FINAL REPORT

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Zero Gravity Clothes Washer

Contract NAS 9-10934

Submitted to: NASA Manned Spacecraft Center
R & D Procurement Branch
Houston, Texas 77058

Submitted by: Whirlpool Corporation
Life Support Systems Group
300 Broad Street
St. Joseph, Michigan 49085

Prepared by:

John J. Symons, Mgr.
Life Support Engineering

Approved by:

Norman G. Roth, Ph.D., Director
Life Support Systems Group

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INTRODUCTION

Scope

This report describes the design, development, fabrication and testing of an approximate half-scale demonstration model of a clothes washer, utilizing principles of fluidics to provide washing action, and with the capability to function under conditions of zero gravity.

The effort was conducted under contract with NASA Manned Spacecraft Center, by the Life Support Systems Group of the Whirlpool Corporation. The program was initiated on June 8, 1970, and was concluded with delivery of the demonstration model to NASA-MSC after a period of eight months.

Background

Manned spacecraft flights in the past have not required provision of equipment for onboard laundering of clothing and other fabric articles. The problem of maintaining good sanitation and comfort standards on short missions is solved by carrying the required number of clothing changes aboard the spacecraft. Future manned missions of long duration, however, will require laundry equipment. The weight and volume of carry-on clothing will be greater than that of equipment necessary to launder a small quanity of clothing for reuse. A further advantage of onboard laundry operations is elimination of the need to store large quantities of soiled clothing, which can create problems associated with odor, production of toxic gases, and generally unsanitary conditions.

Background (continued)

Currently available domestic or commercial laundry equipment is not suitable for use on manned spacecraft for a variety of reasons. As compared with current equipment, a washer for use in spacecraft will operate with smaller loads; shall function in the absence of gravitational forces; shall use less water; shall be smaller and lighter in weight; shall require less power; shall be designed with greater emphasis on convenience and safety; provide higher reliability and require less maintenance; and preferably shall require less detergent and other expendables which are carried on board. In addition, all materials and components shall meet the more stringent requirements imposed by spacecraft environments, launch loads, vibration, and other typical conditions. Less variety in fabric types and finishes can be anticipated, and the composition of soil will also be different.

A clothes washer, utilizing the principles of fluidics, had previously been developed and fabricated in the Whirlpool Research and Engineering Laboratories. The fact that the washing principle is not gravity dependent generated interest in adaptation of the fluidic principle used in this unit for use under conditions of zero gravity in spacecraft. The fact that fewer components are required, and weight and volume are significantly reduced, further increased this interest for potential spacecraft application.

Objectives

The primary objective of the program was to provide a half-scale model of the zero gravity clothes washer that could be used to demonstrate the feasibility of the fluidic washing principle through bench and zero gravity testing. Requirements included fabrication of the tub from transparent materials to permit visual observation of the washing action, and provisions for manual

Objectives (continued)

operation of valves and controls to enhance flexibility of the test program. No provisions for conservation of water were required, and the selection of materials and components was not limited by spacecraft flight requirements. Requirements for testing of the unit by Whirlpool were limited to those tests necessary to establish that the unit was a functional bench test model, as further testing and demonstration operations will be conducted by NASA-MSC.

