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Bridgforth, Jr. et al.

[11] **3,773,574**

[45] **Nov. 20, 1973**

[54] **ROCKET PROPELLANT COMPOSITION INCLUDING HUMAN BODY GENERATED WASTE MATERIALS**

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[21] Appl. No.: **630,562**

[52] **U.S. Cl.** **149/22,** 149/18, 149/19, 149/40, 149/41, 149/42, 149/43, 149/44, 149/37

[51] **Int. Cl.** **C06d 5/06,** C06d 5/10

[58] **Field of Search** 149/18, 19, 44, 109, 149/22, 37, 41, 42, 43

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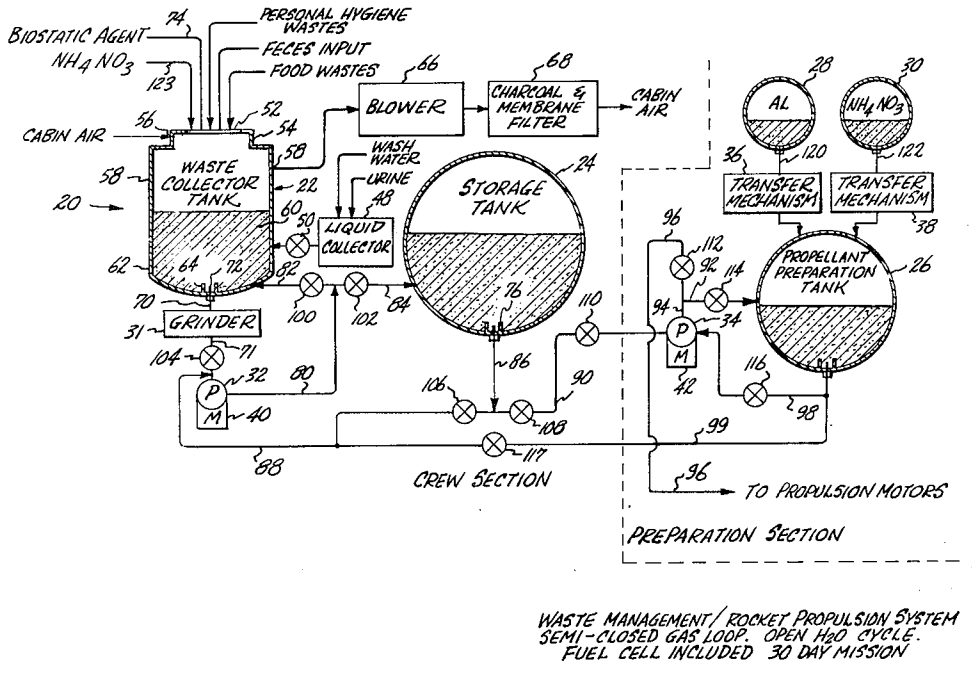
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[57] **ABSTRACT**

A system and method for utilizing and disposing of carbonaceous waste products accumulated aboard a spaceship, including human body generated wastes and other carbonaceous wastes, by processing the waste products into rocket propellants and utilizing such propellants for spaceship propulsion. The propellant compositions thus formulated are characterized by the presence of one or more fuel constituents and one or more inorganic oxidizer constituents (e.g., ammonium nitrate) in homogeneous admixture with the human body generated waste materials (e.g., human excrement).

13 Claims, 11 Drawing Figures



WASTE MANAGEMENT / ROCKET PROPULSION SYSTEM
SEMI-CLOSED GAS LOOP. OPEN H_2O CYCLE.
FUEL CELL INCLUDED 30 DAY MISSION

Patented Nov. 20, 1973 3,773,574

4 Sheets-Sheet 1

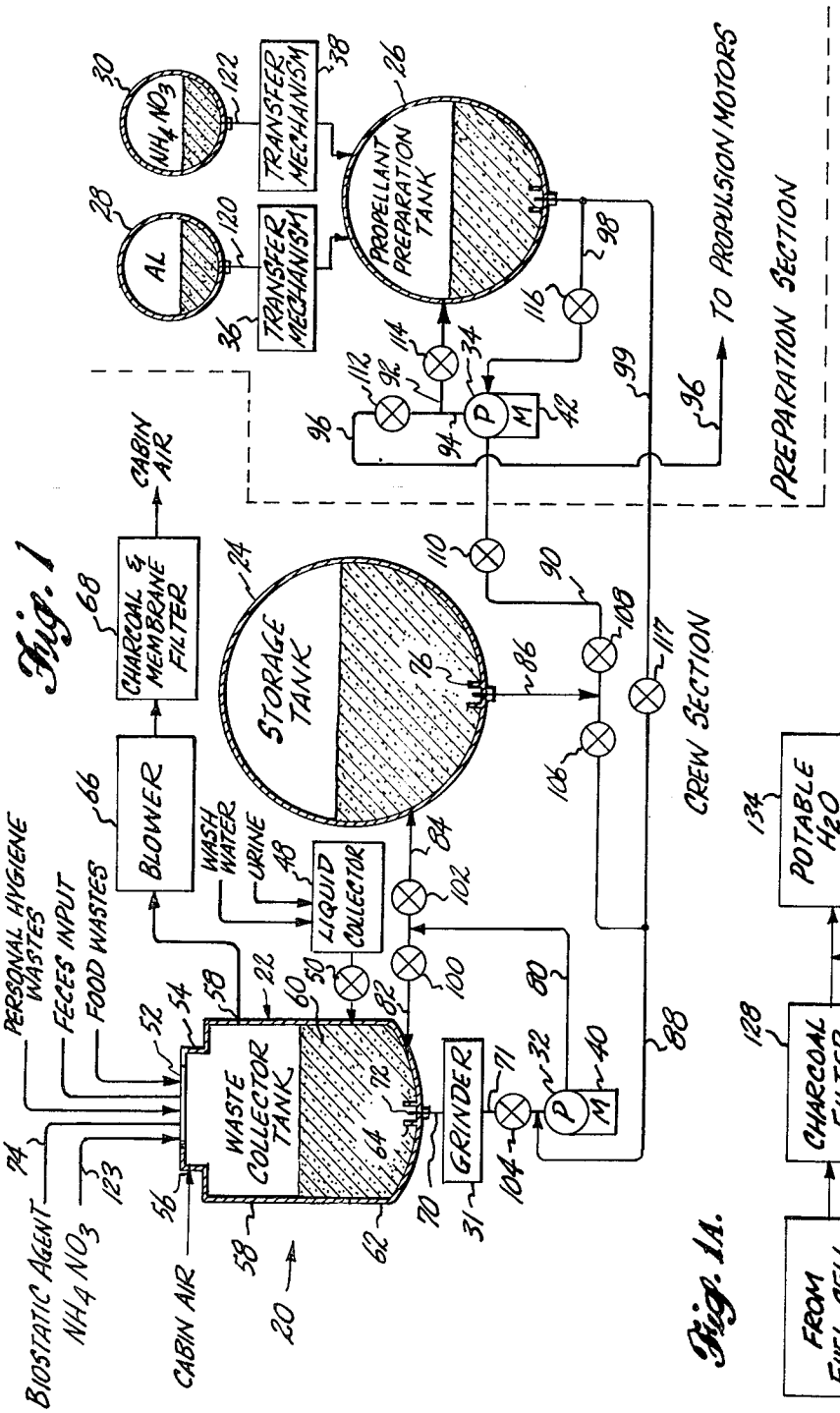


Fig. 1

Fig. 1A.

