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HUMAN WASTE PYROLYZER

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A simple and effective system for thermally reducing and inerting human waste products (feces and urine) has been successfully demonstrated. The modular unit tested should be serviceable by groups of up to 14 men in its present form. Basic system components consist of a 5-gallon collector pail, a liquid-fueled weed burner and a 30 or 55-gallon open-head drum lined with a mineral fiber blanket of insulation to serve as the furnace enclosure. A

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2½ hour burning period will completely reduce a 37 lb (4 gallon) daily waste load to less than ½ lb of dry, sterile, non-polluting residue. Only 1.7 gallons of liquid fuel are required for the complete operation. The only problems encountered were odor (over a 300 ft radius) and occasional burner flame-out.

FOREWORD

This report is submitted in compliance with contractual requirements as directed by the U.S. Army Land Warfare Laboratory, Aberdeen Proving Ground, Maryland, under Contract No. DAAD05-74-C-0723. Mr. Harold H. Rosen, Biological Sciences Branch, served as Technical Supervisor for the work. We would like to acknowledge his recommendations and suggestions for the basic approach and system components used in the process.

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1. INTRODUCTION

The disposal of human feces and urine in remote and/or temporary encampments has become a pressing problem with the stress on ecological protection. Straddle trenches, pit latrines and burnout latrines are no longer acceptable except as emergency measures. In addition, extreme climates such as that in Alaska negate even those methods.

The objective of this work was to develop, demonstrate, and assess a simple means of incinerating human waste that would work even in extreme climates with minimal logistic burden or ecological pollution. Design improvements were investigated which would simplify and add to the overall efficiency of the operation.

The basic system components used in accomplishing this thermal reduction of waste consisted of the following:

(1) A commercially available 2-gallon weed burner as the heat source (Sears "Multi-Purpose Torch and Weed Burner," Model 471112; Kerosene or No. 1 Fuel Fired).

(2) A 5-gallon standard 11-1/2 x 13-1/2 inch open-head drum with carry handle, as the collection bucket. A simple wooden latrine seat could be made to fit over this drum (see Figure 1).

(3) A 30-gallon 18-1/2 x 27-1/2 inch open-head drum as the furnace. It was lined with a 1/2 to 1 inch sheet of mineral wool (Fiberfrax) insulation. The weed burner was positioned beneath the suspended collection bucket through a 6 x 6 inch hole cut in the furnace drum near its base.

2. THEORETICAL

2.1 Design Basis - Quantities, Composition, and Heat Loads

The system was designed to cope with the feces and urine output of a 14 man squad. The average per capita output of feces quoted by various sources is approximately 0.25 lbs. of feces per day (1,2). One bowel movement per day is considered average although variations exist according to diet and individual habits (3). For example, a high protein diet devoid of vegetable cellulose would produce very little fecal matter.

Urine quantity is approximately 450cc per voidage for an average man (3). For design purposes, one voidage at the time of each bowel movement will be assumed.

The composition of feces consists of 20 percent solids (indigestible remnants of foods, namely, proteins, fats, cellulose, and salts) in mixture with approximately 80 weight percent water (3,4). Urine consists of 4 percent solids mainly urea and salts with 96 percent water (4).

The thermal reduction process under investigation will volatilize the water and partially decompose the organics, leaving a small volume of dry sterile residue.

Table 1 summarizes the solid/liquid waste components produced daily by an average 14 man squad. A "safety factor" of two bowel movements per man per day has been incorporated for design purposes.

Table 1

Solid/Liquid Waste Components Produced Daily by a 14 Man Squad

	Weight, lbs	Volume, gal
Feces @ 0.50 lb/man)*	7.0	0.12
Urine @ 900 cc/man)*	29.9	3.36
	36.9 lbs	3.48 gal

*2 bowel movements per man per day assumed for design.

Note that both the weight and volume resulting will be manageable in a 5-gallon container.

