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Waste Management Systems in Mercury, Gemini, Apollo & Apollo Applications Manned Spacecraft

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SUMMARY AND BACKGROUND

Waste management in manned spacecraft has followed a very slow evolution. In short Mercury flights urine was collected in a bag inside the suit and transferred to another holding bag for storage for reentry. No attempt was made to make provisions for collection of feces. Initially the Gemini spacecraft was configured for dumping collected urine overboard through the launch cooling heat exchanger. This concept was changed to a direct overboard dump system before the first manned flight. Urine was collected with a roll-on receiver connected to a membrane bag. After urination, the bag was connected to the overboard dump and emptied, cabin pressure providing positive expulsion. Feces were collected in a hand held bag or defecation glove. This proved to effectively perform the required function but was a less than desirable collection technique. Feces were processed by kneading a chemical disinfectant into the feces. Early in the Apollo program, initial design ground rules dictated a collection technique more similar to those used on earth or in conventional aircraft. The evolution of this system to its current configuration is detailed below.

As longer missions are projected, studies have shown that a better method of processing feces to prevent metabolic activity and resultant noxious gas generation is required and the reclamation of water from urine would be desirable. With the current usage of fuel cells to produce some of the power on the AAP missions, water is plentiful and urine reclamation is not required for a favorable water budget. As shown below, vacuum processing of collected feces appears to be technically acceptable for deactivation of feces although current system configurations require more astronaut manual activity than would be considered desirable on an extended mission.

APOLLO WASTE MANAGEMENT SYSTEM

The Apollo WMS (waste management system) controls or disposes of waste liquids, and gases. The liquids and gases which include urine, water, oxygen, fecal odors, and battery vent fluids, are routed overboard to space vacuum through the ECS (environmental control system) water/urine dump system. The overboard water/urine dump system consists of the following equipment.

Urine Subsystem

a. Urine dump nozzle and heater assembly.

b. Waste stowage compartment.

c. Waste management control panel including shutoff valves and quick disconnects.

d. Stainless steel plumbing.

e. Urine filter - ________________

f. Urine transfer hose.

g. Basic Gemini urine transfer system (receptacle and bag).

h. Quick disconnects.

Fecal Control System

Gemini fecal bags.

Fecal bags stowed in waste stowage compartment after use.

The original Apollo WMS included a urine disposal lock for urine overboard dumping and a fecal canister/blower fecal control system. The original WMS was subsequently redesigned to eliminate the urine disposal lock (UDL) and fecal canister blower in order to simplify system operation and save weight. The new design utilized the cabin to ambient pressure differential of 5 psi to provide the driving force for overboard urine dumping and fecal canister operation. The design change permitted urination directly overboard, thus eliminating the previous two-step urine transfer operation associated with the urine disposal lock. The redesign eliminated the qualification requirements for the UDL and blower, and identified additional testing, including a zero gravity test program, to prove the system.

Extensive laboratory tests were conducted by NASA to resolve a potential urine dump nozzle freezing problem and obtain substantial manned operation data on the direct overboard dump system. The manned tests identified a potential urine backup problem associated with the flow capacity of the system. The 5 psi cabin to space ΔP produced a liquid flow of 1.25 lb/min through the .055 in. diameter urine dump nozzle and a gas flow of 0.4 CFM. Urine backup occurred when the urine flowrate exceeded the system flow capacity, resulting in urine overflow from the urine receptacle and subsequent spillage. This condition is unacceptable for spacecraft operation. In addition, satisfactory fecal canister operation under a 0.4 CFM gas flowrate WMS questioned. NASA subsequently decided to authorize North American Rockwell to conduct a zero gravity test program to resolve the potential problems prior to the Apollo 7 Mission.

North American Rockwell constructed a zero gravity, WMS test fixture, utilizing spacecraft hardware and representing spacecraft plumbing. The zero gravity test program was conducted at Wright-Patterson AFB, Dayton, Ohio, utilizing an Air Force KC-135 aircraft under the cognizance of Air Force, NASA, and North American Rockwell personnel. The zero gravity test program included unmanned and manned tests on the Apollo urine dump system and fecal canister, in addition to evaluation of the vacuum cleaner which also utilized the 5 psi cabin to space bypass for operation. The test results indicated that urine backup was a problem with the existing urine dump configuration and that fecal canister operation was at best, marginal. Various on-the-spot modifications of the urine dump system were tested to preclude the urine backup problem. The data indicated that the problem could be eliminated by designing a plenum chamber with stand-pipe or a piston operated system, both of which would result in additional development and qualification testing. The fecal canister operational problems could also be resolved by conducting additional air flow tests to resolve the air directional/jet flow requirements for adequate fecal matter separation. These changes also required additional development/qualification testing.