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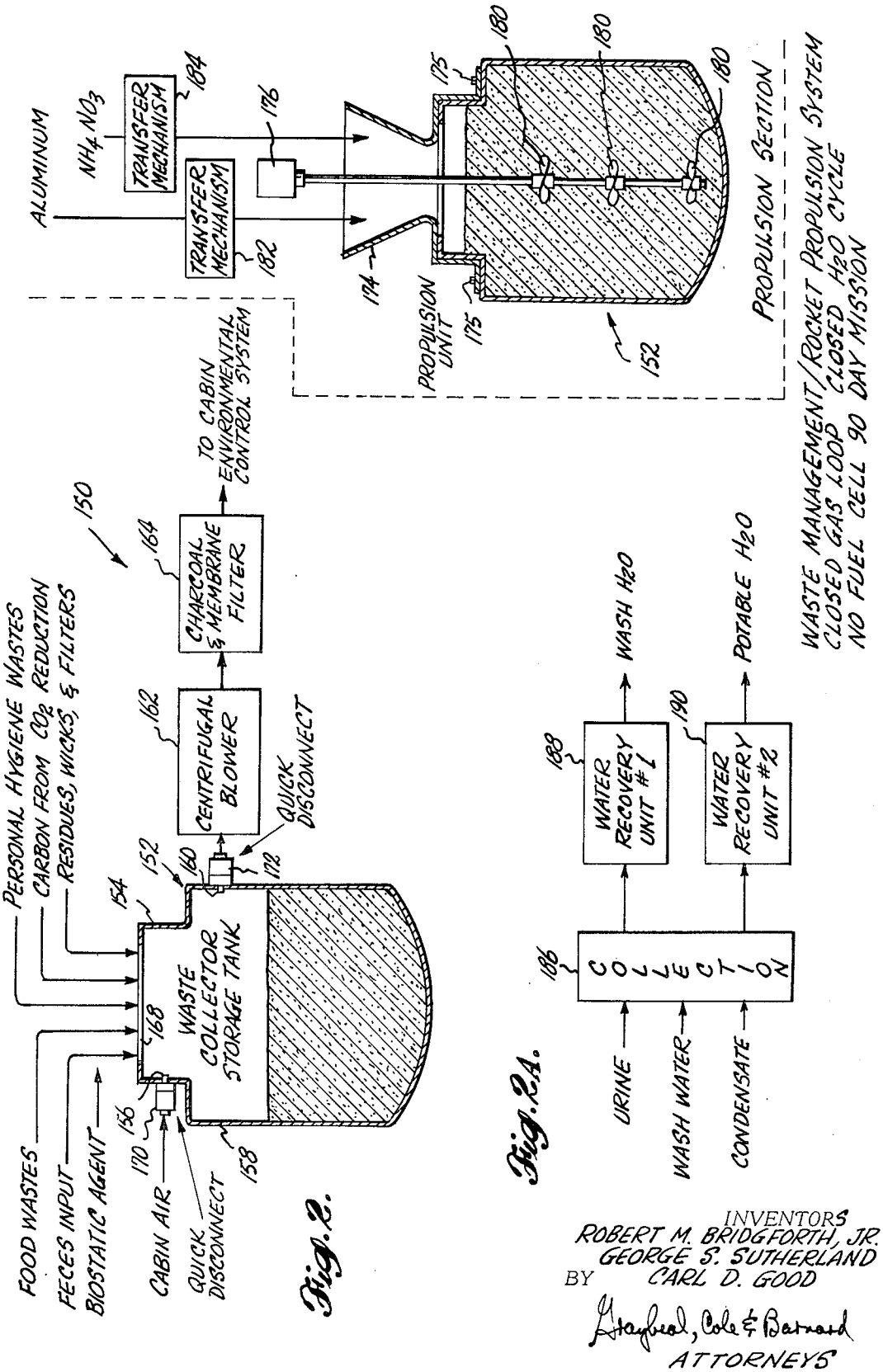


Fig. 2.

Fig. 2A.

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Fig. 4.

Fig. 3.

THEORETICAL SPECIFIC IMPULSE (SHIFTING) VS COMPOSITION MONEX A 1000 = 14.7 psia

Fig. 5.

THEORETICAL SPECIFIC IMPULSE (SHIFTING) VS COMPOSITION MONEX W 1000 psia - 14.7psia DRY FORMULATION

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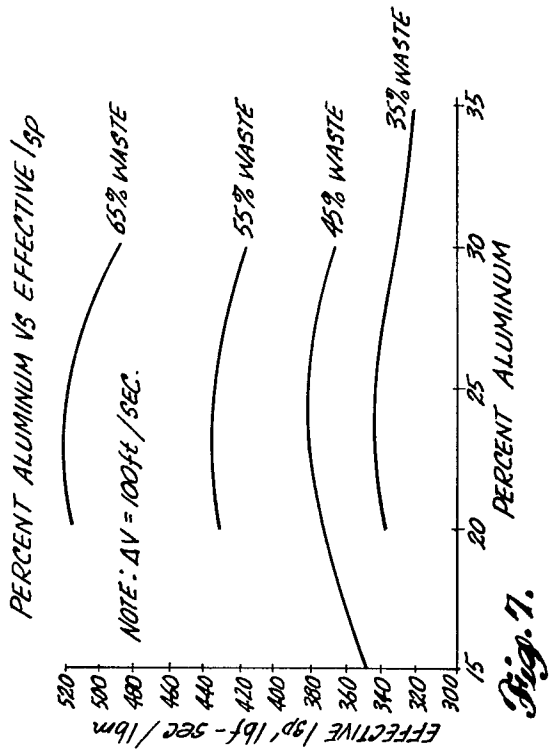


Fig. 7.

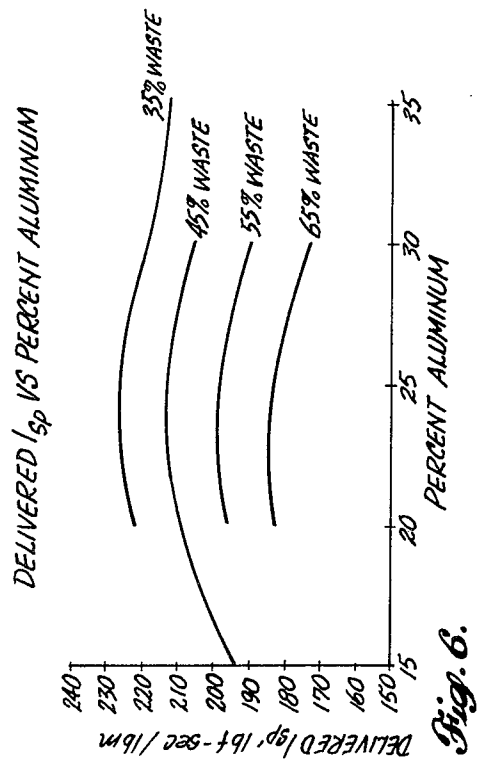


Fig. 6.

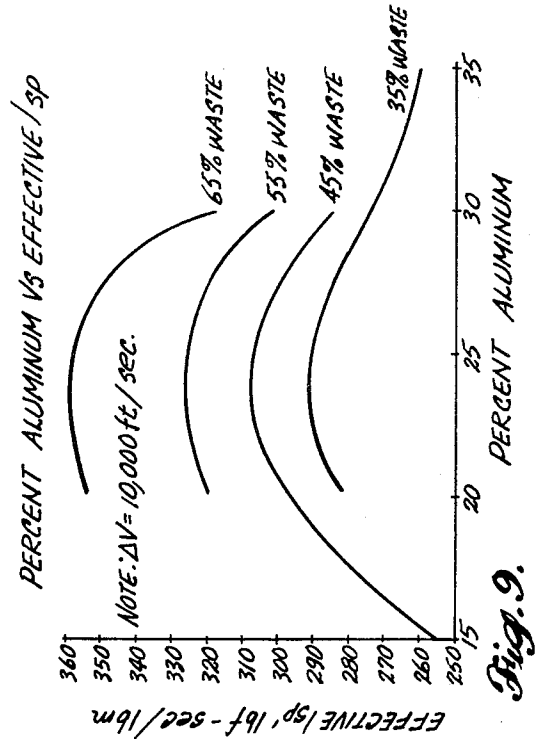


Fig. 9.

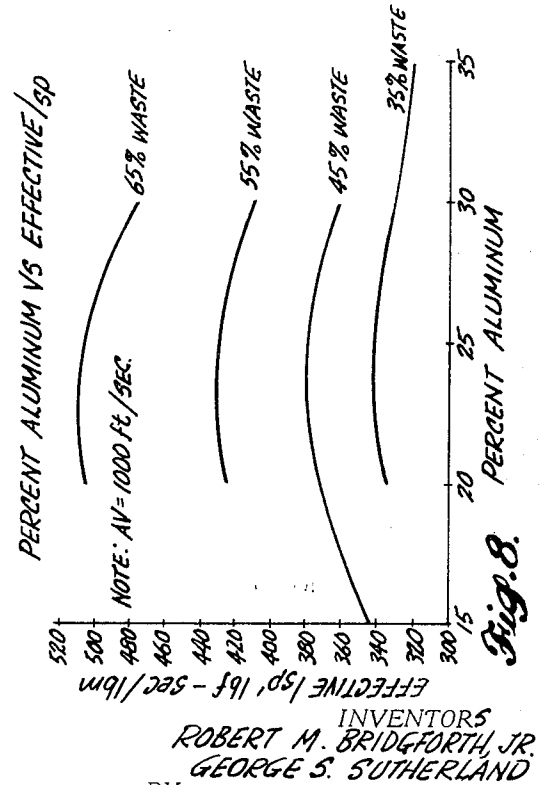


Fig. 8.

