AMRL-TR-67-158

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AD665457

APPLICATION OF RADIOISOTOPES FOR AEROSPACE WASTE RECLAMATION AND WATER SYSTEMS

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AEROSPACE MEDICAL RESEARCH LABORATORIES
AEROSPACE MEDICAL DIVISION
AIR FORCE SYSTEMS COMMAND
WRIGHT-PATTERSON AIR FORCE BASE, OHIO

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FOREWORD

This research program was a joint effort between the Aerospace Medical Research Laboratories, Wright-Patterson Air Force Base, Ohio, and their contractor, General Electric Company, Valley Forge, Pa., and the Atomic Energy Commission, Washington, D. C., and their contractor, Mound Laboratories, Miamisburg, Ohio. The portion of the work done under contract with the General Electric Company was under contract AF 33(615)-3308. The General Electric Company was the contractor for the water recovery, water system, and waste management. The Ionics Company was the contractor for the potability meter produced under separate contract AF 33(615)-2877 for the Aerospace Medical Research Laboratories.

Courtney A. Metzger, Biotechnology Branch, Life Support Systems Laboratory, Aerospace Medical Research Laboratories, Wright-Patterson Air Force Base, Ohio, was the contract monitor. The research was conducted in support of Project 6373, "Equipment for Life Support in Aerospace," and Task 637305, "Analysis and Integration of Life Support Systems."

This report was published in the proceedings of the 2nd International Symposium on Nucleonics, Columbus, Ohio, 12-14 July 1967.

This technical report has been reviewed and is approved.

WAYNE H. McCANDLESS
Technical Director
Biomedical Laboratory
Aerospace Medical Research
Laboratories

ABSTRACT

For the first time, a life support system designed for aerospace application has been thermally powered by a radioisotope heat source at a significant saving in electrical energy. This report summarizes the research program and resulting design, development, and evaluation of a vacuum distillation-vapor pyrolysis water reclamation system that was subjected to a 30-day isotope powered unmanned test. Data obtained from this program will furnish criteria and guidance for future development. In addition to the savings of electrical energy the application of a radioisotope heat source is expected to result in a simple and more reliable water recovery system producing an excellent quality water without the use of pre- or post treatment for extended periods of operation. Discussed are other water recovery processes that show good promise for the utilization of isotopes for the thermal energy that have been subjected to comparison evaluation using electrical energy. The use of several waste management techniques to obtain a complex integrated system are discussed including urine and fecal collection, fecal storage, potable hot and cold water storage and dispensing, and potability measurements that show promise for the use of the waste heat from the isotopes. This research program was a joint effort with the Atomic Energy Commission and their contractor, Mound Laboratories, who furnished consultation in the area of radioisotopes, the isotopes, capsule design, and facilities for testing.

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SECTION I

INTRODUCTION

Longterm aerospace missions planned for the future dictate the recovery of potable water for drinking and for reconstituting dried food. This water will be recovered from human waste, i.e., urine, perspiration, and vapors expelled through the crewmen's breathing. The recovery of water from human waste is a very lucrative area for weight saving. Each crewmember will consume about 6 pounds of water per day. A crew of 6 will consume approximately 7 tons of water during a year's mission. To launch this weight will require approximately 10,000 tons of booster thrust. If wash water is reclaimed,the weight saving would be even more significant.

In addition to satisfying the crewmen's need for potable water, processes and equipment for their personal hygiene needs are required, e.g., human waste (feces and urine) must be collected and stored or recovered since they cannot be ejected into space.

Many water recovery and waste management systems have been evaluated or developed, fabricated, and subjected to comparison testing in an effort to obtain a system that is reliable and will meet the stringent aerospace specification, including zero-G operation during various space missions.

Only systems and items of equipment that show good promise in the early stages of development are carried through to the fabrication of engineering models. These processes include Vacuum Distillation-Vapor Pyrolysis, Vapor Compression, Thermoelectric Distillation, Electrolysis, Electrodialysis, Reverse Osmosis, Membrane Permeation, Air Evaporation, and Vacuum Distillation.

Of the above mentioned processes, radioisotopes can be utilized more advantageously to provide the thermal energy needed for vacuum distillation and vacuum distillation-vapor pyrolysis. These two processes will be discussed in detail in this paper. The other systems are mentioned only for information on processes that have been subjected to considerable investigation.

The integration of fecal and urine collecting and storage units (see fig 1), a water recovery system with storage and dispensing facilities and a potability meter to provide a complex waste management system will also be discussed.

Figure 1. Integrated Fecal and Urine Collecting and Storage Units

In the past when a system required an excessive amount of electrical energy for its operation, it was discarded although it may have had all the other characteristics needed for an acceptable system. Vacuum Distillation-Vapor Pyrolysis was one of these. After this system was developed, the power required was excessive so the system was discarded and efforts were concentrated on processes requiring less energy. The advent of an acceptable radioisotope heat source resulted in another look-see at the VD-VP process. The system that was designed, fabricated, and tested with the isotopes in place is described. This is the first known time that an aerospace life support system has been thermally powered by a radioisotope heat source.

SECTION II

DESIGN REQUIREMENTS

The following design requirements were utilized for the development of the vacuum distillation-vapor pyrolysis process and water system: The system shall yield 90% of the water in 15 pounds of urine and continue to accomplish this on a daily basis for 30 days. The following environment was considered when the system was under development: Normal earth gravity and zero G, temperature range 15.6°C, pressure 380 to 760 mm Hg, humidity 30 to 80% (relative), atmosphere normal and for 100% oxygen, and acceleration 15 cps at 8 G in any plane. Water storage is available in the system for 5 pounds of hot water, and 10 pounds of cold water. Also storage is available for 5 pounds of waste liquid and 5 pounds of urine solids.