In interest in the immediate Apollo 7 Mission and additional program cost, NASA management decided to utilize the basic Gemini urine transfer system and fecal bags previously utilized during the Gemini Program. The Gemini urine transfer system was modified slightly for adaptation to the Apollo WMS interface. Unmanned and manned zero gravity tests were conducted to certify the total system for the Apollo 7 Mission. The present system allows direct overboard urinations and the urine collection bag collects any urine backup caused by excessive urine flow rates.

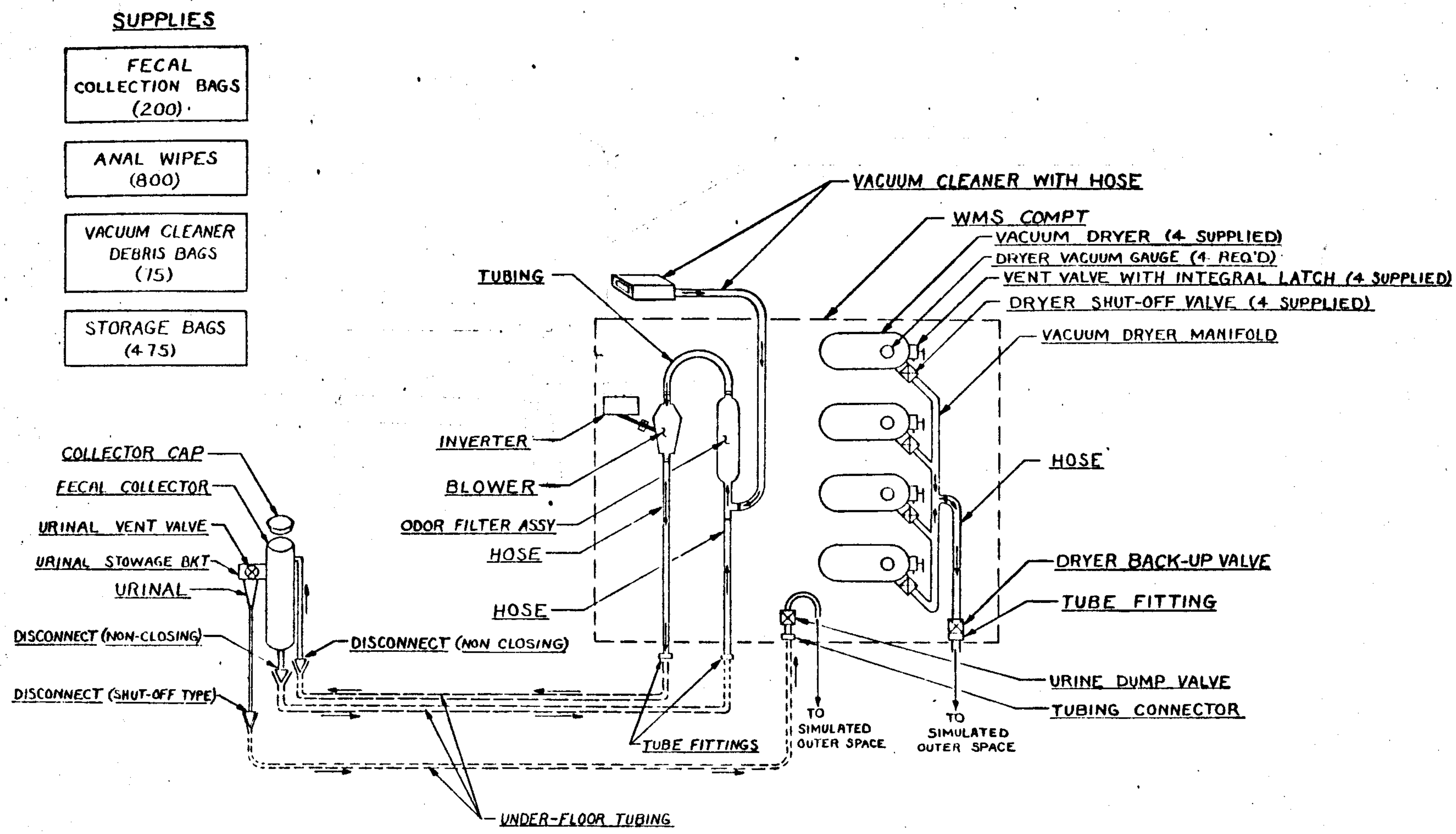
45 DAY EC/LSS WASTE MANAGEMENT SUBSYSTEM

In 1965, MSC contracted with AiResearch Mfg. Division of the Garrett Corporation for the development and fabrication of an environmental control and life support system (EC/LSS) for extended mission Apollo. AiResearch subsequently subcontracted the General American Research Division (GARD) of General American Transportation Corporation to study the requirements for the waste management system. GARD determined that the Apollo system (as configured at that time) could be modified for use on early extended missions (30 to 60 days duration). The waste management system is required to collect urine, feces, vomit and debris and provide disposal or processing for all collected material. The modified Apollo subsystem developed by GARD includes: urine system (identical essentially to the original Apollo subsystem); fecal collection and processing system: porous collection bags, collection cannister, and fecal dryer; and a vacuum cleaner system.