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ROCKET PROPELLANT COMPOSITION INCLUDING HUMAN BODY GENERATED WASTE MATERIALS

BACKGROUND OF THE INVENTION

The present invention relates generally to waste disposal and propulsion systems for manned spacecraft. More particularly, this invention provides an integrated system and method for (*a*) collecting the various wastes generated during a manned space mission, including human wastes, (*b*) processing the wastes to produce a propellant composition, and (*c*) burning the propellant so formulated in the rocket propulsion system of the spacecraft, thereby simultaneously disposing of the wastes and adding to the thrust generating capability of the spacecraft propulsion system. The present invention also relates to novel rocket propellant compositions which include human waste products.

One serious problem in the field of manned space travel is the disposal of the various wastes, including human wastes, which are generated during an extended manned space flight. If the wastes generated during the mission must be stored in the spacecraft, they will contribute to the dead weight, and increase the propulsion requirement of the spacecraft. Moreover, a system must be provided in the spacecraft for inhibiting the growth of bacteria in the waste collected to maintain a sanitary spacecraft environment, thereby creating additional weight and power requirements for the vehicle. Thus, not only are the waste products not used efficiently, but they create an additional burden on the limited thrust capability of the spacecraft.

The periodic dumping overboard of the wastes generated during tbe mission can alleviate the weight problem somewhat, but means must still be provided for sterilizing the waste before expelling it into space. Moreover, this method does not make efficient use of the wastes.

Another problem in the development of manned space travel is how to provide a manned spaceship with a sufficient quantity of propellant for an extended flight without adding excessive weight to the vehicle. Manned space missions must often be terminated sooner than desirable because of the limited supply of propellant which can be carried by the spaceship.

SUMMARY OF THE INVENTION

It is a basic object of this invention to provide a more efficient system and method for disposing of the waste products generated during a manned space mission.

Another object of the present invention is to provide a system and method for increasing the propellant supply aboard a manned spacecraft without adding to the weight of the vehicle.

A further object of the present invention is the provision of a system and method for utilizing the wastes generated during a manned space mission as a constituent of a rocket propellant.

Still another object of this invention is the provision of an integrated system and method for collecting and treating the human body generated waste products generated during a manned space flight to form a rocket propellant which may be utilized on board the vehicle to incrase the propulsion capabilities thereof, thereby permitting extended manned space missions.

Yet another object of the present invention is to provide a rocket propellant which includes human body generated waste products as a significant ingredient.

Another object of this invention is to provide a relatively inexpensive rocket propellant.

The foregoing objects have been realized by providing an integrated waste management/rocket propulsion system aboard a spacecraft, which system includes human body generated waste products collection and storage means, and means for mixing the collected waste products with suitable propellant fuel and oxidizer additives. The fuel-oxidizer-waste mixture may then be delivered to the propulsion motors of the vehicle where it is burned as fuel, thereby simultaneously disposing of the wastes and adding to the propulsion capabilities of the vehicle.

BRIEF DESCRIPTION OF THE DRAWINGS

Other objects, features, advantages, and characteristics of the present invention will become apparent in the following description of certain embodiments of the invention, taken together with the accompanying drawings, wherein like reference characters designate like parts, and wherein:

FIG. **1** is a diagrammatic and schematic illustration of an integrated waste management/rocket propulsion system according to the present invention and provided with hydraulic means for transferring the waste products collected between a waste collector tank, a storage tank, and a propellant preparation tank;

FIG. **1A** is a block diagram showing the water cycle which may be utilized in a spacecraft having a waste management/rocket propulsion system of the type shown in FIG. **1**;

FIG. **2** is a diagrammatic and schematic illustration of another embodiment of a waste management/rocket propulsion system according to the present invention, adapted for use on an extended space mission wherein the used wash water and urine generated during the mission are reclaimed and treated for reuse;

FIG. **2A** is a block diagram showing a water cycle which may be utilized on a space vehicle which includes a integrated waste management/rocket propulsion system shown in FIG. **2**; and

FIGS. **3–9** are various graphical presentations which are referred to hereinafter in analyzing various properties of certain rocket propellants formulated by the systems illustrated in FIGS. **1** and **2**.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. **1** depicts an integrated waste management/-propulsion system **20** typifying the present invention and particularly suitable for use on a manned spaceship (not shown) whose mission does not require that the generated liquid wastes be reclaimed and treated for reuse. Waste management/ propulsion system **20** comprises a waste collector tank **22** into which the various waste products generated are initially deposited, a storage tank **24** which receives the waste products from the waste collector tank **22**, either before or after admixture thereof with the fuel-oxidizer constituents, and stores them for a prescribed period of time depending upon the propulsion requirements of the spaceship, and a propellant preparation tank **26** which receives the waste products either from the collector tank **22** or from the storage tank **24** and also receives suitable fuel

and oxidizer additives from a fuel storage tank 28 and an oxidizer storage tank 30. The waste collector tank 22, storage tank 24, propellant preparation tank 26, fuel storage tank 28 and oxidizer storage tank 30 are interconnected by a hereinafter discussed network of hydraulic transfer lines and products handling stages, which network comprises a grinder unit 31, pumping units 32, 34, transfer mechanisms 36, 38, and mixing units 40, 42.

The waste collector tank 22 receives such solid, carbonaceous wastes as human feces; food wastes, including the food packaging material, personal hygiene wastes such as towels, sponges, detergents, toothpaste, hair and nail clippings, etc.; and such miscellaneous wastes as carbon from the spacecraft's atmosphere-regeneration systems, evaporator wicks, condenser wicks, chemical additives and used charcoal from the spacecraft's air purification systems. Liquid carbonaceous wastes such as urine and used wash water are also discharged into the waste collector tank 22 from a separate collector 48 and an associated valve 50 which permits a portion of the liquid wastes to be recovered from physiological sampling and analysis or treated for reuse in the spacecraft. Of course, any or all of the solid and liquid wastes may be collected singly or collectively, depending upon the disposition to be made of the wastes. If no recovery of the urine or used wash water is required in the spacecraft, the liquid collector 48 may be eliminated and the liquid wastes may be deposited in the waste collector tank 22 at the same point as the other wastes. Means defining a waste inlet opening 52 is provided on top of the collector tank 22 and may include suitable means, such as a toilet seat (not shown), to facilitate the input of human feces.

Since the waste collector tank 22 will be operating under zero "*g*" or partial "*g*" conditions, pneumatic force or some other positive method of collecting the various wastes is required. Accordingly, the waste collector tank 22 in the FIG. 1 embodiment is designed to utilize cabin atmospheric gas (hereinafter referred to simply as air) to collect the waste products by eductor action while preventing contamination of the vehicle atmosphere. The waste collector tank 22 has a vortex tube design which includes a reduced-diameter upper section 54 having an air inlet orifice means 56 and an enlarged-diameter lower section including an air outlet orifice means 58 in the upper portion thereof, and a storage chamber 60 beneath the gas outlet means 58.

By virtue of the vortex design of the waste collector tank 22, the wastes entering the collector are given both a downward velocity which carries them to the bottom of the storage chamber 62, and a tangential velocity which induces a centrifugal force to separate the entrained gases from the solid-liquid waste mixture.

The waste may be directed into the storage chamber 62 of the waste collector tank 22 by aerodynamic drag instead of the eductor action method described above. However, the eductor action process provides more positive separation.

A cylindrical surface-tension baffle 64, fastened to the bottom of the waste collector tank 22, serves to stabilize the solid-liquid and gas interface of the wastes deposited in the tank, thereby maintaining the separation of the gas phase from the solid-liquid mixture and insuring that only the solid-liquid mixture will enter the grinder unit 31. Zero "*g*" tests conducted on a spacecraft fuel tank having a surface-tension baffle comparable to baffle 64 have shown that such a baffle is effective in maintaining a stable interface. In this regard, see Petrash, D.A. et al, "Effect of the Acceleration Disturbances Encountered in the MA-7 Spacecraft on the Liquid Vapor Interface in a Baffle Tank During Weightlessness," NASA Publication TN D-1577, for example.

The steady state configuration of the waste collector tank 22 is one in which the baffle 64 is completely full, and the remaining wastes are uniformly distributed at the base of the baffle. During the flight tests on the fuel tanks referred to in the preceding paragraph, it was observed that this configuration was independent of any initial misalignment of the baffle axis with the gravity of the thrust vector. Moreover, these tests established that the acceleration imposed upon the experimental tank during orientation maneuvers in orbit had no effect on the liquid-vapor interface configuration.

The gas phase of the waste products deposited in the waste collector tank 22 is removed from the tank by means of a blower 66 cnnected to the air outlet orifice means 58 in the waste collector tank lower section 60. The gas-contaminated air from the tank 22 passes through a charcoal and membrane filter unit 68 which decontaminates the air and sends it back into the cabin air supply. Thus, the FIG. 1 embodiment system includes what may be termed a semi-closed gas loop.