SECTION III

SYSTEMS DESCRIPTION

The system (fig 2) is divided into three main subsystems; namely, collection, processing, and storage (fig 3). The collection subsystem consists of a urinal, phase separator, waste liquid storage reservoir, blower, air filter, and controls. (See fig 4.)

The user micturates into the urinal after starting the phase separator and blower. The urinal has an adjustable orifice that provides a positive and gentle seal. The urine is conveyed (for zero-G operation) by a cabin airstream which enters through the urinal. The urine-air mixture enters the phase separator where the air is centrifugally separated and is drawn through the blower, bacteria-charcoal filter and is vented to the cabin. The urine is pumped to a storage reservoir from which it is metered into the processing subsystem.

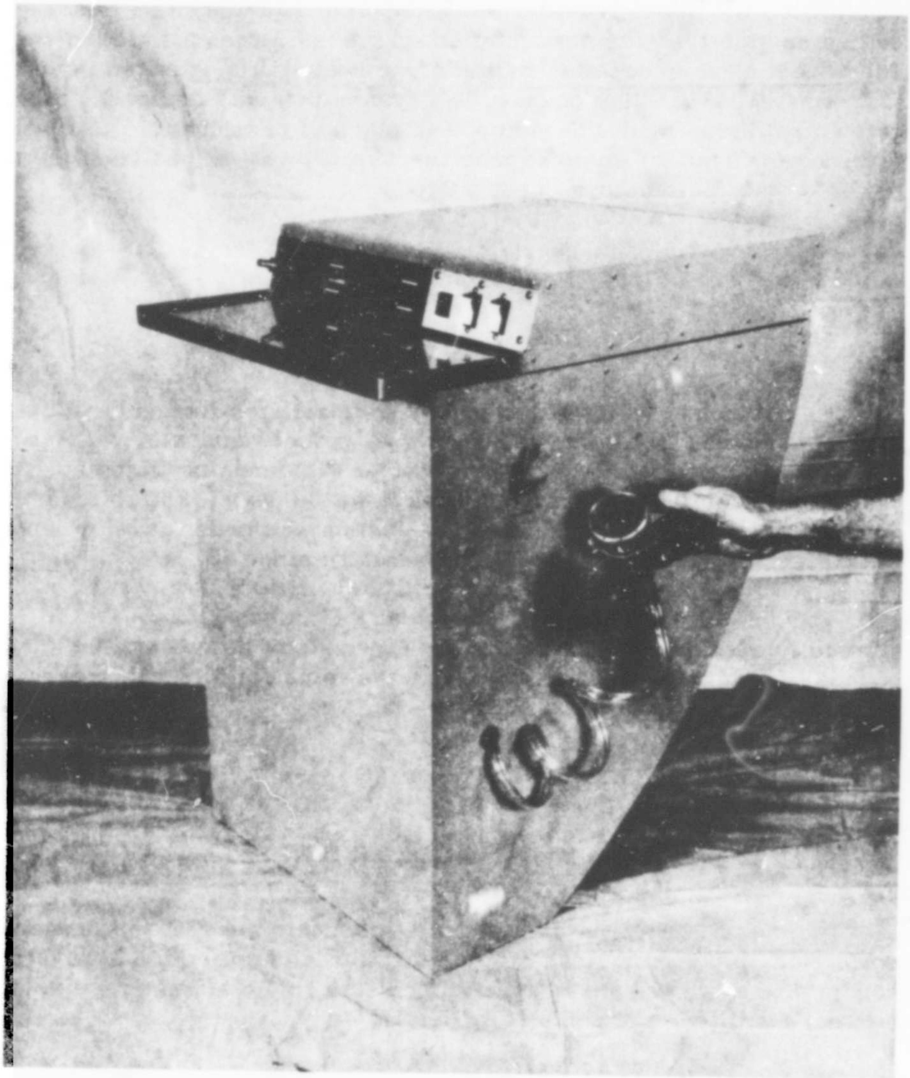


Figure 2. Exterior View - Water Recovery System

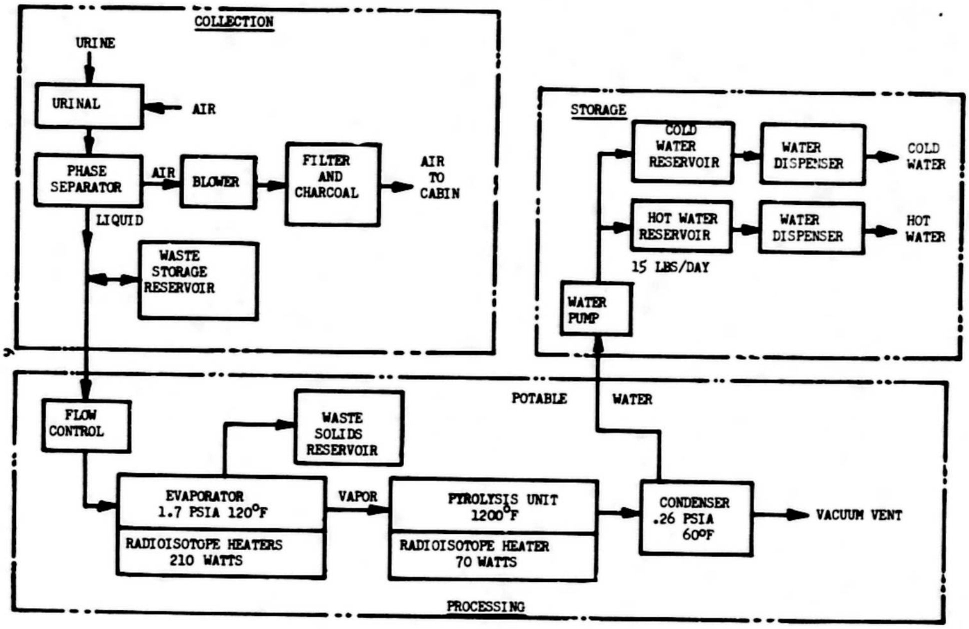


Figure 3. Vacuum Distillation-Vapor Pyrolysis Water Recovery Unit Utilizing Radioisotope Heat Sources