Heat for vaporizing the water component will be the primary heat load in the process exclusive of heat losses to the environment. The total water content in the 36.9 lbs of mixed wastes is 34.3 lbs (93%). A total of 40,200 BTU will be theoretically required to heat this water from 40°F to 212°F and to evaporate it. Burning one gallon of liquid fuel such as kerosene or No. 1 fuel oil at 2,000°F produces 152,000 BTU. Therefore, roughly 0.264 gal. of liquid fuel will be required to thermally reduce the total waste load from 14 men. Heat losses from the crude drum furnace should increase this fuel quantity by a factor of approximately 4-5 (5).

2.2 Process Analysis

The thermal reduction process will consist of three operations, namely (1) evaporation; (2) drying; and (3) partial combustion/decomposition. These operations will take place in a batchwise sequential manner. Evaporation and drying will take place near the atmospheric boiling point of water (viz 212°F), with combustion/decomposition occurring between approximately 1000-2000°F. The working flame temperature that can be expected from air burning of liquid fuels is approximately 2000°F.

The optimum rate of heat delivery for the evaporation and drying steps is not the maximum rate of heat delivery to the exterior heat transfer surface. Nucleate boiling is the desired phenomenon at the interior heat transfer surface of the 5-gallon drum. If film boiling should set in, as a result of too high a heat-flux or interior surface temperature, then heat pickup by the semi-solid mass will actually decrease (the thick gaseous film of low thermal conductivity that will develop at the drum's surface will serve as an insulator). Nucleate boiling, where bubbles of vapor form and rapidly travel away from the interior heat transfer surface, will deliver the maximum amount of heat/unit time to the drum contents. Film boiling could be suppressed if mechanical agitation of the system were possible. However, this would not be acceptable to the present operation.

Empirical observation of the boiling rate is the best way of ensuring the presence of nucleate boiling. If the 2000°F flame is too close to the can less bubbling will be seen. If the can is heated by tempered combustion gases, boiling action will be accelerated. A distance of 6-10 inches between flame and can should keep the contents under nucleate boiling conditions.

When the evaporation step is ended, boiling will cease. However, a high heat flux is still undesirable at this phase. Premature charring of the material at the surface could occur which might impede drying. This phenomenon would not be highly significant since the drying step will be of relatively shorter duration than the evaporation step.

The final step, combustion/decomposition should occur relatively fast and at temperatures of 1000-2000°F, as produced by the 2000°F flame.

A relatively simple and apparently acceptable method of potentially accelerating the evaporation/drying steps would be to place an iron chain at the bottom of the 5-gallon can. This would provide additional heat transfer surface, serve as a heat sink to stabilize the burning process, and enable an easy clean-out of the char from the can bottom.

3. EXPERIMENTAL

3.1 Preliminary Small Scale Experiments

A great deal was learned about system behavior and performance as a result of several small scale experiments. These were conducted primarily to become familiar with the materials' qualitative behavior.

One pound coffee cans were used, with small amounts of both simulated and actual human wastes. Simulated wastes consisted of canned dog food, which physically approached the composition of human wastes quite closely. Water was added to simulate urine.

The most significant thing learned from these small scale tests was that the chain on the can bottom did little to improve the operation. The chain links did not contact the can bottom very well, except at a few points; therefore, it appeared that the chain may actually have been impeding natural agitation and evaporation.

3.2 Large Scale Experiments

Collection of large quantities of human waste took place using the setup shown in Figure 1. An ordinary office chair with its seat removed and replaced by a glued-down toilet seat was positioned above the 5-gallon collection can. A board with a hole can be used as a field expedient if necessary. Wastes were collected from volunteer laboratory personnel. Approximately 1 gallon of mixed feces and urine was collected.

Pre-announcement and five hours of active solicitation to approximately 40 men in the laboratory produced 20% participation and approximately 1-gallon (2.7 inches) of human wastes. This is the equivalent to 8 bowel movements.