A hydraulic transfer line 70 connects the tank 22 to grinder 31 and hydraulic transfer line 71 connects the pumping unit 32 and mixing unit 40 to a grinder 31, which is provides at the outlet in the bottom of the waste collector tank 22 to reduce the solid waste products passing therethrough to a sufficiently small size to pass through the system's transfer lines. The transfer line 70 includes an inlet and 72 located concentrically within the baffle 64 and extending above the bottom of the tank to insure flooded suction and prevent gas from being drawn into the mixing unit 40.

Preferably, a biostatic agent is introduced into the waste collector tank 22 as at 74 and is mixed with the collected waste products to prevent bacterial action and gas production during storage. Alternate methods of treating the wastes include vacuum drying, refrigeration, high temperature treatment and hermetical sealing. However, the drying process inherently removes water from the wastes which must be used in the hydraulic transfer system (discussed below), and the refrigeration, high temperature and drying methods require costly power for operation. Thus, these three methods are presently considered to be impractical. The time period during which the waste products must be stored prior to transfer to the preparation tank and propulsion motors will, of course, be an important consideration in selecting the optimum waste preservation method.

The storage tank 24 also contains a cylindrical surface-tension baffle 76 which is similar to the baffle 64 of the waste collector tank 22 for maintaining effective liquid-solid and gas phase separation. The storage tank 24, the waste collector tank 22 and the preparation tank 26 are interconnected by a series of hydraulic transfer lines 70, 80, 82, 84, 86, 88, 90, 92, 94, 96 and 98 with associated pumping units 32, 34, mixing units 40, 42, and selectively operable valves 100, 102, 104, 106, 108, 110, 112, 114 and 116, which permit selective recycling of the waste and propellant mixtures at

various stages of the waste processing operation in a manner described more fully below.

The fuel storage tank **28** and the oxidizer storage tank **30** are connected to the preparation tank **26** through transfer lines **120** and **122**, respectively. Line **120** includes a suitable transfer mechanism **36** such as a screw conveyor, and line **122** includes a like transfer mechanism **38**.

In typical operation, with waste products at the bottom of waste collector tank **22**, valve **104** in the transfer line **70** is opened and the pump **32** and mixing unit **40** are turned on to suction the waste products through the grinder unit **31** and the associated transfer line, to mix the products into a substantially homogeneous, slurry-like mixture. In order to obtain a homogeneous mixture, it may be necessary or desirable to recycle the waste products through the mixing unit **40** several times, depending upon the nature of the waste products collected. This may be accomplished by opening the valves **100** and **104** while holding the remaining valves in the system closed, whereby the pumping unit **32** causes the waste mixture to cycle through the lines **80** an **82**, waste collector tank **22**, line **70**, grinder unit **31**, line **71** and mixer **40**.

When the waste mixture has recycled through the mixing unit **40** a sufficient number of times to obtain the desired degree of homogeneity, valve **100** is closed and valve **102** is opened so that the pumping unit **32** pumps the waste mixture into the storage tank **24** where it is stored until needed for use in the spacecraft propulsion motors. The mixture in the storage tank should be used as it is accumulated, to the extent possible, to fulfill the spacecraft's propulsion system requirement, since this will minimize the size and weight requirements for the storage tank **24** and the other various units of the system **20**, as well as the weight of the waste carried by the vehicle. Of course, other parameters, such as the power requirements of the spacecraft, also need to be considered in determining the optimum waste load which the storage tank **24** is designed to carry, and the frequency with which the mixture in the storage tank needs to be transferred to the preparation tank **26** and the propulsion motors of the vehicle.

Depending upon the amount of time the waste mixture must be stored in the storage tank **24**, it may be desirable to recycle the mixture from the tank **24** through the mixing unit **40** one or more times prior to delivering it to the propellant preparation tank **26**. For this purpose, transfer line **88**, including valve **106**, is provided. When it is desired to recycle the waste mixture from the tank **24** through the mixing unit **40**, the valves **102** and **106** are opened, the remaining valves in the system are held closed, and the pumping and mixing units **32** and **40** are turned on. The mixture from the storage tank **24** then is pumped through transfer lines **86** and **88**, mixing unit **40**, line **80** and **84**, and back to the storage tank **24**. The mixture may then be pumped from the storage tank **24** to the propellant preparation tank **26** by opening the valve **108**, **110** and **114** while holding the remaining valves in the system closed, and turning on the pumping and mixing units **34** and **42**. The pumping unit **34** then pumps the mixture from the waste storage tank **24**, through transfer line **86** and **90**, mixing unit **42**, and lines **94** and **92**, to the preparation tank **26**.

Suitable fuel and oxidizing agents, such as aluminum powder and ammonium nitrate, respectively, are introduced into the propellant preparation tank **26** from their respective storage tanks **28**, **30** via transfer lines **120**, **122** and transfer mechanisms **36**, **38**, respectively. Valves in the system are held closed, and the pumping and mixing units **34** and **42** are turned on to cycle the waste-fuel-oxidizer mixture from the propellant preparation tank **26**, through transfer line **98**, mixing unit **42**, transfer lines **94** and **92** and back to the preparation tank **26** a sufficient number of times to form a homogeneous propellant mixture.

When the waste-fuel-oxidizer mixture has cycled through the mixing unit **42** a sufficient number of times to form a homogeneous propellant mixture, the valves **116** and **112** are opened and the remaining valves in the system are held closed, whereupon the pumping unit **34** pumps the propellant mixture from the propellant preparation tank **26**, through transfer lines **98**, **94** and **96** to the reaction propulsion motor means provided on the spacecraft for burning this propellant mixture.

The waste products and fuel-oxidizer transfer and storage system shown in FIG. **1** also permits admixture of the waste products with some or all of the fuel or oxidizer, or both, prior to storage in the storage tank **24**. Immediate mixing of waste products having a relatively high solids content with ammonium nitrate, prior to storage of the waste products, has been found to be particularly advantageous from the point of view of handleability and storability of the waste products, since the ammonium nitrate promotes liquification of (i.e., fluidizes) certain waste products solids. Thus, to accomplish an immediate ammonium nitrate addition to the waste products for example, an ammonium nitrate can be added directly to the waste collector tank **22** or a pre-mix rich in ammonium nitrate can be maintained in preparation tank **26** and transferred therefrom by pump **34** to the input line **88** of pump **32** via line **99** and valve **117**. The mixture recycling through pump **32** and tank **22** can then be transferred to the storage tank **24** or can be recirculated through the tanks **24**, **26** with additional fuel and oxidizer makeup as desired in the final propellant mix. In this mode of propellant preparation, no raw waste products need be stored for any appreciable time and the mixes in storage tank **24**, and in preparation tank **26** as well, can be the final propellant blend or any intermediately mixed variation thereof which may be desired under any particular operational conditions.

The pumping and mixing units **32**, **40**, and **34**, **42** are suitably in the form of one or more rotary screw conveyors in the respective transfer lines which perform the dual function of pumping and blending the mixtures circulatory therein. Alternatively, the pumping and mixing units may be separate, independently operable units, if desired.

As noted above, the system **20** in the FIG. **1** embodiment of the invention is particularly adapted for use in space vehicles having missions which do not require that spent wash water and urine generated during the flight be reclaimed and treated for reuse by the crew members. Such a mission typically can be a short term mission of **30** days, for example. For such a mission, it is contemplated that fuel cells will be used for the generation of electrical power.

Referring to FIG. **1A**, which illustrates a semi-closed water recovery system which may be employed in conjunction with the system of FIG. **1**, it is seen that con-

densate from the fuel cells and the environmental control system of the spacecraft may be passed through suitable charcoal filter units **128** and **130** and selectively operable valve means **132** to potable and wash water storage units **134** and **136**, respectively, and for reuse by the crew. Benzalkonium chloride (BAC) is added to the wash water, as shown in FIG. 1A, for disinfectant purposes, in a manner conventional per se.

The modified integrated waste management/propulsion system **150** illustrated in FIG. **2** is particularly suitable for use on a spacecraft having a mission which requires that the used wash water and urine generated during the flight be reclaimed, treated and reused by the spacecraft personnel. Since the liquid content in the solid waste products collected during such a mission may be insufficient to act as a transport medium for a hydraulic transfer system such as used in the FIG. **1** system, it is deemed advisable to combine the waste collection and storage functions into a single unit and to provide alternative means for mixing the wastes collected and transferring them to the spacecraft propulsion system.