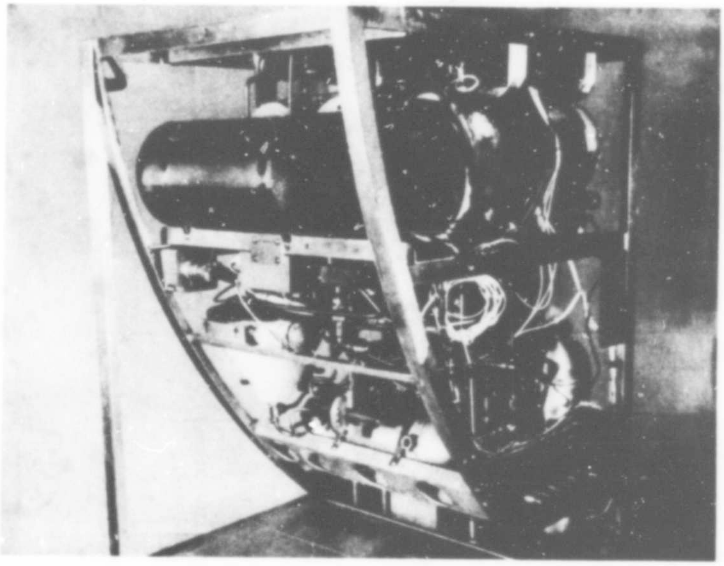


Figure 4. Interior View -Water Recovery System

The processing subsystem consists of an evaporator, pyrolysis unit, condenser, condenser water pump, solids storage reservoir, and controls. The waste liquid is metered into the evaporator by a solenoid valve controlled by a liquid level sensor in the evaporator. The liquid is heated to 48.9°C (120°F) by 210 watts of either radioisotopic heat, electrical heat or waste heat and boils at the reduced pressure of approximately 87.5 mm Hg (1.7 psia). The vapor is passed through a superheating heat exchanger, which assures that liquid is not carried with the vapor flow. The vapor then passes through the pyrolysis unit where it is heated to 650°C (1200°F) in the presence of a ruthenium or rhodium catalyst. The heat is supplied by radioisotope (see fig 5) with an output of 70 watts. The impurities in the water vapor are catalytically reduced and/or oxidized in the pyrolysis unit and are removed via the vacuum vent in the condenser as the water vapors are liquified. Also, any microorganisms in the vapor stream are incinerated, thus providing a sterile vapor. The vapor is condensed at approximately 15.6°C (60°F) which establishes a vapor pressure of approximately 13.2 mm Hg (1.26 psia). The vapor pressure differential between the evaporator and condenser is the driving force which causes the vapor to flow through the subsystem. The water pump is activated by a timed cycle and draws the water from the condenser. The positive displacement piston pump is pneumatically powered from a regulated 90-psig oxygen source. The oxygen is vented to the cabin after it is used to activate the pump; thus, it is consumed by the crew and not wasted.

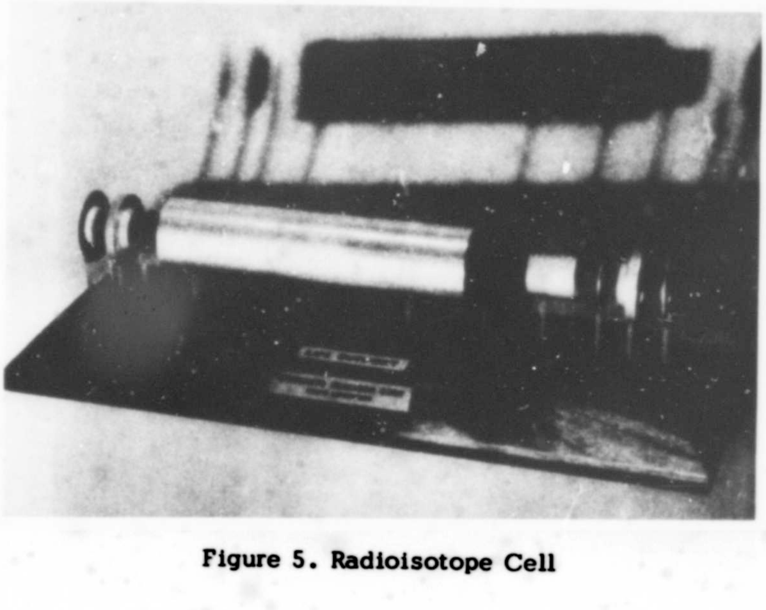


Figure 5. Radioisotope Cell

The urine input onto the evaporator contains approximately 5% solids which are separated from the liquid (vapor) by the distillation process. The solids are then centrifugally conveyed to the storage reservoir by the impeller in the evaporator.