PRINCIPLES OF OPERATION

Washing and Rinsing

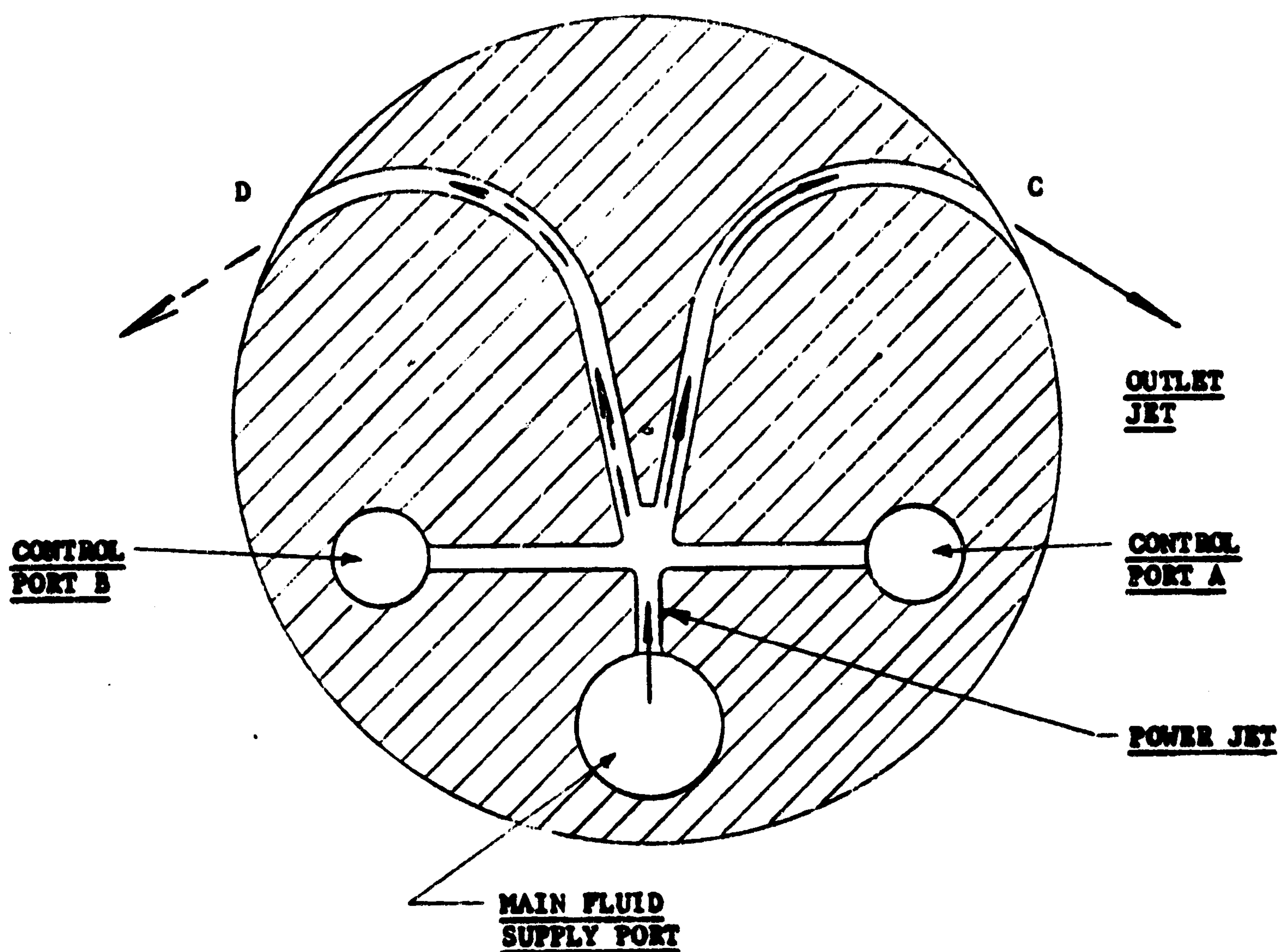
Simply stated, the washing of fabrics involves the process of detergency (soil removal), which is a procedure for the removal of soil from the surface of a solid by means of a liquid. This requires wetting (intimate contact of the detergent solution with the surface of the fabric); soil separation (transfer of the soil from the surface of the fabric to the bulk of the solution); and soil suspension (suspension of removed soil in the solution so that it will not redeposit on the cleaned surface). The energy required for detergency includes physical energy supplied by the surfactant in the detergent to remove the insoluble soils; chemical energy supplied by various alkaline salts in the detergent to convert some of the insoluble soils into a soluble form; and mechanical energy to aid the chemical laundering solution in removing various insoluble soils. Mechanical energy, which is supplied by the washing machine, must flex the fabric fibers; provide relative motion between fabric and laundering solution to physically detach and entrain soils in the moving solution after release; and continuously open folds in the fabric to expose all portions to the flushing action of the solution. These functions must be provided without excessive abrasion of the fibers, and without applying excessive tensile stresses to the fabric. Within limits, detergency is accelerated with increasing temperatures.

Washing and Rinsing (continued

In the fluidic washer, mechanical energy is supplied by the kinetic energy of liquid jets issuing from a center post in a tub filled with laundering solution. Alternating the direction of multiple jets provides the necessary agitation. This is accomplished by synchronous switching of liquid flow through the outlet ports of a stack of bi-stable fluidic switches which form the center post.

A bi-stable fluidic switch is one of the most widely used fluidic devices. A general purpose bi-stable switch is illustrated in Figure 1. Liquid enters the switch through a main supply port. As fluid flows from the supply port, it forms a power jet, which is acted upon by a pressure differential resulting from the difference in pressures imposed on control ports "A" and "B". If pressure at control port "A" is greater than pressure at port "B", fluid will flow from port "D". Conversely, if the higher control pressure is applied to port "B", fluid will flow from the switch through port "C". A very small pressure differential across the power jet is sufficient to switch the main flow, and bi-stable switches have been developed that require only covering one control port and exposing the other to ambient to accomplish the switching function. As the majority of commercially available bi-stable fluidic switches are designed to operate with air as the working fluid, it was necessary to develop special hydraulic switches to handle liquid flows of practical magnitude for laundry equipment applications.

In the fluidic washer adapted for zero gravity operation, a number of bi-stable hydraulic fluidic switches, with outlet ports located at points 120° apart on the periphery of each switch body, make up the center post of the washer. All switches are identical, but each is rotated at an angle of 120° to adjacent switches when assembled into the stack. Liquid is admitted to the supply port of each switch through a common manifold, and control ports are similarly



Bi-Stable Fluidic Switch

FIGURE 1

Washing and Rinsing (continued)