Accordingly, the integrated waste management/propulsion system **150** of FIG. **2** comprises a combination waste collector-storage tank **152** into which are deposited such carbonaceous waste products as human feces, food wastes, personal hygiene wastes, carbon from the carbon dioxide reduction system of the spacecraft, evaporator wicks, chemical additives and charcoal from the spacecraft's air purification system. Like the waste collector tank **22** shown in FIG. **1**, the combination waste collector-storage tank **152** in the embodiment shown in FIG. **2** has a vortex tube design which includes a reduced-diameter upper section **154** having air inlet orifice means **156** and an enlarged-diameter lower section **158** having air outlet orifice means **160** in the upper portion thereof. By virtue of this vortex tube type design, the various waste products entering the collector-storage tank **152** are given both a downward velocity to carry them to the bottom of the tank, and a tangential velocity which creates a centrifugal force to separate the entrained gases from the solid waste products.

The gases are removed from the tank **152** by means of a centrifugal blower **162** connected to the outlet orifice means **160.** The gas-contaminated air from the tank **152** passes through a charcoal and membrane filter unit **164** which decontaminates the air and sends it back into the cabin environmental control system. Thus the FIG. **2** system includes what may be termed a closed gas loop.

A biostatic agent is preferably introduced into the waste collector-storage tank **152** as at **166** to prkvent bacterial growth therein.

The waste collector-storage tank is further provided with means defining a waste inlet opening **168** having suitable means, such as a toilet seat (not shown), connected thereto for facilitating the input of human feces. In addition, quick disconnect type fittings **170** and **172** are provided as part of the air inlet orifice means **156** and the air outlet orifice means **160,** respectively, to permit the tank **152** to be removed from the system.

Periodically, either when the waste collector-storage tank **152** becomes about half full (for example), or when the waste products therein are needed for additional fuel for the spaceship propulsion system, the tank **152** is disconnected from the system via the quick disconnect fittings **170** and **172** and manually or otherwise moved to a mixing location. At this location, reaction nozzle **174** is placed over the open end **168** of the tank **152** and suitably affixed thereto as by bolts **175.** The agitator **180** of a mixer unit **176** is then inserted through the nozzle **174** into the waste. Suitable fuel and oxidizer additives, such as aluminum and ammonium nitrate, respectively, are added to the waste from suitable sources (not shown), via suitable transfer mechanisms **182, 184,** such as screw conveyors, as diagrammatically shown in FIG. **2.** The fuel-oxidizer-waste mixture is then blended to a substantially homogeneous mixture, and the mixer unit **176** removed.

The assembly **152, 174** is then relocated to storage, or moved directly to the propulsion section of the spacecraft, and a suitable pyrotechnic or like igniter (not shown) is there installed at the exposed surface of the propellant, whereupon the unit is ready for firing on demand.

A above noted, the integrated waste management/propulsion system **150** shown in the FIG. **2** embodiment is considered particularly useful on a spacecraft having an extended mission which requires that the used wash water and urine generated during the flight be recovered, treated and reused by the spacecraft personnel. Such liquid reclamation requirements may be present, for example, during a mission of 90 days or more. FIG. **2A** illustrates, in block diagram form, a closed water recovery system which may be employed on such a mission, in conjunction with the integrated waste management/propulsion system **150** of FIG. **2.** Condensate used wash water, and urine generated during the mission are collected in a central unit **186,** and fed to separate water recovery and treating units **188** and **190** where the liquids are treated for reuse as wash water and potable water. It is contemplated that a solar dynamic or isotope dynamic power source will be employed on spacecraft having such extended missions. For environmental control, the craft can also employ a Bosch CO_2 reduction system, such as disclosed in a technical report entitled "Carbon Dioxide Reduction Systems," presented by Martin Mackline at the AIAA 4th Manned Space Flight Meeting, held at St. Louis, Missouri, on Oct. 11–13, 1965, for example.

It has been noted above that aluminum powder is a suitable fuel additive and that ammonium nitrate is a suitable oxidizer additive for the integrated waste management/propulsion systems of FIGS. **1** and **2.** Other fuels, such as beryllium or boron, for example, are also suitable for use in either of these systems, either in lieu of or conjunctively with the aluminum and ammonium nitrate fuel-oxidizer mix above discussed.

It is apparent from the foregoing that the integrated waste management/propulsion systems described herein provide numerous advantages over the present separate waste management and propulsion systems currently employed on space vehicles. In the first place, the integrated systems of this invention efficiently utilize the waste products generated during manned space missions to provide improved spacecraft propulsion capabilities. Moreover, they provide more sanitary spacecraft environments by eliminating large quantities of waste materials. A third advantage of these systems, weight saving, will be apparent from the weight analysis which follows the propellant composition discussed below.

The propellants produced by the integrated waste management/propulsion systems of FIGS. 1 and 2 are quite similar to a family of monopropellants which have been investigated and developed at Rocket Research Corporation of Seattle, Washington, except for the presence and utilization of the waste products. These monopropellants, unlike most medium and high energy monopropellants, exhibit a high degree of stability. These monopropellants are designated by the proprietary term MONEX, and for simplicity this designation is employed in the following discussion.

The MONEX family of monopropellants operates on the concept or principle of a combined heat source and working fluid, wherein the reaction or combustion is essentially a two-step process. Reaction between two or more of the constituents, usually a gelled liquid and a light metal additive, provide the thermal energy release; and a third component, or working fluid, is decomposed and heated to provide a low molecular weight exhaust, and hence, high performance. These propellants, bearing the various designations MONEX A, B, C and D, are heterogeneous thixotropes which, in contrast to other high energy monopropellants, can be readily desensitized without severe reduction in performance characteristics. They are high density propellants (1.1 to 1.6 gm/cc) and have theoretical specific impulses from about 240 seconds to in excess of 300 seconds (based on a chamber pressure of 1,000 psia). Depending upon the specific formulations, the cost per pound of propellant is low, and certain of the formulations are of a non-toxic nature.

Safety of many of the MONEX propellant formulations has been demonstrated by means of impact sensitivity tests and the JANAF card gap test, a standard means of determining the sensitivity of liquid propellants to detonation initiation. This card gap test is presented in detail in a publication entitled "Liquid Propellant Test Methods," published by The Liquid Propellant Information Agency, Applied Physics Laboratory, The Johns Hopkins University, Silver Spring, Maryland, dated March 1960, for example.

One of the MONEX propellants, MONEX A, is disclosed in copending Bridgforth et al U.S. Pat. application Ser. No. 340,127, entitled Stable, High Energy Compositions. MONEX A is a multi-component propellant consisting basically of powdered aluminum, ammonium nitrate and water. Numerous tests carried out on MONEX A have indicated that the propellant can be ignited in a smooth and reproduceable manner and burns with good combustion efficiency. The characteristics of two MONEX A formulations are presented below in Table 1:

TABLE 1.—MONEX A CHARACTERISTICS

Composition	MOD III weight percent	MOD V weight percent
Al	36.00	42.06.
NH_4NO_3	31.81	20.96.
H_2O	26.89	31.48.
Burning rate additive (e.g. Teflon powder)	5.00	5.00.
Gellant (Guartec XO-402)	0.30	0.50.
Ballistic properties, theoretical specific impulse (1,000/14.7 p.s.i.a.):		
Shifting, lbf.-sec./lbm	243	241.
Frozen, lbf.-sec./lbm	241	240.
Chamber temperature, ° F	5,300	5,480.
Exhaust temperature, ° F	3,680	3,680.
Physiochemical properties:		
Freezing point, ° F	32	−4.
Vapor pressure at 25° C., mm. Hg	17	21.
Detonability (JANAF card gap test):		
Zero plexiglass attenuation	Negative	Negative.
Impact sensitivity, negative at	120 kg-cm.	120 kg.-cm.
Flow properties	Good	Good.

The propellant formulations of the present invention employ carbonaceous waste products, such as human excrement, carbon residue from the carbon dioxide reduction system of a spacecraft, and other carbonaceous wastes such as evaporator wick filters, paper, and food wastes, in place of the water in the MONEX A propellant formulations (Table I). For simplicity, waste propellant formulations of this invention will be referred to hereinafter as MONEX W.

A typical MONEX W formulation, which amounts to a basic derivative of MONEX A, is presented below in Table II.

TABLE II

EXPERIMENTAL MONEX W FORMULATION

Composition	Weight Percent
Aluminum	19.60
Ammonium Nitrate	45.00
Urine	10.00
Feces	20.00
Darco (bone black carbon)	5.00
Guartec XO-402 (gellant)	0.40

COMPOSITION OF WASTE MATERIAL

	Urine (weight %)	Feces* (weight %)	Present in Propellant (Weight Percent)
Water	93.00	65.00	22.30
Inert	2.00	14.00	3.00
Organic	3.50	14.00	3.15
Nitrogen	1.50	7.00	1.65

* Estimated (based on average composition of human feces)

A 500 gram batch of MONEX W was fired at the 15 pound thrust level in an end-burning motor 3.8 inches in diameter and 2.5 inches deep. The engine was fitted with an ATJ graphite nozzle 0.241 inches in diameter. The 500 gram thixotropic propellant charge of MONEX W filled the motor to a depth of 1.4 inches. A 17.5 gram pyrotechnic bag ignitor (composed of 44% Al, 25% Mg and 31% $KClO_4$ by weight) produced rapid and smooth ignition. Combustion was sustained for 45 to 50 seconds and was accompanied by a brilliant orange flame and white exhaust plume.

