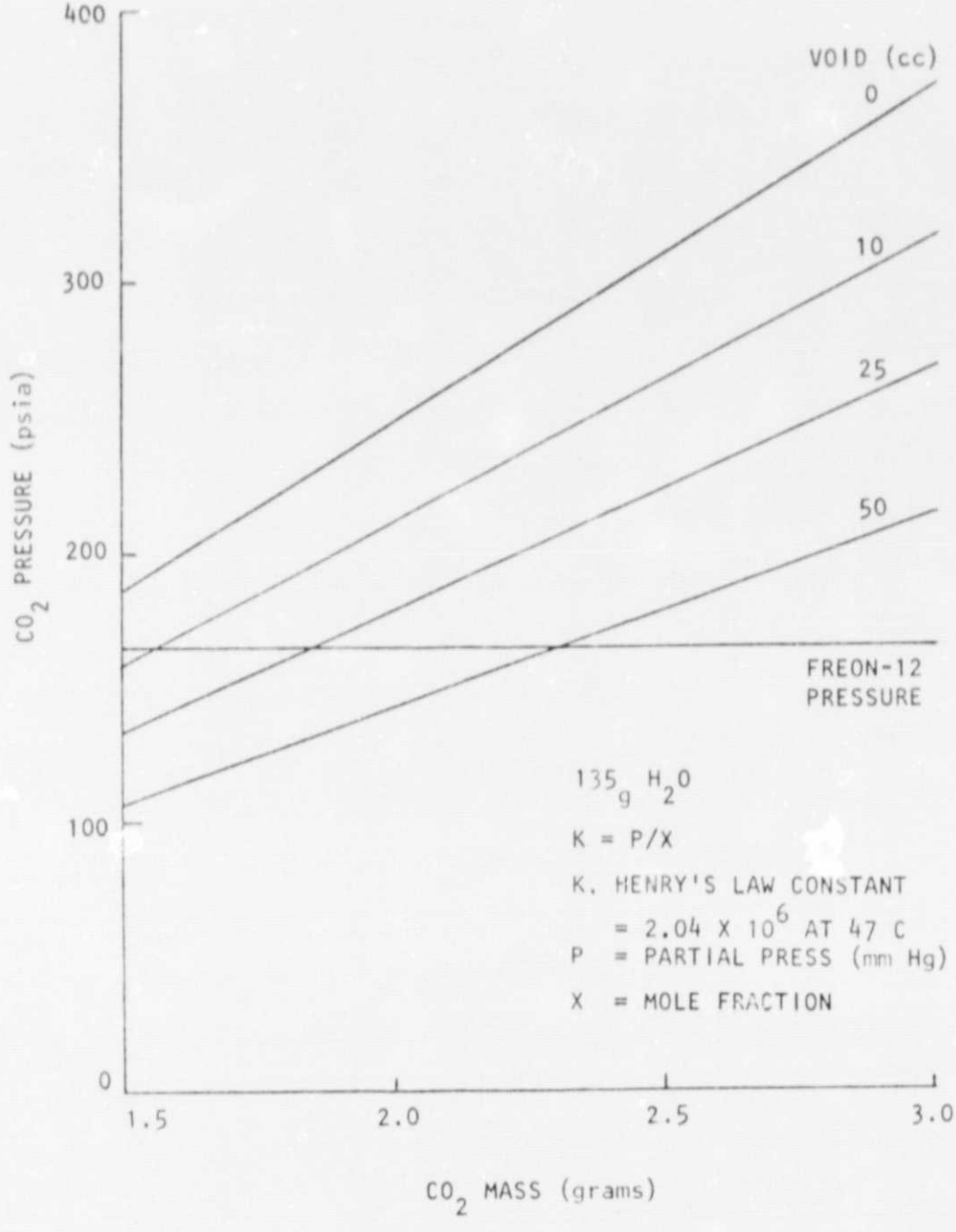


Figure 3. CO_2 PRESSURE AT 47 C

4.5.2.2 Application. Application of the foam over the surface to be cleaned was generally easily accomplished. The foam was spread fairly uniformly without breakaway. Various application techniques were investigated.