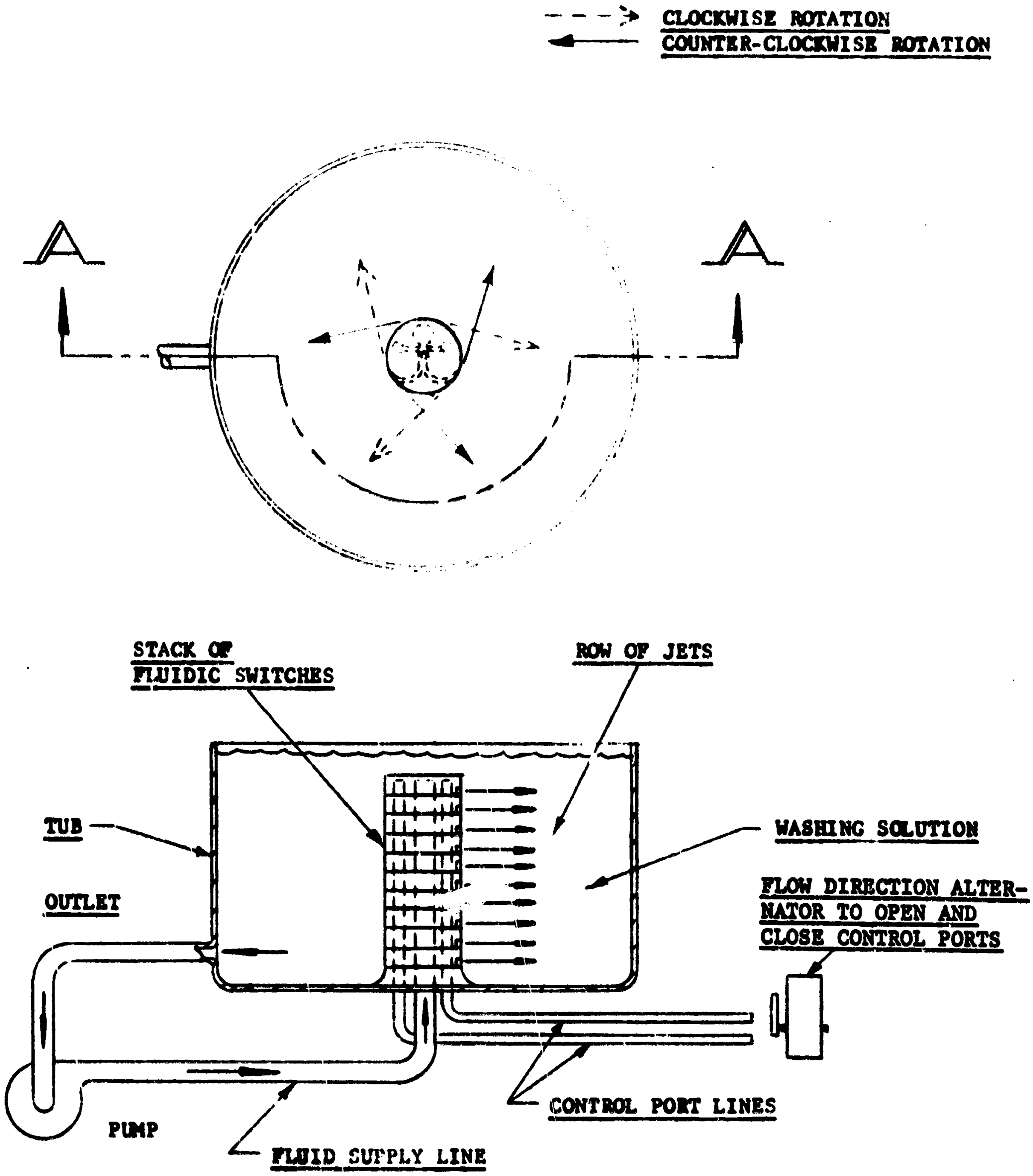
interconnected by two manifolds. With one control port closed, all switches direct flow through outlet ports in a clockwise direction, providing three rows of jets, equally spaced around the column of switches. With the other control port closed, flow is directed through the opposite outlet port of each switch, producing jets in a counterclockwise direction. A schematic drawing of the resulting washing action, illustrating the control method, is presented in Figure 2.

Extraction

Following wash and rinse cycles in the fluidic washer, it is necessary to extract the major portion of water remaining in the clothes load. In the original prototype developed by Whirlpool prior to this contract, rotation of the tub to extract water centrifugally was accomplished hydraulically, by directing a jet of water against a series of turbine blades mounted on the exterior of the tub bottom. In the small scale model fabricated during this contractual effort, however, it was found that space limitations precluded provision of a sufficiently large jet of water to properly rotate the tub. Centrifugal extraction, therefore, is provided in the demonstration model by means of an electric motor equipped with a small diameter rubber wheel that can be moved against the lower tub rim when rotation is desired.

DESCRIPTION OF ZERO GRAVITY CLOTHES WASHER

The washer, as delivered on this contract, consists of a rotatable tub, provided with the previously described stack of fluidic switches along its vertical axis, a removable lid, an air vent, and a pick-up disc; a motor-driven pump; a chopper, or a flow direction alternator; a motor for spinning the tub; a filter in the water recirculation line; a sump valve; an open sump, or reservoir; electrical control



Washing Action and Control
Device in Fluidic Washer

FIGURE 2

switches; and necessary electrical and hydraulic lines. A schematic drawing of the washer is presented in Figure 3. The assembly is mounted on a platform equipped with casters to permit convenient handling. The following paragraphs describe construction and function of each of the major components, and detailed operating instructions are presented in Appendix A. These instructions are written to provide all information required to understand operation of the unit without reference to the complete Final Report.

Rotatable Tub

The tub, or washing container, is a cylindrical vessel, tapering to a smaller diameter at the top. It is provided with a gasketed cover that may be secured in place with machine screws. A perforated inner basket, spaced from the inner wall of the tub, is provided to separate the clothes load from the tub wall and permit water extracted from the load to freely move to bottom of tub, where the pick-up disc is located. Both tub and inner basket are fabricated from transparent plastic to permit observation of washing action. The entire tub, supported by bearings in the hub, rotates about the stationary center post. A spring-loaded rubber seal between the stationary and rotating components prevents leakage.

Center Post Assembly

This assembly supports the stack of fluidic switches and the pick-up disc. It also includes the hub, in which are located passageways leading from external hoses to the discharge port of pick-up disc; power jet manifold; and the fluidic switch control port manifold.