The storage subsystem consists of hot and cold water reservoirs, water dispensers, and controls. The water is pumped through check valves into storage reservoirs pressurized at 23.5 psig. The hot water reservoir check valve has a cracking pressure of 0.5 psig and the cold water reservoir check valve has a cracking pressure of 4.0 psig; therefore, the hot reservoir must be full before the cold reservoir will fill. This assures an ample supply of hot water. The hot water reservoir is heated by the steam from the pyrolysis unit and the cold water reservoir and consenser are cooled by a liquid coolant. The water is dispensed in calibrated amounts as required. This is accomplished by a variable time control which holds the water dispenser solenoid valve open until a calibrated amount of water is dispensed. For example, if 5 ounces of hot water are required to reconstitute a dried food, the user sets the selector switch to 5, attaches his food bag to the hot water dispenser and presses the hot water switch.

SECTION IV

COMPONENT DESCRIPTION

Of the three main subsystems; namely, collection, processing, and storage, the processing section will receive the only detailed description because it is the main topic of this discussion. A full report will be forthcoming in an Air Force publication.

COLLECTION

The collection subsystem collects and transports the urine to an intermediate storage tank. The waste liquid is then metered into the processing subsystem.

PROCESSING

Evaporator Fill Control

The evaporator is filled as required to maintain a certain liquid level. This is accomplished by an ultrasonic-type level sensor in the evaporator. Liquid is added from the waste liquid reservoir by electrically opening two series-redundant solenoid valves, as necessary to maintain the level. Originally, conductivity probes were used for level sensing, but these were short circuited by solid accumulations on the probes.

Evaporator

The urine evaporator (fig 6) is a vessel containing ports for the admission and discharge, respectively, of urine and steam. Heat is provided by 3 electrical heaters, a liquid waste heater or 3 radioisotope heaters, with each heat source integral with its own heat exchanger. A bladed rotor driven at 60 rpm by the evaporator motor and gear box through a "Quad-Ring" shaft seal provides the gravitational field necessary to convective nucleate boiling in a zero gravity environment. The evaporator is constructed of 6061-T6 aluminum, "Tufram" coated for corrosion resistance.

Evaporator Phase Separator

The evaporator phase separator consists of a superheating exchanger and a baffeled exit. Liquid, initially carried with the steam, is vaporized and flows from the evaporator when reheated.

The original design of the phase separator used a slinger and turbine drive, whereby the steam flowing through the slinger's hollow shaft passed through a pinwheel reaction turbine which in turn drove the centrifugal separator (slinger). Difficulties resulted in holding the extremely close tolerances necessary to the impeller-turbine bearings. Accordingly, the turbine was replaced by the static device described above.

Pyrolysis Unit

The pyrolysis unit (fig 7) consists of a counter-flow heat exchanger, a heat source (either electric or radioisotope), catalyst and an evacuated insulation jacket. Steam entering the pyrolysis unit, initially flows through the tubes of the counter-flow exchanger and is heated by the steam leaving the exchanger. Exiting from the exchanger, the steam flows through a tube containing the centrally located heater surrounded by catalyst, the latter performing the additional function of assisting the heat transfer to the steam. Upon leaving the heater, the steam enters the catalyst bed completely surrounding the heater tube, turns and flows back through the catalyst bed to the counter-flow exchanger and out, giving up some of its heat to the incoming steam.