As will be apparent, hypergolic ignition, as by use of ClF_3 can also be used for a MONEX W type propellant.

Three 10-gram samples were extracted from a MONEX W batch as set forth in Table II, and set aside for ground storage tests. One of the samples was open to air at 70° F., and the other two were sealed. After 60 days storage, none of the stored propellants showed any visible signs of bacterial growth. Visual observation of the sealed containers revealed that the gel structure had been maintained during the storage period and that propellant gassing had not occurred. On the open sample, the water had evaporated and the ammonium nitrate crystallized out, as expected.

From these tests it appears the MONEX W formulation is a stable propellant for periods up to 60 days or longer and can be readily ignited in small engines.

The integrated waste management/propulsion systems of FIGS. 1 and 2 produce MONEX W type propellant formulations. The system of FIG. 1 produces what will hereinafter be referred to as a "wet" MONEX W propellant formulation due to the presence of urine and used wash water therein. The system of FIG. 2 produces a "dry" MONEX W propellant formulation because of the low water content waste products collected therein, the urine and used wash water generated by the spacecraft personnel being reclaimed and treated for reuse.

As noted above, "wet" MONEX W derived from the high water content waste products of the FIG. 1 system is similar to MONEX A. A trinary plot of theoretical specific impulse (I_{sp}) for various MONEX A compositions (with H_2O as the working fluid) is presented in FIG. 3 for comparison. Performance data are based on expansion to sea level and would be higher for expansion to vacuum. By substituting waste for H_2O, representative MONEX W performance curves can be approximated. Addition of the solids (dry feces, polyethylene containers, and papers, for example) does not degrate the performance appreciably, since they are organic materials. It should be noted that specific impulse can be varied over a wide range by shifting the aluminum (Al), ammonium nitrate (NH_4NO_3), and water proportions, thereby permitting flexibility in selection of propellant combinations. FIG. 5 shows that formulations containing as much as 50 percent waste (by weight) produce a specific impulse of 200 seconds. However, since 50 percent of the MONEX W propellant is "free" waste, the effective I_{sp} of the MONEX W propellant is much higher than the numbers presented in FIG. 5. A discussion of the effective I_{sp} is presented below.

The integrated waste management/propulsion system of FIG. 1 is particularly suitable for short term missions, as noted above. Table III below presented the type and quantity of wastes that are expected to be collected per day from four men on a typical 30 day mission.

TABLE III

TYPE AND QUANTITY OF WASTES COLLECTED PER DAY FROM FOUR MEN WASTE MANAGEMENT SYSTEM NO. 1

Waste		Weight, pounds
Urine	(95% H_2O)	13.3
Wash Water	(>99% H_2O)	13.3
Feces	Wet Weight	1.32
	Dry Weight	0.32
Personal Hygiene		
	Detergent (Benzyl Ammonium Chloride)	0.08
	Solids	0.04
	Sponges	0.04

While performance of the "wet" MONEX W is very attractive from a propulsion standpoint for short duration missions, it is not attractive when excess water is not available, as on extended missions where the used wash water and urine generated must be reclaimed and treated for reuse. Table IV below presents the type and quantity of wastes expected to be collected per day from four men in a space vehicle on a typical 90 day mission.

TABLE IV

TYPE AND QUANTITY OF WASTES THAT ARE COLLECTED PER DAY FROM FOUR MEN IN A CLOSED WATER AND OXYGEN LIFE-SUPPORT SYSTEM[2]

	Daily Waste (pounds)
Urine Wastes	
Urine Solids (dry)	0.620
Urine Solids (wet)	1.24
Food Wastes	
Packaging (dry)	0.8
Food Wastes (as H_2O)	0.64
Feces	
Wet Weight	1.32
Dry Weight	0.32
Carbon (from Bosch System)	2.62
Personal Hygiene	
Detergent (benzyl ammonium chloride)	0.08
Solids	0.04
Sponges	0.04

In addition, every 90 days the following wastes will also be collected for a four-man crew:

Wash Water Waste	
Evaporator wick and chemical additive	
Condenser Wick	4.5
Charcoal for vapor	(dry weight)
Charcoal for condensate	
Urine Wastes	
Evaporator wick and chemical additive	11.7
Condenser wick	
Charcoal for vapor	14.0
Charcoal for condensate	
Personal Hygiene Wastes	
Towels	0.5
Dry Wipes	0.11
Atmosphere Control Wastes	
Charcoal for air purification	3.5

2. Personal Communication, J. Zeff, ARDE, INC., and C. D. King, GD/Convair, August, 1965.

Table V below presents the chemical compositions of the prospective waste products (from Table IV) collectible from four men during a 90 day mission.

TABLE V.—CHEMICAL COMPOSITION OF WASTE PRODUCTS—DRY

Material and source*	Weight (lb.)		Approximation and assumptions	Weight in pounds (4 men, 90 days) C	H	O	N	Inert
1. Wash water waste		4.50	Polypropylene wicks, charcoal, chemical additives. Estimate 95% C, 5% H.	4.28	0.22	0.00	0.00	0.00
2. Urine wastes:								
a. Charcoal	14.00		100% C	14.00	0.00	0.00	0.00	0.00
b. Evaporating system	11.70		Polypropylene, CrO_3 treated charcoal (CrO_3 conc. unknown). Estimated 98% C, 1% H, 0.4% N, 0.6% inert.	11.46	0.12	0.05	0.00	0.07
c. Urine solids:								
57.5% urea	32.0			6.40	2.15	8.52	14.93	0.00
7.5% organics	4.2		Estimated 51.3% C, 9.4% H, 27.4% O, 11.9% N for organic based on $C_5H_{11}O_2N$.	2.15	0.39	1.15	0.51	0.00
27.5% NaCl	15.3			0.00	0.00	0.00	0.00	15.30
5.0% phosphates	2.8		O content based on basis of K_3PO_4	0.00	0.00	0.84	0.00	1.96
2.5% sulfates	1.4		O content based on basis of K_2SO_4	0.00	0.00	0.51	0.00	0.89
		81.40						
3. Food management:								
a. Packaging	72.0		Polyethylene, etc. 95% C, 5% H	68.40	3.60	0.00	0.00	0.00
b. Food waste	57.6		Assume 100% H_2O	0.00	6.45	51.15	0.00	0.00
		129.6						
4. Personal hygiene		60.0	Towels, sponges, detergent, toothpaste, hair, nail clippings, etc. Approx. as being all cellulose $(C_6H_{10}O_5)_x$.	26.70	3.70	29.60	0.00	0.00

TABLE V.—CHEMICAL COMPOSITION OF WASTE PRODUCTS—DRY

Material and source*	Weight (lb.)	Approximation and assumptions	Weight in pounds (4 men, 90 days) C	H	O	N	Inert
5. Atmosphere drying—							
Oxygen recovery:							
a. Carbon	236.0	100% C	236.00	0.00	0.00	0.00	0.00
b. Charcoal	3.5		3.50	0.00	0.00	0.00	0.00
	239.5						
6. Feces:							
a. Water	90.2		0.00	10.09	80.11	0.00	0.00
b. Dry solids	28.8	Estimate 5.0% inert, 7.5% N, 9% H, 60.6% C, 17.9% O	17.45	2.59	5.16	2.16	1.44
	119.0						
Total	634.0		390.34	29.31	177.09	17.60	19.66
Weight percent			61.57	4.62	27.93	2.78	3.10

*Reference Table IV—Wet urine solids not included in Table III. Personal hygiene weights are not in accordance with Table IV.

From the waste data presented in Table V, a composite heat of formation and waste binder formula was calculated. The composite binder formula is:

Element	Weight Percent	Gram-Atoms/ 100 Grams
C	61.57	5.126
H	4.62	4.583
O	27.94	1.746
N	2.77	0.198
Na	1.22	.053
Cl	1.88	.053

It has been assumed for calculation purposes that all of the inert material listed in Table V consists of NaCl; although in reality only about 78 percent is NaCl, and the remainder is composed of small amounts of K, S, P, Ca, Fe, Mg, etc.

The composite heat of formation may be determined by dividing the products into subgroups and the resulting heats of formation are listed in Table VI.