SCHEMATIC DRAWING OF ZERO GRAVITY CLOTHES WASHER
(NORMAL GRAVITY OPERATION)

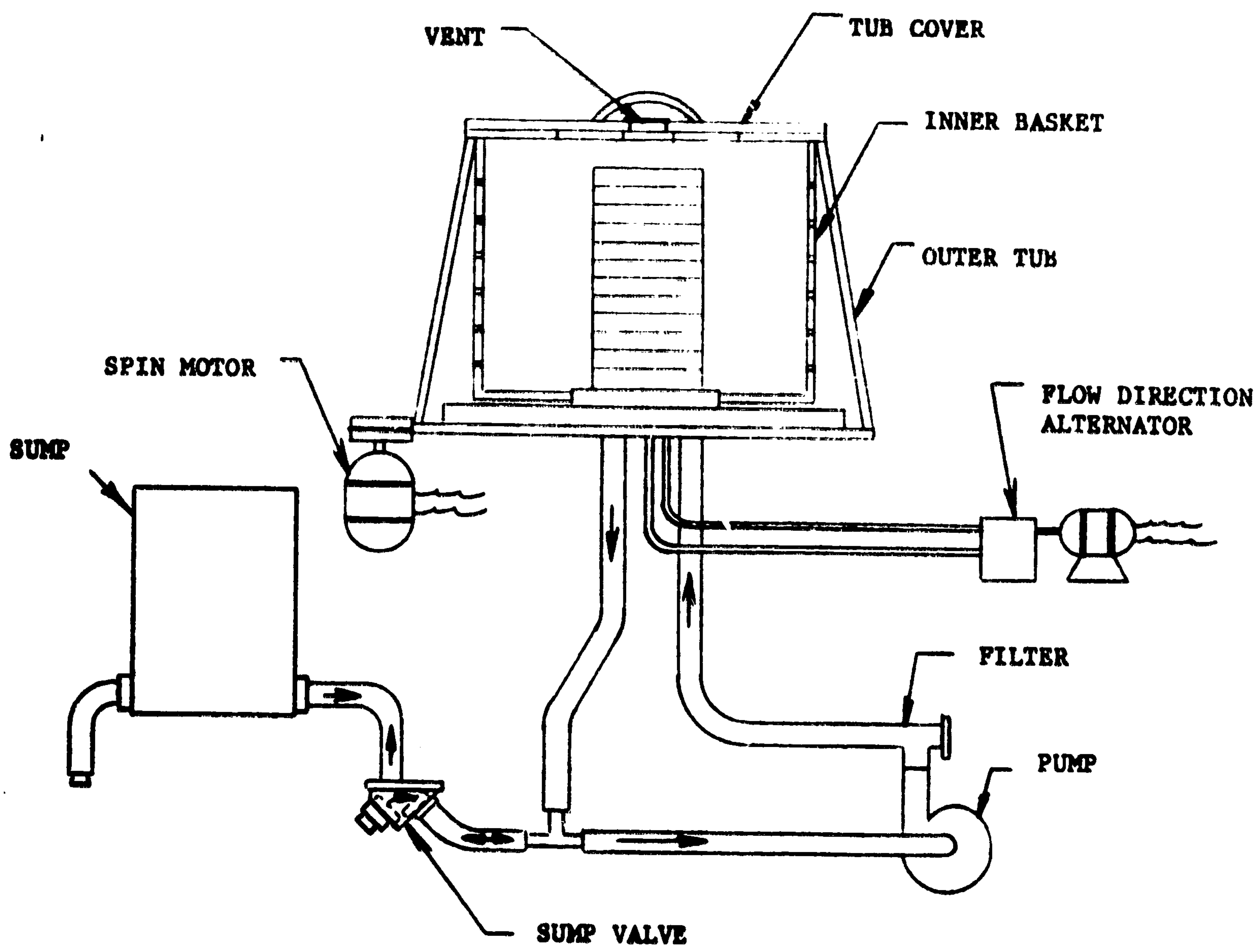


FIGURE 3

Pick-up Disc

The pick-up disc, utilized for removing water from tub during extraction, is a flat circular disc with multiple radial holes extending from the periphery to passageways in center post. This concept was originally developed by Whirlpool for use in liquid-gas separators, where feasibility was first demonstrated. When tub is rotating during the extraction cycle, under conditions of zero gravity, water is forced to wall of tub, leaving a cylindrical void along the axis of the tub. A radial pressure gradient is induced in the rotating body of water, with pressures varying from zero at the surface of the void to a significant pressure at the greatest radius of the tub.

Radial holes in the pick-up disc terminate near the greatest tub radius, at the point of greatest pressure. As these holes communicate with the drain line, which is at ambient pressure, water will flow into the pick-up disc and be removed from the washer. The same result can be accomplished by use of tubes extending from center post to tub wall, but it has been experimentally determined that turbulence around such a tube causes much more air entrainment and flow resistance than that produced with a pick-up disc. A further advantage of the pick-up disc is that pressure at peripheral openings of the radial holes decreases as water leaves tub, and flow into the disc ceases immediately before the last small volume of water leaves tub. Little air, therefore, can be admitted to the drain line, minimizing problems resulting from air in the sump.

Lid Vent

A vent, centrally located in the tub cover, permits air to enter tub when water is draining, and permits air to leave tub during filling operations. The vent must be closed, however, when tub is not rotating during wash and rinse operations.

Lid Vent (continued)

The unit was delivered with a vent suitable for operation during bench tests under normal gravity conditions. When water level reaches top of tub, an integral float on the vent mechanism moves a seal into place in the lid opening. A vent suitable for zero gravity operation is described in detail in the Operating Instructions included in Appendix A to this report. Materials required to modify the vent for zero gravity operation were provided with the unit on delivery.