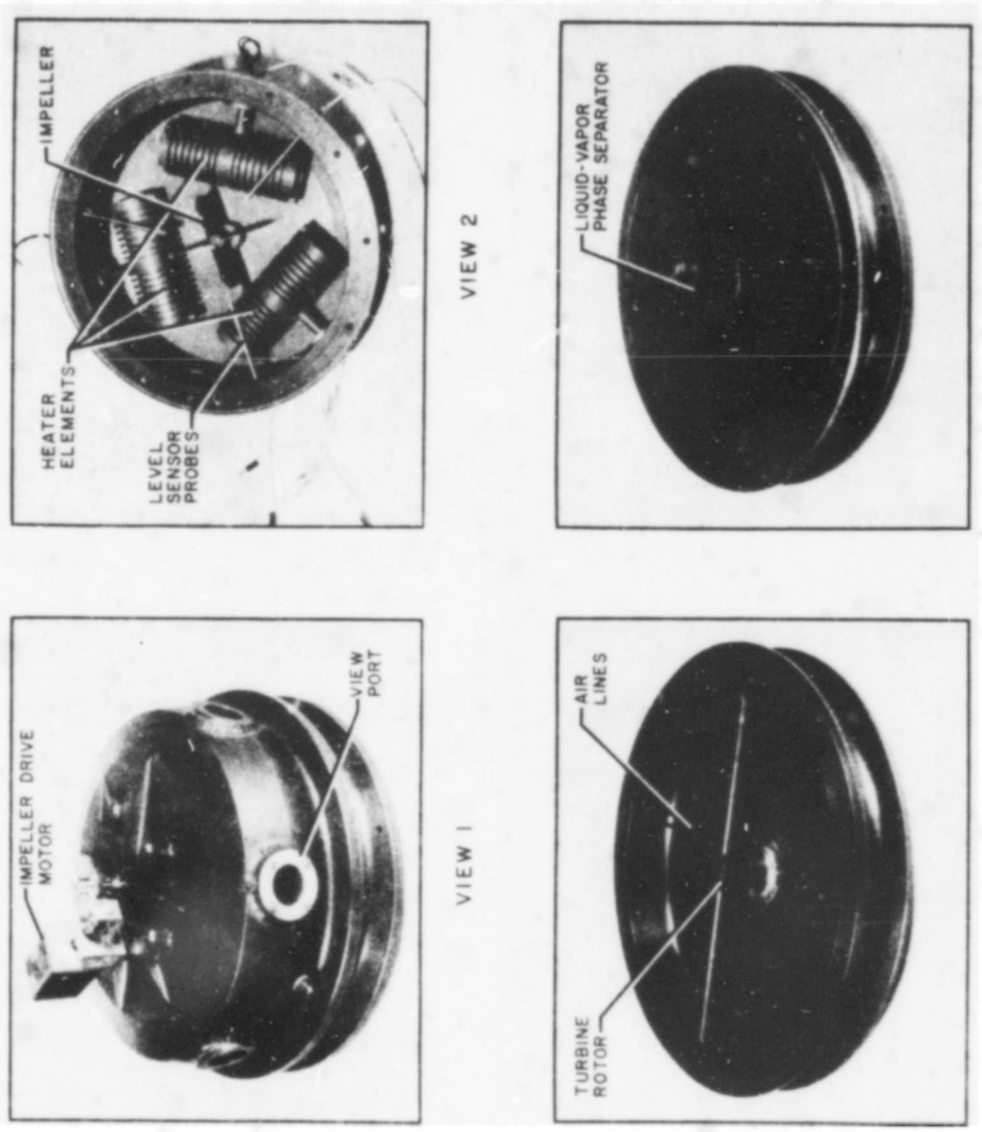
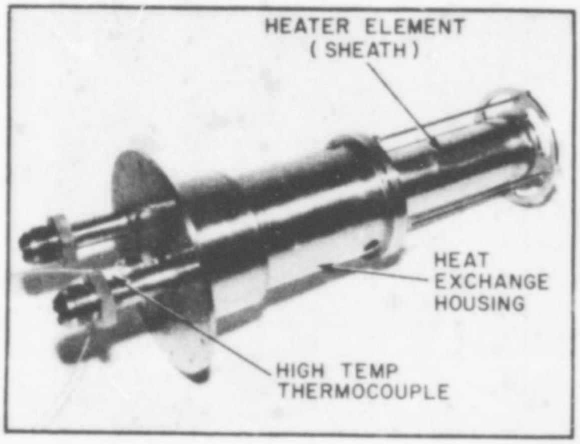
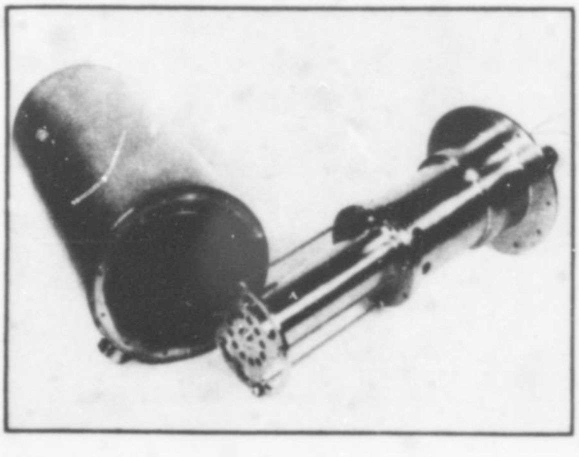


Figure 6. Evaporation Unit

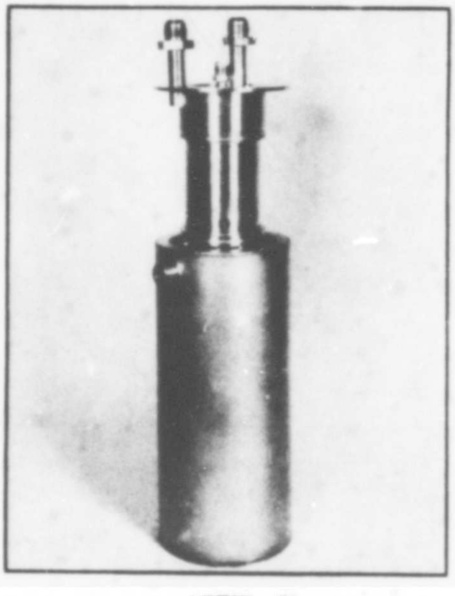


VIEW 1

VIEW 2



VIEW 3



VIEW 4

Early in the design of the program, a steam temperature of 1800°F was believed to be required to effect sufficiently complete ammonia decomposition with a platinum catalyst. Accordingly, Hastelloy X was chosen for the fabrication material, based upon its strength at that temperature and its resistance to corrosion by the common metalurgical test environments. Since no materials performance data were available for Hastelloy X in an ammoniacal environment, tests were run upon tungsten inert gas welded lap joints (with and without Hastelloy X filler wire) and electron beam butt welded joints and tube to bulkhead joints. Tests confirmed the selection of Hastelloy X for this application.

Condenser

The conically shaped condenser is constructed of aluminum with an externally wrapped cooling coil and foam silicone rubber insulation. The condenser is "Tufram" coated for corrosion resistance and nonwetting surfaces; however, a section of the internal surface near the apex is anodized to provide a wetting surface. In a zero-gravity environment, the condensed water will collect in the minimum energy configuration at the wetting surface of the apex. Internally, the condenser has a baffle at the steam inlet to deflect the steam over the cool wall for better heat transfer. The vacuum vent line that controls the system pressure enters the condenser in the steam line. Thus the possibility of the vented gas freezing in vent line is eliminated by the heat transferred from the steam.

Condenser Level Control

The condenser level control consists of an electrical timer which activated the pump at a rate slightly faster than normally required. This assures that the water level will always be controlled at a low level thus providing a constantly large condenser surface area.

Potable Water Pump

The pump draws the potable water from the apex of the condenser. The pneumatically powered positive displacement piston pump produces a suction which draws the water through a check valve and into the cylinder of the pump. Gaseous oxygen then drives the piston forward forcing the water through a check valve into the water storage reservoir. The oxygen is then vented to the cabin for breathing.