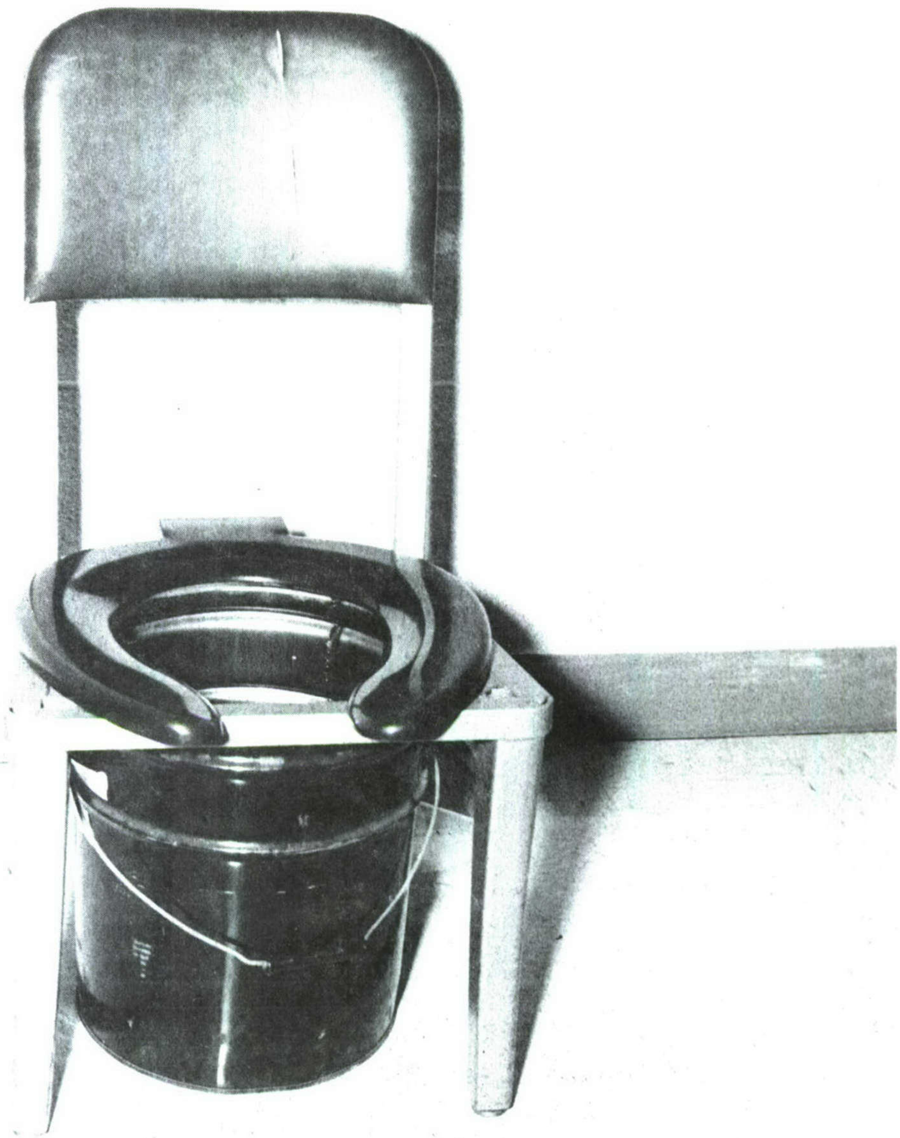

Figure 1. Waste Collection

The 5-gallon can was suspended 6 inches above the flame by a 1/4 inch steel rod, through its handle. Supporting the can on bricks was also found to be satisfactory. Ambient conditions during the experiment were:

Temperature	74°F
RH	56%
Wind	5-15 mph
Barometer	30.00

Vigorous boiling as evidenced by the formation of a 1 to 2 inch continuous layer of surface bubbles occurred. Liquid contents remained at approximately 220°F during the evaporation. No spattering occurred. Approximately 45 minutes were required to reduce the 1-gallon batch. Approximately four flame-outs occurred during this period. It appeared that the weed burner flamed-out when air pressure dropped below 20 psig. This occurred after about 10 minutes of operation.

Figure 2 shows the pyrolyzing equipment in operation. Figure 3 shows the inside of the 5-gallon can during operation, while Figure 4 shows the residue at the end of the burn-out.