TABLE VI

HEATS OF FORMATIONS OF WASTE PRODUCT SUBGROUPS

Component	Weight lbm	Weight Percent	H_f° Kcal /mole	H_f° Kcal /mole	Weighted Value Kcal/100 g
Carbon	266.9	42.10	0.0	0.0	0.0
Water	147.8	23.31	−68.32	−379.2	−88.4
Urea	32.0	5.05	−79.6	−132.5	− 6.7
NaCl	20.9	3.30	−98.3	−168.2	− 5.6
Organic	166.4	26.24	−30.0	− 22.4	− 5.9
	Composite Total				−106.6

Organic waste values are based on the composition listed in Table VII below, which are, in essence, the remainder after the other four subgroups have been removed from Table V.

TABLE VII

COMPOSITION OF ORGANIC WASTE

Component	Weight	Weight Percent	Gram-Atoms
C	117.12	70.40	5.862
H	10.66	6.41	6.359
O	35.91	21.59	1.349
N	2.67	1.60	0.114

If the nitrogen content is assumed to be small, an empirical formula of $C_{13}H_{14}O_3$ describes the organic waste composition, and a heat of formation of −30 Kcal/mole can be assumed.

The heats of formation used as input data in determining the theoretical specific impulse of the Al/NH_4NO_3 wastes system are:

Ammonium Nitrate——102.11 Kcal/100 gm

Aluminum —0

Waste Products ——106.6 Kcal/100 gm

By considering the waste products as a single composition, and using the foregoing heat of formation in the propellant performance calculations, the weight percent of waste products can be varied so as to provide data plots useful for various missions. Calculations have been completed in which the percentage of solid waste has been varied from 30 to 65 weight percent, the weight percent aluminum from 15 to 35, and the weight percent ammonium nitrate from 5 to 45. The theoretical calculations are based on a chamber pressure of 1,000 psia exhausted to sea level (14.7 psia). These data have been converted to operation at 500 psia chamber pressure and vacuum exhaust conditions using the following approximations:

Conversion of chamber pressure from 1,000 psia to 500 psia

Multiply by 0.93

Conversion of back pressure from sea level to vacuum

$$C_{f\,vac}/C_{f\,sea\ level} = 1.89/1.47 = 1.25$$

Conversion factor = (1.25) (0.93) = 1.162

$$I_{sp\ (500\text{–}Vac)} = 1.162\ I_{sp\ (1{,}000\text{–}14.7)}$$

The results of these calculations are listed in Table VIII below and are plotted in FIGS. 4 and 5.

TABLE VIII

THEORETICAL PERFORMANCE RESULTS

Case No.	Weight Percent Al	AN	Binder*	I_{sp}, lbf-sec/lbm 1000 − 14.7	500 − Vac
1	35	30	35	210.3	245
2	35	35	30	217.5	253
3	30	05	65	171.2	199
4	30	15	55	187.9	219
5	30	25	45	202.9	236
6	30	35	35	216.9	252
7	25	10	65	181.1	211
8	25	20	55	196.3	228
9	25	30	45	210.4	245
10	25	40	35	223.8	260
11	20	15	65	180.8	210
12	20	25	55	194.4	226
13	20	35	45	207.5	241
14	20	45	35	220.2	256
15	15	40	45	192.0	223

* Waste Products

Results from these fifteen thermodynamic calculations (Table VIII) show that moderate theoretical specific-impulse valves can be obtained from systems containing high solids loading. Only 23.31 percent binder H_2O was available for propulsion use, and a large percentage came from non-reclaimable feces water. Inter-

estingly, 42.1 percent of the binder consisted of carbon. As shown in FIG. 4, the performance is greatly affected by the percentages of Al and waste products present. Performance decreases with an increased aluminum content, due to the lack of oxidizing agent, and decreases with increased waste percentage. However, the effective I_{sp} increases with increased waste percentage. The determination and assumptions used in determining this effective specific impulse value are described below in the weight analysis discussion.

For any given mission, a given amount of waste products will be available for propulsion, and a given amount of energy, as measured by the burnt velocity increments, will be required from the propulsion system. These two factors determine the optimum propellant formulation. Examples of the manner in which these optimum propellant determinations may be made are illustrated below in the weight analysis discussion for a 30-day mission and a 90-day mission.

In determining the propellant requirements for any given space mission, the waste products available are first determined from the selected vehicle/mission analysis. Next, using a calculation procedure similar to that described above, the propellant formulation should be optimized so as to make maximum use of the waste products, and to obtain the highest possible burnt velocity increment, while carrying the lowest possible weight of aluminum (or other fuel) and ammonium nitrate or other oxidizer into space.

The following weight analyses compare the weights of the integrated waste management/propulsion systems of FIGS. 1 and 2 with comparable nonintegrated systems. These analyses rely upon the thermochemical calculations discussed above, and utilize weight and power estimates set forth in the text below for the waste collectors, pumps, valves, preparation tanks, mixers, and other waste management subsystem components.

The exemplary integrated waste management/propulsion systems of FIGS. 1 and 2 are compared herein to separate, nonintegrated waste management and propulsion systems burning a storable biopropellant, N_2O_4/Aerozine 50, operating pressure-fed with a delivered vacuum specific impulse of 290 lbf/sec/lbm.

The two specific missions selected for study in connection with the integrated waste management/propulsion systems of FIGS. 1 and 2 are: (1) a four-man, 30-day mission without water or CO_2 reclamation, and (2) a four-man, 90-day mission with water reclamation and CO_2 recirculation systems. The propellant derived from the waste collected during the first mission is "wet" MONEX W. The propellant from the second mission is "dry" MONEX W. The constituents of the wastes utilized in the "wet" and "dry" MONEX W formulations are tabulated in Tables III and IV above.

The theoretical I_{sp} of a moderate energy monopropellant (MONEX A — 37% Al, 33% NH_4NO_3, and 30% water) has been calculated as 242 lbf-sec/lbm at a chamber pressure of 1,000 psia, exhausting to 14.7 psia, which converts to 303 seconds at a chamber pressure of 500 psia exhausting to vacuum. Assuming 87 percent specific impulse efficiency, a predicated delivered I_{sp} (at altitude) of 263 IBF-sec/lbm results. A preliminary estimate of the impulse requirements for orbit adjust (drag makeup) of a 30-day mission is approximately 150,000 lb-sec. In order to account for I_{sp} differences between the competing systems, the impulse requirement was converted to a ΔV delivered to the vehicle at a specific impulse of 290seconds. The amount of propellant required to produce the same ΔV to the same final vehicle weight, utilizing the MONEX A, was calculated to be 500 pounds.

As noted above, the water content of MONEX A iw replaceable by the highly liquid waste materials generated by four men during a 30-day mission. It is calculated that the propellant requirements are 203 pounds of aluminum, 182 pounds of ammonium nitrate, and 165 pounds of waste material. As shown in Table III above, the total waste produced by four men in a 30-day mission is approximately 852 pounds, of which 14.4 pounds is solid material. This solid material and part of the liquid waste will be burned in the propulsion system. The excess liquid material will be disposed of through the overboard dump, as would be done in a nonintegrated system. It is important to note that a greater impulse requirement (ΔV requirement) would significantly improve the weight advantage of the integrated waste management/propulsion system of FIG. 1, since all rather than only part of the liquid waste material would be utilized to produce impulse.

With respect to "dry" MONEX W, thermochemical calculations for the aluminum, ammonium nitrate, and dry waste propellant composition yielded the theoretical performance curves shown in FIG. 4. Assuming an 87 percent specific impulse efficiency, these numbers are convertible to delivered specific impulse as a function of propellant composition, as shown in FIG. 6. To compare the performance attainable by this propellant combination with the competing bipropellant system, while simultaneously accounting for the fact that a specific ΔV is required rather than just a total impulse, the following technique derives an effective specific impulse.

Assuming the same ΔV is to be applied to the same final vehicle weight, the amounts of propellant required by a bipropellant system delivering a specific impulse of 290 seconds and a waste management propellant delivering the I_{sp} shown in FIG. 6 were determined, and the amount of propellant to be carried into orbit in order to deliver this ΔV was calculated. This computed amount of propellant is merely equal to the total propellant requirements, multiplied by the sum of the weight percents of aluminum and ammonium nitrate for the particular propellant composition under study. The ratio of the required bipropellant weight to this propellant weight, multiplied by the specific impulse of the bipropellant system (290 seconds), was then defined as the effective I_{sp}. Values of the effective I_{sp} as a function of propellant compositions for ΔV's of 10, 1,000 and 10,000 feet per second are shown in FIGS. 7, 8 and 9, respectively.