Flow Direction Alternator

A device is provided to automatically reverse direction of flow of water from outlet ports of the fluidic switches. Plastic hoses, leading from each of the control port manifolds, are connected to ports in the flow direction alternator that are alternately opened and closed by openings in a rotating plate driven by a small electric motor.

Pump

A commercially available centrifugal pump is provided to initially move water from sump to tub, and to recirculate water from the pick-up disc to the fluidic switches during washing and rinsing operations.

Sump

The sump serves as a reservoir to contain a measured amount of water before it is pumped into the tub.

Sump Valve

The sump valve is a solenoid-actuated two-way valve, which permits water to flow from the sump, through the pump, to tub when the solenoid is energized.

Sump Valve (continued)

The line to sump is closed when solenoid is not energized, allowing water to be recirculated through tub.

Filter

A screen type filter is provided at the pump outlet to prevent recirculation of insoluble soil and lint, removed from the laundry load, back to tub during washing and rinsing operations. The filter element can be removed and cleaned as required.

Electrical Switches

Switches on the control panel are provided to control spin motor, pump, sump valve, and flow direction alternator. Two additional switches are provided to control additional functions, such as control of valves required to permit re-use of rinse water for the subsequent washing operation, if it is desired to add such features in the future.

DEVELOPMENT TEST PROGRAM

The development test program was limited in scope, as the contract required only that a functional demonstration model, capable of verifying the feasibility of the fluidic washing principle under conditions of zero gravity, be fabricated. No attempt was made to optimize washing efficiency, minimize water requirements, power, weight, or volume, or to automate the operation of the unit. Testing of the unit under simulated zero gravity conditions in Keplarian trajectory aircraft flights was not included in contractual requirements, although the unit was delivered with all components and materials required to permit modification of the washer for zero gravity operation, with the exception of a bladder-type sump to be provided by NASA.

Functional testing of the washer indicated the necessity to provide eight radial holes in the pick-up disc in order to insure sufficient velocity of flow from fluidic switches. Modifications were also required to the original flow direction alternator to eliminate leakge of air across control ports, which had prevented proper reversal of water jet direction. After these modifications were completed, function of fluidic switches was satisfactory.

As previously stated, testing indicated that spinning of the tub by a hydraulic turbine was not feasible for the small scale demonstration model. The use of an electric motor, through a direct friction drive, was found to be satisfactory for rotating the tub to provide the extraction function.

Limited washability tests were conducted to determine capability of the unit to remove soil from certain fabrics, to establish size of test loads, and to evaluate effects of various washing solutions on performance of the washer. Optimization of washing efficiency in the half-scale demonstration model is limited by several factors. The requirement for a transparent tub imposed a limit on the temperature of water that can be used without damaging the plastic (approximately 120°F). As soil removal is also influenced by the amount of washing solution removed from the load by extraction following the washing operation, washability is improved by high speed extraction. The transparent plastic tub construction has insufficient strength to withstand forces produced by high rotational speeds, so spin speed is limited to approximately 360 rpm. Despite these limitations, tests indicated that the unit was capable of increasing the reflectance of standard clay/triolein soil samples from 49 to 54. A reflectance value of 60 is typical of excellent washability in commercially available household laundry equipment. Further tests were conducted using swatches of synthetic fabric which had been soiled by wiping dusty surfaces with the damp material, and washing these swatches in the unit. Only slight traces of the soil remained after washing. The above results were obtained by washing in a 0.2% solution of a special low-sudsing detergent without surfactant, in 80°F water for fifteen minutes.

Generally speaking, commercially available laundry detergents are not suitable for use in the fluidic washer. So-called low-sudsing products tend to produce excessive foaming, which interferes with proper washing action. For this reason, a supply of special detergent, containing no surfactants, was furnished with the unit. A supply of liquid surfactant was also included, and this may be added to the washing solution in progressively larger quantities to determine the optimum amount of surfactant for use with any particular type of fabric that may be utilized in laundry tests to be conducted by NASA.

ADDITION OF OTHER FEATURES TO BASIC WASHER

Modifications to the unit to permit operation under simulated zero gravity conditions are described in detail in the Operating Instructions. The basic fluidic washer, however, can be provided with additional features that will increase its utility.

Water Conservation

It may be anticipated that laundry equipment, designed for use in manned space missions of long duration, will be required to operate with minimum consumption of water, thereby reducing the required capacity of water reclamation systems. This may be accomplished by several methods, but the most effective single procedure involves the use of rinse water as the supply for the subsequent washing operation. An additional sump, together with added valves and hoses, can provide this capability, as illustrated in the schematic drawing presented

Water Conservation (continued)

in Figure 4. At the beginning of each laundry cycle, Sump #1 is filled with rinse water from the previous cycle, all valves are closed, and pump is not operating. Valve E is opened to admit fresh water to Sump #2, and is closed when sump has been filled. Valves B and C are opened, and with tub spinning, the pump motor is energized, pumping water from Sump #1 into tub. Valves B and C are closed, tub ceases to spin, and after detergent is added, the pump recirculates washing solution through jets in the center post and back to the pump through the pick-up disc. At the end of the washing operation, pump motor stops, tub is spinning, Valves A and C are opened, and wash water is discharged to drain. Valves A and C are then closed, and Sump #1 is empty. To initiate the rinsing operation, pump motor is energized, tub is spinning, and Valve D is opened. Fresh water in Sump #2 is pumped into tub, and Valve D is closed. The tub stops spinning, and the rinsing operation continues for the desired period of time. Valves B and C are opened, tub is spinning, pump motor stops, and rinse water is directed into Sump #1, where it is retained until the beginning of the next laundry cycle, when the entire operation is repeated.