a) Personal Hygiene Agents. The agent was applied directly to the hands, or to a wet or dry wipe or cloth and then spread over the required areas. Figures 4 and 5 show test subjects applying the personal hygiene agent. Portions of the body cleaned included hands, face and neck, chest, armpits, legs and feet. With the exception perhaps of the hands most subjects preferred to apply the agent with a wet terry cloth. This probably most nearly resembles a ground procedure. No difficulty was experienced by hairy subjects in spreading and working the agent. Vigorous washing did not cause loss of the agent to the cabin environment. Only by a sharp clapping of hands on the foam was the foam broken away.

b) System Maintenance and Life Science Payload Agents. Application was accomplished by either applying the agent to the surface in a line or by first applying the agent to a wipe. The agent could be spread easily without breakaway. Rivets or beads gave no problems. Foam did tend to creep into folds and collect in inside corners. Results were uniformly good for painted surfaces, plastic or aluminum panels. Some difficulty was encountered with screening such as might be used in animal cages. When the agent was applied directly to the screen, the wipe pushed the foam through the screen and it adhered to the reverse side. If the agent was applied first to a wet wipe, the result was better but some foam was pushed through the screen. Best results were obtained by working the foam into a wet wipe to break down the foam somewhat and then wiping the screen.

4.5.2.3 Removal. Sanitation agent removal was accomplished with wet and dry wipes, and also with wet wipes followed by dry wipes. There was no possibility of sanitation agent loss to the environment since the agent was spread to a thin layer or the foam was broken down. If two parabolas were required for application and removal the agent was often dry before removal was attempted.

With personal hygiene agents the test subjects were most satisfied with a wet wipe removal followed by a dry wipe. Cloth was preferred over paper wipes. Use of a dry wipe only sometimes resulted in a feeling of stickiness by residual agent on the skin. This feeling was most pronounced while the skin was still moist and when completely dry was not always objectionable. With a wet wipe, the agent was readily removed from most body areas including hairy areas. Some difficulty was experienced in complete removal between toes. When dry this too was no problem. The quantity of water in the wipes is small compared to the quantities likely to be allotted on Shuttle. For hand washing on Shuttle a stream or spray of water would be available. For body washes wipes or sponges could be rinsed adequately to insure

Figure 4. Test Set-Up in KC-135.

Figure 5. Seated Subjects Applying Personal Hygiene Agent.

Figure 6. Standing Subject Applying Personal Hygiene Agent.

adequate removal. When the personal hygiene agent was satisfactorily removed, there was no objectional taste to the fingers although some small residual agent may have been present.

All the agents were satisfactorily removed from equipment surfaces either by dry or wet wipes. The wet wipes leave less residual agent on the surface and probably is more effective in removing soil. There was no stickiness to the dried surfaces.

4.5.2.4 Efficacy. When properly applied and removed all agents were effective in removing soil. The subjective assessment of the personal hygiene agent was that it produced a feeling of cleanliness. The reaction was most positive when the subject was sweaty or soiled at the beginning of the flight than later on after repeated washings. In some subjects the odor of the non-functional perfume in the personal hygiene agent was objectional during the first day's flight when there was some flight sickness at zero-g. This scent is perhaps better left off in future formulations.

The general appraisal was that the agents performed their functions well and could be safely and easily applied and removed at zero-gravity.

5.0 CONCLUSIONS

This test program has shown that sanitation agents can be formulated and conveniently dispensed as a foam from packages operable under spacecraft conditions. Three product types have been developed for personal hygiene, general system maintenance, and for use with life science payloads. Application and cleansing with these agents is easy and requires a minimum of water to use and for rinsing. They are effective in cleaning and demonstrate bacteriocidal properties. Because of high pressures developed at elevated temperatures it may be necessary to limit storage temperatures. There would be no problem in the spacecraft environment.