For purposes of preliminary weight estimates, a propellant containing 25 percent aluminum, 30 percent ammonium nitrate, and 45 percent waste was chosen as the candidate propellant for the integrated waste management/propulsion system of FIG. 2. By referring to FIGS. 7 through 9, inclusive, it is seen that such composition does not represent the maximum effective specific impulse attainable. However, because there can be some doubt as to the combustion characteristics of propellant containing greater than 45 percent waste material; and since a 45 percent waste material propellant composition will effectively ignite, this propellant system has been used for the weight comparison.

Based on preliminary calculations for an extended space mission, the requirements for spin-up and despin once every 90 days demand a total thrust of approximately 300,000 pound-seconds. A final vehicle weight of approximately 10,000 pounds corresponds to a ΔV requirement of approximately 1,000 feet per second. From FIG. 8, at a ΔV of 1,000 feet per second, this candidate propellant is seen to yield an effective I_{sp} of 380 seconds.

At this specific impulse, 790 pounds of ammonium nitrate and aluminum are required to mix with the waste material in order to deliver the total of 300,000 pound-seconds. The total propellant weight breakdown is thus 360 pounds of aluminum, 430 pounds of ammonium nitrate, and 646 pounds of waste, for a total propellant weight of 1,436 pounds.

Based upon the foregoing performance values, the weight comparisons for the two missions (30 and 90 days) of interest are tabulated below.

An estimate of the total weight of separate, nonintegrated waste management and bipropellant propulsion systems for the 30-day mission has been determined as follows. Assuming the waste collector tank can contain 4 man-days of waste, a typical waste management system would weigh approximately 25 pounds. This is broken down as follows:

	Weight, Pounds
Waste collection	7
Storage tank	15
Blower	1
Filter and deodorizer	2

The bipropellant propulsion system weight for the 30-day mission was calculated based on an assumed I_{sp} of 290 seconds and a mass fraction of 0.8, which yields a propulsion system wet weight of 648 pounds. The combined weight of the two separate systems totals 673 pounds.

The integrated system weight analysis is based on the following weight breakdown:

	Inert Weight (Pounds)
Waste collector	7
Storage tank	15
Preparation tank	15
Blower	1
Filter and deodorizer	2
Transfer pumps (4)	8
Aluminum storage tank	12
Ammonium nitrate storage tank	14
Plumbing and pressurization hardware	10
Structure and mounts	26
Valves (13)	10
Water collector	4
Thruster (including valves, lines)	30
Total	154

The combined weight of aluminum and ammonium nitrate to be carried into orbit is 385 pounds.

The following additional power requirements, above and beyond those of a normal mission, were assumed:

Transfer pumps (4) —200 watts

Assuming that a fuel cell penalty of 3watts per pound yields a power system weight penalty of 67 pounds, the total integrated system weight is 606 pounds.

This comparison, therefore, shows a 67 pound weight advantage to the integrated waste management propulsion system of FIG. 1, based upon conservative assumed values. Additional weight savings which may be realized are discussed below, following the weight analysis of the FIG. 2 system.

The estimate of the total weight of separate, nonintegrated waste management and bipropellant propulsion systems for a 90 day mission assumed a total weight required of 48 pounds. This was made up as follows:

	Weight, Pounds
Waste collector unit	45
Blower	1
Filter and Deodorizer	2
Total	48

Assuming a bipropellant specific impulse of 290 seconds, with a mass fraction of 0.8, the propulsion system wet weight is 1,295 pounds, and the total weight of the two systems is 1,343 pounds.

The integrated waste management/propulsion system weight analysis assumed an inert parts weight of 203 pounds, broken down as follows:

	Inert Weight (Pounds)
Waste collector (90 units)	45
Blower	1
Filter and deodorizer	2
Mixer	3
Aluminum storage tank	18
Ammonium nitrate storage tank	31
Structures and mountings	42
Valves (2)	1
Transfer Pumps (2)	4
Plumbing and pressurization hardware	6
Propulsion (including propellant valve, lines, and fittings)	50
Total	203

The weight of aluminum and ammonium nitrate to be carried into orbit as discussed previously is 790 pounds. In addition, a power system weight penalty was assessed, based on an assumed value for fuel cells of 3 pounds per watt. A power penalty of 75 watts for the mixer, and 100 watts for the two transfer pumps, was assumed, yielding a total of 175 watts power penalty during operation. On the basis of 3 watts per pound, this amounts to 58 pounds penalty. As a result, the total integrated system weight is 1,051 pounds, 292 pounds less than the weight of the non-integrated systems.

The above comparisons show significant weight advantages for the integrated waste management/propulsion systems, based on conservative assumptions with regard to performance, storage, and transfer systems. The effective I_{sp} as used herein is based upon delivery of a specified amount of velocity change in the same final vehicle weight. This assumption does not account for the fact that the final vehicle weight with the bipropellant system would have to be increased to allow for the waste which has accrued up until that time and is being carried on board. In the case of the 30-day mission, assuming the liquid is dumped overboard, this build-up of waste is negligible (14.4 lb-m). In the case of the 90-day mission with water recirculation, however, the build-up of solid waste is quite significant (443 lb-m).

Certain components in a vehicle incorporating the integrated system of FIG. 1, such as instrumentation hardware or tools, may be fabricated of powderized aluminum, held together with a water soluble binder, and protected by a disposable coating. These components could be placed in the aqueous waste mixture in the FIG. 1 collector tank or preparation tank when they were no longer needed during the mission. The water

soluble binder would then dissolve in the mixture, and the aluminum powder would disperse and serve as a fuel additive, thereby requiring less aluminum to be carried by the spacecraft and offering additional significant weight savings to the vehicle.

If a missile system is designed with the integrated waste management/propulsion system as the basic design concept, a number of advantages can be realized. For example, the third stage boosters or service modules which now remain in orbit can be designed to provide the necessary fuel and oxidizer material. Many knobs and panels could be fabricated from nitrocellulose or similar materials, or from powdered metal, and used as propellant constituents when the unit in which they were contained had completed its mission. Organic materials such as the coverings on electronic components and packing materials could also be utilized.

The waste management/propulsion system shown in FIG. 1 includes a water collector and an overboard dump. This is necessary because the small total impulse requirement assumed does not allow for the complete utilization of all the water produced in the waste. Should it be desirable to produce more total impulse, more of this waste material could be utilized, with significant results in overall weight savings from any competing systems. FIG. 1 and the weights allowed in the system comparisons above also include separate gear pumps for each operation. However, some pumping equipment and valving arrangements can readily be integrated and optimized so as to improve the weight efficiency of the system.

From the foregoing considerations, various further modifications, formulations, and utilization techniques characteristic of the invention will be apparent to those skilled in the art, within the scope of the following claims.

What is claimed is:

1. A rocket propellant comprising a mixture of:
fuel constituents, including human body generated waste products and one or more metallic fuels; and one or more inorganic oxidizers, such oxidizers being of a nature and present in an amount sufficient to combustively react with said fuel constituents.

2. A rocket propellant mixture according to claim 1, wherein said human body generated waste products include human excrement.

3. A rocket propellant mixture according to claim 2, wherein said human excrement relatively comprises between about five percent and about 65 percent of the weight of the mixture; the metallic fuel relatively comprising between about 10 percent and about 40 percent of the weight of the mixture; and the oxidizer relatively comprising between about five percent and about 50 percent of the weight of the mixture.

4. A rocket propellant mixture according to claim 2, wherein said human excrement comprises about 30 percent of the weight of the propellant mixture; the metallic fuel comprising about 20 percent of the propellant mixture; and the oxidizer comprising about 45 percent of the weight of the mixture.

5. A rocket propellant mixture according to claim 1, wherein said metallic fuel is selected from the group consisting of aluminum, beryllium boron, and mixtures thereof.

6. A rocket propellant mixture according to claim 5, wherein said metallic fuel comprise aluminum powder.

7. A rocket propellant mixture according to claim 1, wherein said inorganic oxidizer is selected from the group consisting of ammonium nitrate, ammonium perchlorate, alkali metal perchlorates and mixtures thereof.

8. A rocket propellant mixture according to claim 7, wherein said inorganic oxidizer comprise ammonium nitrate.

9. The propellant mixture according to claim 2, wherein the human body generated waste products include human feces.

10. The propellant mixture according to claim 2, wherein said human body generated waste products include human urine.

11. A rocket propellant mixture according to claim 4, wherein said human excrement comprises about one-third human urine and about two-thirds human feces, by weight.

12. A rocket propellant mixture according to claim 4, and further including carbon particles comprising about five percent of the weight of the propellant mixture.

13. A rocket propellant composition, comprising a mixture of about 20 percent aluminum, about 45 percent ammonium nitrate, about 10 percent human body generated urine, about 20 percent human body generated feces, about five percent bone black carbon and less than about one percent gellant.

* * * * *