By operation of valves and motors in different sequences, it is also possible to reuse wash water several times before it is discharged to the drain, adding detergent to wash water as required. It is assumed that a flight-type washer will be equipped with an automatic sequence timer to provide desired cycles, similar to timers currently utilized in domestic laundry equipment.

Addition of Drying Capability

One of the advantages of the fluidic washer is that drying capability can be added with minor modifications to the basic unit. It is necessary only to add

MODIFICATION OF ZERO GRAVITY CLOTHES WASHER
TO REDUCE WATER CONSUMPTION

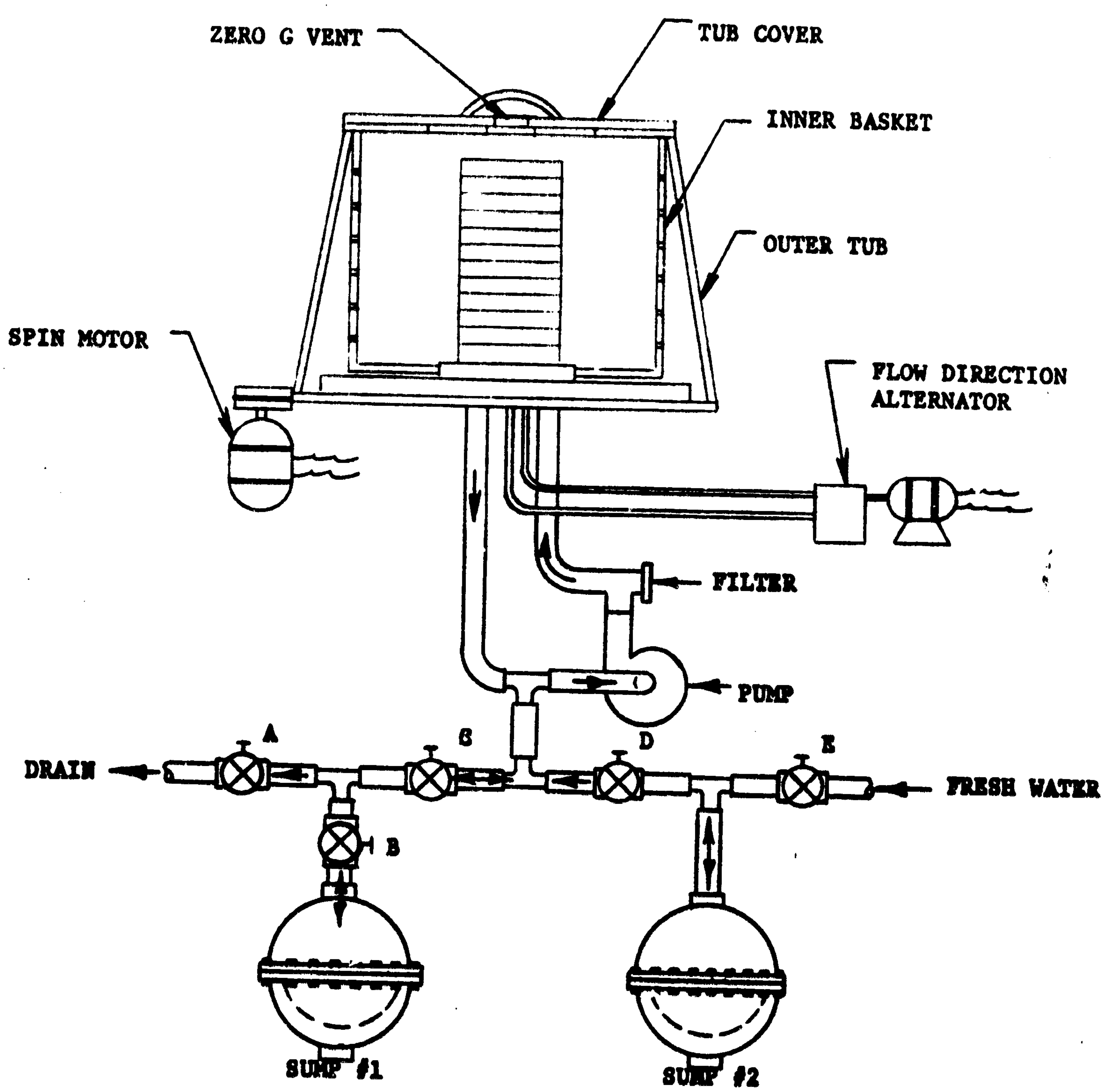


FIGURE 4

Addition of Drying Capability (continued)

a heater and blower, together with valves in the hydraulic lines to permit heated air to be drawn into the supply manifold for the fluidic switches, and to allow moist air to be exhausted through the pick-up disc to the exterior of the unit. This modification is illustrated schematically in Figure 5. Under conditions of zero gravity (this concept is not operable under normal gravity conditions), the reversing air jets agitate the damp clothes floating in the tub, evaporating remaining water to provide the drying function. The drying operation takes place after rinse water has been extracted from the load, and it is necessary to manually detach the load from walls of the inner basket before beginning the drying operation.

CONCLUSIONS AND RECOMMENDATIONS

The demonstration model will serve to verify the feasibility of the fluidic washing principle under conditions of zero gravity. It will also demonstrate the decreased weight and complexity of the unit as compared to a washer utilizing a mechanically driven agitator to provide agitation of the clothes load. Reduction of the number of components results in higher reliability.