Solids Pump

The initial design for the solids pump admitted a slurry of urine solids to a cam actuated solids pump. With rotation of the pump, the piston advanced from the bottom dead center towards top center, first squeezing the slurry and permitting liquid to permeate through a porous plug in the piston head and get behind the piston, simultaneously trapping the solids ahead of the piston. Further rotation exposed the trapped solids ahead of the piston to a discharge port leading to the solids storage reservoir. Rotation past the discharge port then results in retraction of the piston and backflushing the fluid through the porous plug along with admission of additional slurry for the next pumping cycle.

Wear resulting from unanticipated, extremely abrasive action of the solids in the urine indicated the necessity for a different mechanism of solids separation. Accordingly, the port which previously led to the solids pump has been directly connected to the solids reservoir, separation now being effected inertially, using the centrifugal field established by the evaporator rotor. Accordingly, separation is accomplished without the need for the separate solids pump, with the slight penalty of incomplete recovery of liquid.

STORAGE

The storage subsystem stores, heats or cools, and dispenses the potable water. Storage is in three reservoirs with a capacity of 5 pounds of water each. The reservoirs contain elastic expulsion bladders for zero-gravity operation. Two reservoirs are cooled by the coolant loop and one is heated by the steam from the pyrolysis unit. The water is dispensed by the timed actuation valves so that a known amount of water exits for a set time of valve opening.

Another water recovery system "Vacuum Distillation-Vapor Filtered" also shows good promise for the utilization of radioisotopes. The unit (fig 8), which was designed, developed, and fabricated in-house uses the vacuum and cold of space and the thermal energy from electric heaters, waste heat, or the most promising radioisotope heat source. The isotope supplies the thermal energy for evaporating the urine and the heating of the catalyst. The unit is of simple design and has a minimum of working parts. For operation, the preheated urine from the storage tank is drawn into the evaporator to a desired level. The reduced pressure in the evaporator plus the heat cause the water in the urine to vaporize. The vapors pass through a microporous membrane through a catalytic oxidation unit to the condenser where they are condensed and recovered as water. The low temperature-low pressure evaporation of the water from the urine and the passage of the vapors through a microporous membrane and the catalyst provide a recovered product of high quality. The use of space vacuum and cold and radioisotopes make the technique extremely attractive for aerospace applications.

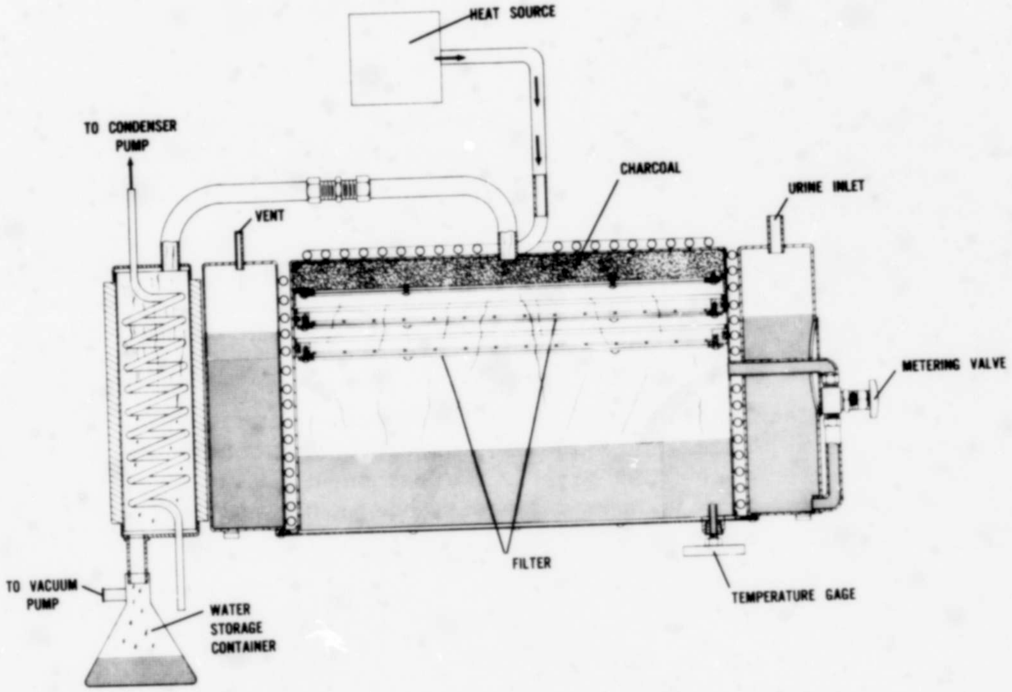


Figure 8. Vacuum Distillation-Vapor Filtered Water Recovery System

POTABILITY METER

The Potability Meter consists of an all-electronic analytical system based on the response of specific-ion electrodes. All system conponents are contained in a lightweight, portable, metal instrument case with overall dimensions of approximately 5 by 10 by 8 inches (see fig 1). Weight is approximately 5 pounds. The interior is accessible via a hinged, latched top and divided into two sections: a compartment containing the sampling manifold with mounted electrodes and necessary valving and a compartment containing all electronic components.

The meter indicates via a go-no go signal when a water sample meets or fails to meet the standards: less than 450 ppm chlorides, less than 2.5 ppm fluorides, pH between 5.5 and 8.0, and specific conductivity not greater than 500 μmhos/cm.

Red and green lights for go and no-go readout, a rotary switch for measurement selection, and valves and tubing connections for the manifold are mounted on the front panel of the instrument. All meter components were selected to give maximum ruggedness compatible with simplicity and ease of adjustment.

SECTION V

CONCLUSIONS

The use of radioisotopic heat sources in space vehicle life support systems has shown good promise and should, in the final analysis, be preferable to other type (electrical or liquid) heaters.