Odor was a problem for a radius of approximately 300 feet even though there was a strong breeze.

Approximately 1/2 gallon of kerosene was used to reduce the 1-gallon of waste to dryness in the 45 minute period. This amounts to 0.062 gallons of kerosene per bowel movement or 1.73 gallons kerosene per 14 men (using the safety factor of 2 bowel movements per day per man). This is 6.7 times the theoretical fuel consumption. This is not bad for a simple furnace construction.

One gallon of water was added to the dried residue and the experiment repeated. A 35 minute burn-out period was recorded for the reconstituted material. This is a reasonably close check to burning out 1-gallon of material. Less than 1/2 lb of residue remained in the can at the conclusion of the pyrolysis.

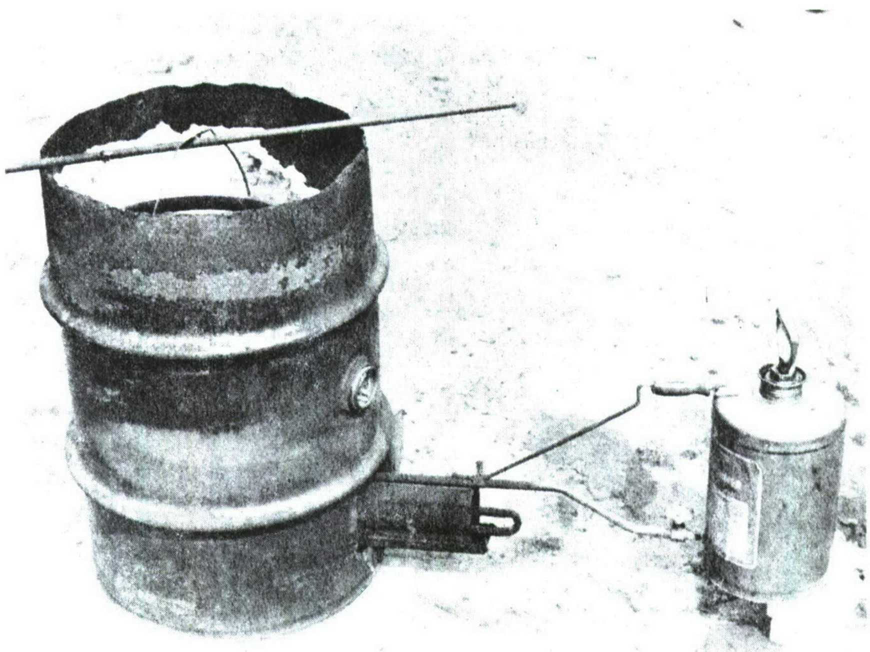

Figure 2. Pyrolyzer in Operation

Figure 3. View Inside of Operating Pyrolyzer

Figure 4. Residue

Burning out the 3.4 gallons of wastes from a 14-man squad should take 153 minutes (2 hours 33 min.). Fuel consumption would be approximately 1.7 gallons of kerosene. A significant reduction in operating time will occur if urine voidance during defecation can be avoided. Steady burner operation with equipment such as was used in the present experiments would require frequent operator attention. On the basis of the present results it appears that 1 collection pail would last for at least 5 burn-outs and possibly as many as 10. Inspection of the bottom of the 5-gallon can following burn-out showed but little sign of corrosion.

CONCLUSIONS

1. The basic system design as submitted by USALWL works with reasonably high efficiency and convenience.

2. A 5-gallon can is of adequate size to collect the daily waste output from a 14 man squad.

3. A 2-1/2 hour burn-out period will completely reduce the wastes from 14 men to dryness; using 1.7 gallons of either kerosene or No. 1 fuel oil.

4. Sputtering, foaming, or boil-over are not a problem. However, objectionable odors can be detected for a radius of 300 feet.

RECOMMENDATION

The US Army Troop Support Command, the designated parent agency for the human waste pyrolyzer, should pursue further development and testing, including field testing and user evaluation, along the lines initiated in the present study with particular emphasis on arctic requirements.

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