It is recommended that follow-up programs be considered, to permit complete exploitation of the inherent advantages of this approach. A full-scale unit, equipped with automatic controls, and designed to incorporate water conservation and drying functions, could provide complete laundry facilities for long duration manned missions with minimum weight, volume and power penalties. To permit complete optimization of such a unit, however, it will be necessary to tailor the design to the specific crew size, types of fabric utilized in clothing and other articles to be laundered, nature of water reclamation system utilized in the spacecraft, power limitations, water usage limitations, and other factors resulting from requirements for interfacing with other spacecraft systems.

ADDITION OF DRYING CAPABILITY TO
ZERO GRAVITY CLOTHES WASHER

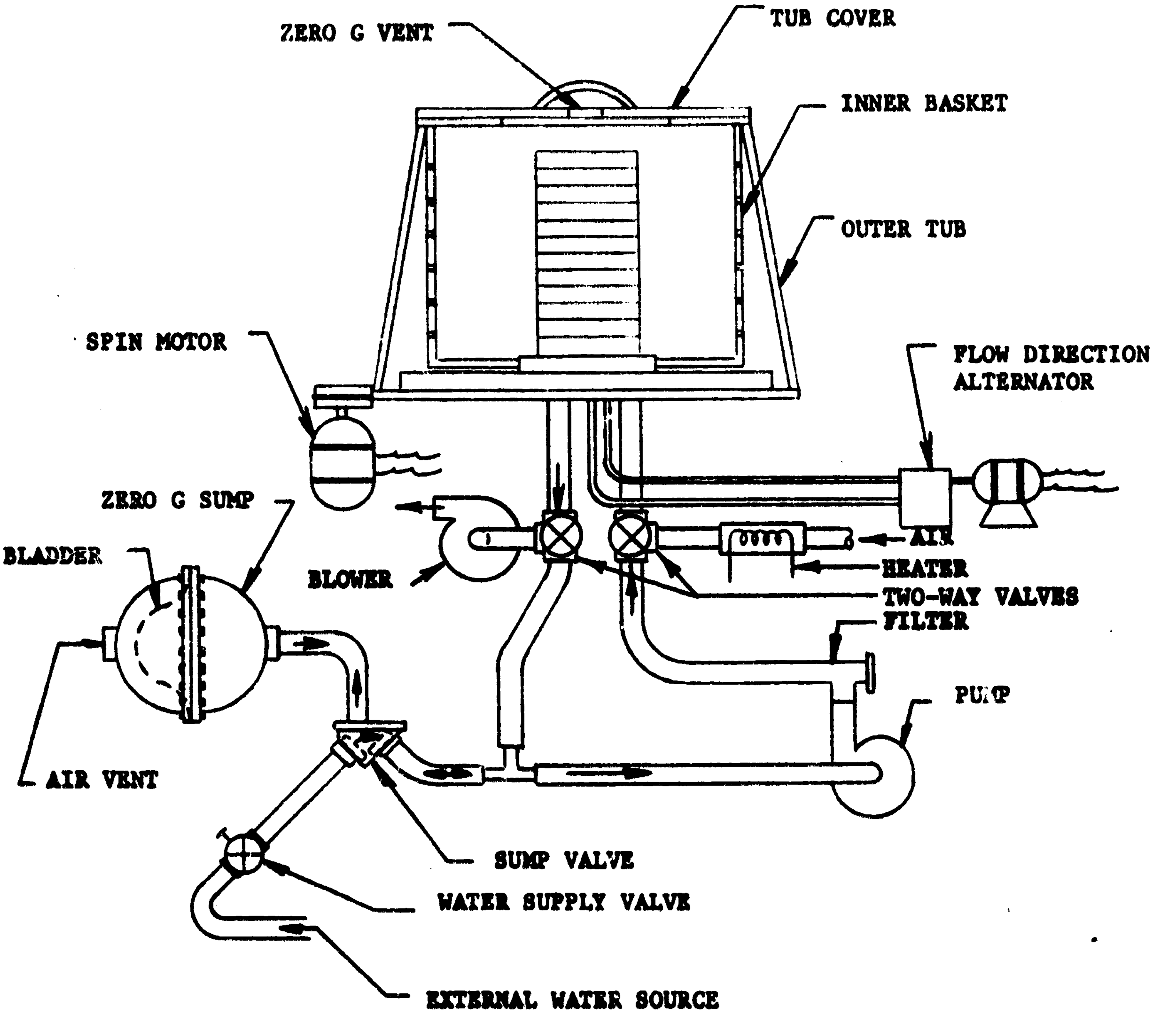


FIGURE 5

ADDENDUM A

OPERATING INSTRUCTIONS

Zero Gravity Clothes Washer
Contract NAS 9-10934

1.0 GENERAL DESCRIPTION

1.1 Purpose

The washer, a prototype bench test model approximately one-half scale, was designed to demonstrate the feasibility of the fluidic washing principle for laundering fabrics under conditions of zero gravity. The unit, as delivered, is suitable for operation under normal gravity conditions, but can easily be modified by the additon of a bladder-equipped sump to permit operation under weightless conditions.