Vacuum distillation-vapor pyrolysis and vacuum distillation-vapor filtered water recovery processes produce potable and sterile water from urine. Recovery efficiencies (urine in versus water out) are good, averaging 93% for the two longest runs. Of the 15 water samples obtained from the vapor pyrolysis process and analyzed throughout the various tests (see table I) four were obviously contaminated when the evaporator liquid level sensor failed and four were slightly contaminated by improper cleaning after a control failure. This leaves seven good samples on which the success of the system is based. Subsequently, the system controls were modified and several tests were conducted using simulated urine (5000 ppm NH_3 in water). These tests confirmed the previous good test results.

ANALYTICAL RESULTS-RECLAIMED WATERS

PROCESS	VD-VP	VD-VP	VD-VP	VD-VP	VD-VP	VD-VP	VD-VP	VD-VP	VD-VP	VD-VP	VD-VP	VD-VP	VD-VP	VD-VP	VD-VP	URINE	U.S. PUBLIC HEALTH DRINKING WATER STANDARDS (1962)
MFR	GE	GE	GE	GE	GE	GE	GE	GE	GE	GE	GE	GE	GE	GE	GE	–	
SAMPLE NO (TC)	313	314	315	316	317	318	319	320	321	322						216	
DATE	9-19-66	11-10-66	11-10-66	12-6-66	12-6-66	12-6-66	12-8-66	12-8-66	12-16-66	12-16-66						9-7-66	
AMOUNT (ml)	–	–	–	–	–	–	–									–	
HEAT SOURCE	E	E	E	RI	RI	RI	RI	RI	RI	RI	E/W	E/W	E/W	E/W	E/W	–	
SPECTROGRAPHIC DATA (ppb)																	
1 ZINC	36	150	26	200	230	14	38	35	63	<5	–	–	–	–	–	<27	5000
2 CADMIUM	<5	<5	<5	<5	<5	<5	<5	<3	<3	<5	–	–	–	–	–	<27	10 R
3 BORON	18	30	18	8	<5	14	<5	7	2	<5	–	–	–	–	–	333	
4 PHOSPHORUS	<20	105	<20	90	60	<25	<25	35	55	30	–	–	–	–	–	[illegible]	
5 IRON	5	25	7	75	25	26	20	40	25	9	–	–	–	–	–	14	300
6 MOLYBDENUM	*	*	*	*	*	*	<10	<10	<10	<10	–	–	–	–	–	<54	
7 MANGANESE	<3	9	<3	8.5	<2.5	<2.5	3.5	<3	<5	<3	–	–	–	–	–	<14	50
8 ALUMINUM	1375	2500	1500	2250	1500	1800	46.5	1000	<2.5	70	–	–	–	–	–	<54	
9 BERYLLIUM	<.03	<.03	<.03	<.03	<.03	<.03	<.03	<.03	<.03	<.03	–	–	–	–	–	<14	
10 COPPER	500	500	350	225	175	6	7	25	<3	<3	–	–	–	–	–	<14	1000
11 SILVER	<.5	5	<.5	<.5	<.5	<.5	<.5	4	<.5	3	–	–	–	–	–	<27	50R
12 NICKEL	<5	20	<5	16	<5	<5	<5	<5	<5	<5	–	–	–	–	–	<27	
13 COBALT	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	–	–	–	–	–	<27	
14 LEAD	<10	<10	<10	45	<10	15	15	40	<10	30	–	–	–	–	–	<54	50R
15 CHROMIUM	<3	17	<3	21	10	<5	<5	<3	<8	<3	–	–	–	–	–	<14	50R
16 VANADIUM	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	–	–	–	–	–	<54	
17 BARIUM	4	12	4	5	14	1	4	80	<1	<1	–	–	–	–	–	<3	1000R
18 STRONTIUM	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	–	–	–	–	–	14	
19 MERCURY	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
20 ARSENIC	<.25	<.25	<.25	<.25	<.25	<.50	<.50	<.25	<.25	<.25	–	–	–	–	–		
CATIONS (mg/l)																	
1 CALCIUM (Ca)	<1	<1	<1	–	–	–	–	–	–	–	–	–	–	–	–	52	
2 MAGNESIUM (Mg)	<1	<.2	<1	–	–	–	–	–	–	–	–	–	–	–	–	102	
3 SODIUM (Na)	<1	1	<1	5	3.1	<1	4	<1	<1	<1	–	–	–	–	–	2200	
4 POTASSIUM (K)	<.5	<.5	<.5	3.1	3.1	0.4	1	<.1	<.1	<.1	–	–	–	–	–	1700	
5 ARSENIC (As)	–	–	–	–	–	–	–	–	–		–	–	–	–	–	–	.05R
6 AMMONIA (NH3/N)	87	250	25	10	6.3	17	8	1500	4.2	3.0	5	3.5	0.03	.003	0.4	–	
7																	
ANIONS (mg/l)																	
1 SULFATE (SO4)	45	60	35	12	9	11	21	25	<1	7	8	–	–	–	0	900	250
2 CHLORIDE (Cl)	9	250	2.5	46	36	6.5	6.5	18	11	4	2.5	30	12	3	5.5	5700	250
3 NITRATE (NO3/N)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	10	45
4 TOTAL PHOSPHATE (PO4)	0.06	0.06	–	4.25	4.28	0.06	0.55	0.02	<.01	<.01	–	–	–	–	–	1400	
5 ABS	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0.5
6																	
OTHER TESTS																	
1 pH	6.2	9.2	9.1	4.1	4.4	5.9	5.2	8.7	4.0	6.3	5.8	4.2	3.9	4.5	5.3	–	
2 CONDUCTIVITY (µmhos/cm)	270	1570	260	265	165	125	170	2000	77	116	120	130	100	25	14	–	
3 TURBIDITY-JACKSON UNITS	–	–	–	0	0	0	0	–	–		–	–	–	–	–	–	
4 COLOR	–	–	–	0	0	0	0	–	–		–	–	–	–	–	–	15
5 ODOR	–	–	–	–	–	[illegible]	[illegible]	–	–		0	0	0	0	0	–	3
6 TOTAL HARDNESS (CaCO3)	<1	<1	<1	14	5	6	6	<1	<1	<1	–	–	–	–	–	530	
7 TOTAL ALKALINITY (CaCO3)	290	1500	356	0	0	226	86	6200	58	52	0	0	0	1	6	92	
8 TOTAL SOLIDS	–	–	–	–	–	–	–	–	–		–	–	–	–	–	–	500
9 CHEM O2 DEMAND	–	–	–	–	–	–	–	–	–		18	144	40	16	23	10000	
10 UREA	88	<.1	<.1	10	10	<.1	<.1	80	<.1	<.1	–	–	–	–	–	5000	
11 TOTAL PLATE COUNT	–	–	–	–	TNTC	–	[illegible]	–	–	[illegible]	0	37	0	0	0	–	
12 TOTAL CARBON	710	35	2800	135	2000	52	4	45	12	3	–	–	–	–	–	6300	