As the EC/LSS development program progressed, extended mission Apollo evolved into the Apollo Applications Program; but, the EC/LSS development was still based on a 45-day mission with a fuel cell power supply providing an ample supply of water. The initial GARD study effort determined the need for a technique for processing feces for extended storage. Tests determined that the chemical disinfectant techniques proposed for the Apollo program's 14-day missions were not feasible for missions longer than 30 days. This determination was based on two facts; the weight of alternate deactivation methods (vacuum drying) become advantageous for missions of 30 days or more, and chemical disinfectants could not prevent gas generation during the storage periods required for extended missions. Development tests were initiated to determine the feasibility and requirements for vacuum processing of feces before storage.

A vacuum drying system with a fixed penalty of 5 pounds would be required to perform the function of 13 pounds of disinfectant for a 45 day mission. Development tests determined that removing as little as 60 percent of the available water in collected feces by vacuum drying would insure deactivation for storage of the material in non-porous containers. It was determined that feces with 50 percent of the water removed would not generate gas during the storage period. In that this was determined as a lower allowable limit, 60 percent water removal for operational hardware was set as the specified required water removal requirement.

GARD did testing to determine a desirable configuration for a flight prototype feces dryer. This program resulted in the GARD model 1276 waste management system dryer built and delivered with the AiResearch 45-day EC/LSS. The entire waste management system is shown schematically on the following page. The vacuum cleaner is identical to the unit GARD developed for Apollo. The fecal collector blower was an available "off the shelf" unit and the collection system has never



SYSTEM SCHEMATIC

been subjected to a zero "g" test program.

After the acceptance test program on the completed hardware, the GARD development engineers recommended the following design changes in any future flight hardware evolving from this system: Modify the dryer cavity to insure good contact between the collection bag and hence the feces with the cavity wall so heat conduction into the material being processed can be improved, redesign the collection bags including this consideration, and change the porous bag material to include provisions for increased tear strength.

AAP ORBITAL WORKSHOP SUBSYSTEM

When the AAP flight program was initiated, the requirement for a waste management system in the Orbital Workshop was determined. In addition to the requirements stated for the system developed by GARD, the OWS system must be configured to collect data and samples for the M-052, Bone and Muscle Changes Experiment. These additional requirements are: 1) ten percent of all urine from each crew man must be collected, in separate samples for each 24-hour period, and dehydrated for return for post-flight analysis and 2) feces for a seven-day period after the mission routine is established must be collected and vacuum dried until 95 percent of the water is removed before storage and subsequent return for post-flight analysis. The higher water removal is required to prevent the feces from changing chemical composition prior to post-flight reconstitution and analysis. The OWS waste management system provides waste management compartment and food preparation area odor and particulate matter removal through the use of compartment ventilation fans and filters; and either a common odor absorber, or odor absorbers integrated as required to prevent any noxious odors from returning to the OWS with the effluent from the various parts of the subsystem.

It has been proposed that the fecal collection system use cabin gas and a blower for pneumatic feces collection using the gas flow as transport media to direct the feces into the collection bag and to aid in detaching feces from the anal perimeter. This system requires the use of anal wipes. The requirement for the more sophisticated technique of a water anal area wash followed by drying with cabin gas has not been identified at this time; although, it may become desirable after further evaluation with zero "g" testing of the pneumatic collection technique. The water wash technique has been incorporated in prototype systems built by General Electric in several programs among which are the MSC Hydro-John project and the MSC integrated waste management and water recovery system developed by Marquardt.

The urine collection system will require a closed or semi-closed loop system using cabin gas as a urine transport media. This requires a phase separator to separate the transport gas from the collected urine prior to the volume determination and sampling operations required for Experiment M-052. Due to the length of the mission, dumping cabin gas overboard imposes a weight penalty in lost cabin gas greater than the fixed weight of the blower and power source. The AAP system will be configured to allow collection of urine and feces using cabin gas flow overboard in case of a power failure in the waste management area as a backup mode.