LEGEND:

E/W Electrically heated pyrolysis unit and waste heat liquid for evaporator.

E Electrically heated pyrolysis and evaporator units.

RI Radioisotopically heated pyrolysis and evaporator units.

REMARKS (SEE REMARK SHEET NO.)

— No Data
* Al. interference
** Agar Pour Plate Technique

FORM AMRL-O 9 (ONE-TIME WRMBE 200 CYS - OBSOLETE AFTER 1 JUL 67)
APRIL 65

Table I. Reclaimed Water - Analytical Results

Liquid level controls proved to be the most difficult problem in the water recovery systems. Simplified methods with minimal electronics proved to be the best approach.

Urine solids are extremely abrasive and require special handling procedures. The solids are detrimental to seals, bearings and close tolerance devices.

Static phase separators in the urine evaporator are preferable to dynamic devices because of power considerations and the abrasive characteristics of the urine solids on moving parts.

Although a catalytic oxidizer has not been corporated in the vapor filter system, good quality water has been obtained utilizing only carbon. The addition of a catalytic burner will further improve the quality of water.

SECTION VI

RECOMMENDATIONS

More evaluation is required to determine the optimum catalyst for utilization in the water recovery systems. Catalysts such as platinum, ruthenium, and rhodium have been used successfully. Better catalysts may lower the required operating temperature, but lower temperatures may not sterilize the vapor.

Both reducing and oxidizing atmospheres have been used on the pyrolysis chamber. Exact benefits of each are not known and require further study.

More activity in the area of controls, especially liquid level sensors for zero-gravity environments, is required.

More evaluation of static and dynamic-phase separators in a zero-gravity environment is required.

Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY *(Corporate author)* Aerospace Medical Research Laboratories, Aerospace Medical Division, Air Force Systems Command Wright-Patterson AFB, Ohio 45433	2a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED 2b. GROUP N/A

3. REPORT TITLE

APPLICATION OF RADIOISOTOPES FOR AEROSPACE WASTE RECLAMATION AND WATER SYSTEMS

4. DESCRIPTIVE NOTES *(Type of report and inclusive dates)*

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6. REPORT DATE September 1967	7a. TOTAL NO. OF PAGES 17	7b. NO. OF REFS 0

8a. CONTRACT OR GRANT NO. AF 33(615)-3308 and AF 33(615)-2877	9a. ORIGINATOR'S REPORT NUMBER(S) AMRL-TR-67-158
b. PROJECT NO. 6373	
c. Task No. 637305	9b. OTHER REPORT NO(S) *(Any other numbers that may be assigned this report)*
d.	

10. DISTRIBUTION STATEMENT

Distribution of this document is unlimited. It may be released to the Clearinghouse, Department of Commerce, for sale to the general public.

11. SUPPLEMENTARY NOTES Published in the proceedings of the 2nd International Symposium on Nucleonics, Columbus, Ohio, 12-14 July	12. SPONSORING MILITARY ACTIVITY Aerospace Medical Research Laboratories Aerospace Medical Div., Air Force Systems Command, Wright-Patterson AFB, Ohio 45433

13. ABSTRACT

For the first time, a life support system designed for aerospace application has been thermally powered by a radioisotope heat source at a significant saving in electrical energy. This report summarizes the research program and resulting design, development, and evaluation of a vacuum distillation-vapor pyrolysis water reclamation system that was subjected to a 30-day isotope powered unmanned test. Data obtained from this program will furnish criteria and guidance for future development. In addition to the savings of electrical energy the application of a radioisotope heat source is expected to result in a simple and more reliable water recovery system producing an excellent quality water without the use of pre- or post treatment for extended periods of operation. Discussed are other water recovery processes that show good promise for the utilization of isotopes for the thermal energy that have been subjected to comparison evaluation using electrical energy. The use of several waste management techniques to obtain a complex integrated system are discussed including urine and fecal collection, fecal storage, potable hot and cold water storage and dispensing, and potability measurements that show promise for the use of the waste heat from the isotopes. This research program was a joint effort with the Atomic Energy Commission and their contractor, Mound Laboratories, who furnished consultation in the area of radioisotopes, the isotopes, capsule design, and facilities for testing.

Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Radioisotopes						
Waste management						
Water reclamation						
Life support						
Potability sensor						

Security Classification