1.2 Washing Principle

An imperforate outer tub, tapering from a larger diameter at the top, contains a perforated cylindrical inner tub in which laundry load is placed. When tub is filled with detergent solution, with tub lid sealed in place, solution is recirculated through tub, and a filter in an external hose, by means of a pump. Solution enters tub through a series of jets issuing from ports in a stack of bi-stable fluidic switches which form a center post in tub. A motor driven device, at 15 second intervals, reverses the pressure differential across control ports of the fluidic switches, alternating fluid flow from outlet ports of each of the fluidic switches. Jets issuing tangentially from the surface of center post, in three vertical rows, impart first a clockwise rotation to solution in tub, and then a counterclockwise rotation, providing movement of load in tub necessary to furnish washing action. Solution continuously leaves tub through outlets in tub bottom, and returns to pump inlet. Tub does not

1.2 (continued)

rotate during this process, and a vent in tub cover allows air to leave or enter tub during filling or draining operations.

1.3 Extraction Principle

Removal of fluid from tub after washing or rinsing operations, and extraction of portion of the residual fluid in laundry load, is accomplished by rotation of tub. Centrifugal forces move fluid to lower corner of the tub, where it enters passageways in a pickup disc in bottom of tub, and is forced from tub outlet to a drain or fluid storage sump.

1.4 Controls

A control panel is provided with six switches. Only four switches are required to manually control operation of the unit. From left to right on control panel, the first switch controls spin motor; the next two are spares that may be utilized if additional sumps are added to the unit to permit reuse of water; the fourth switch controls pump motor; the fifth switch operates a three-way valve; and the sixth switch controls motor driving device that alternately opens and closes the control ports, which is designated the flow direction alternator.

2.0 OPERATION (NORMAL GRAVITY)

2.1 Loading

1. Set control switches:

   Spin Motor - OFF (down)

   Pump - OFF (down)

   Sump Valve - FILL OR DRAIN (up)

   Flow Direction Alternator - OFF (down)

2.1 (continued)

2. Remove tub cover by removing four machine screws.
3. Add 15 grams of special detergent (powder), and 0.75 grams Alfonic #1215-b liquid surfactant (both furnished with unit) to tub. If excessive sudsing is experienced during washing, reduce amount of liquid surfactant.
4. Add laundry load to tub and replace tub cover, using four machine screws to secure cover. (Unit will satisfactorily launder approximately 144 square inches of fabric, preferably in several pieces.)

2.2 Fill

1. Connect power cord to 115 volt alternating current power source.
2. With external water supply hose, fill insulated sump with clean water to red line on inner surface of sump. (Do not overfill). Water temperature should not exceed 120°F. to prevent damage to plastic tub, which is provided to permit visual observation of washing action.
3. Move pump switch to ON (up) position. Water will be transferred from center post jets in a single direction. When all water has been pumped from sump, initiate washing operation, described below.

2.3 Wash

1. Move sump valve switch to RECIRCULATE (down) position.
2. Open clamps on plastic hoses leading to flow direction alternator.
3. Move flow direction alternator switch to ON (up) position.
4. When desired washing time (approximately 15 minutes) has elapsed, initiated extract and drain operation, as described below.

2.4 <u>Extract and Drain</u>

1. Tighten clamps on plastic hoses leading to flow direction alternator.
2. Move flow direction alternator switch to OFF (down) position.
3. Move sump valve switch to FILL OR DRAIN (up) position.
4. Move pump switch to OFF (down) position.
5. Move spin motor switch to ON (up) position.
6. Remove stopper from short hose extending from bottom of sump, and direct water to external drain.
7. When flow from sump drain has ceased, move spin motor switch to OFF (down) position.

2.5 <u>Rinse</u>

1. With external water supply hose, wash down interior of sump, replace stopper in sump drain line, and fill sump to red line.
2. Move pump switch to ON (up) position, and when all water has been pumped from sump, move sump valve switch to RECIRCULATE (down) position; open clamps on plastic hoses leading to flow direction alternator; and move flow direction alternator switch to ON (up) position. When desired rinsing time (approximately 5 minutes) has elapsed, initiate extract and drain operation, as described in paragraph 2.4 of these instructions.

2.6 <u>Unload</u>

1. Replace stopper in sump drain line.
2. Remove tub cover and remove load.
3. All switches may be left in same positions, and unit will be ready for next wash cycle.

3.0 OPERATION (ZERO GRAVITY)

Before unit can be operated under zero gravity conditions, it must be modified by the substituion of a bladder-equipped sump (not furnished), in place of open sump, and detergent and surfactant required for each load must be mixed together and enclosed in a water-soluble plastic pouch prior to the experiment. In addition, vent in tub cover must be modified. This modification requires removal of 1-g float-type vent in tub lid, and securing disc of hydrophobic porous material over opening. The material freely passes air, which leaves tub during filling, and enters tub during draining. As tub is spinning during both fill and drain periods, centrifugal forces force water to walls of the tub, leaving a column of air around tub axis, directly under vent. When tub is not spinning, water covers vent and hydrophobic material prevents escape of water from tub. Several grades of hydrophobic material (DuPont Remay Spunbonded Polyester, styles No. 2033, 2038, and 2470) are furnished with unit, so that the most suitable grade may be selected by testing under conditions of zero gravity. Test discs can be secured over the vent opening by use of pressure sensitive tape. The unit, as modified, can then be operated through a wash cycle as described below. (See Figure 3.0 (A)). If both washing and rinsing operations must be demonstrated under zero gravity conditions, additional modifications will be required, as described in the Final Report.

3.1 Loading

1. Set control switches:

   Spin Motor - OFF (down)

   Pump - OFF (down)

   Sump Valve - RECIRCULATE (down)

   Flow Direction Alternator - OFF (down)

WASHER MODIFIED FOR ZERO GRAVITY OPERATION

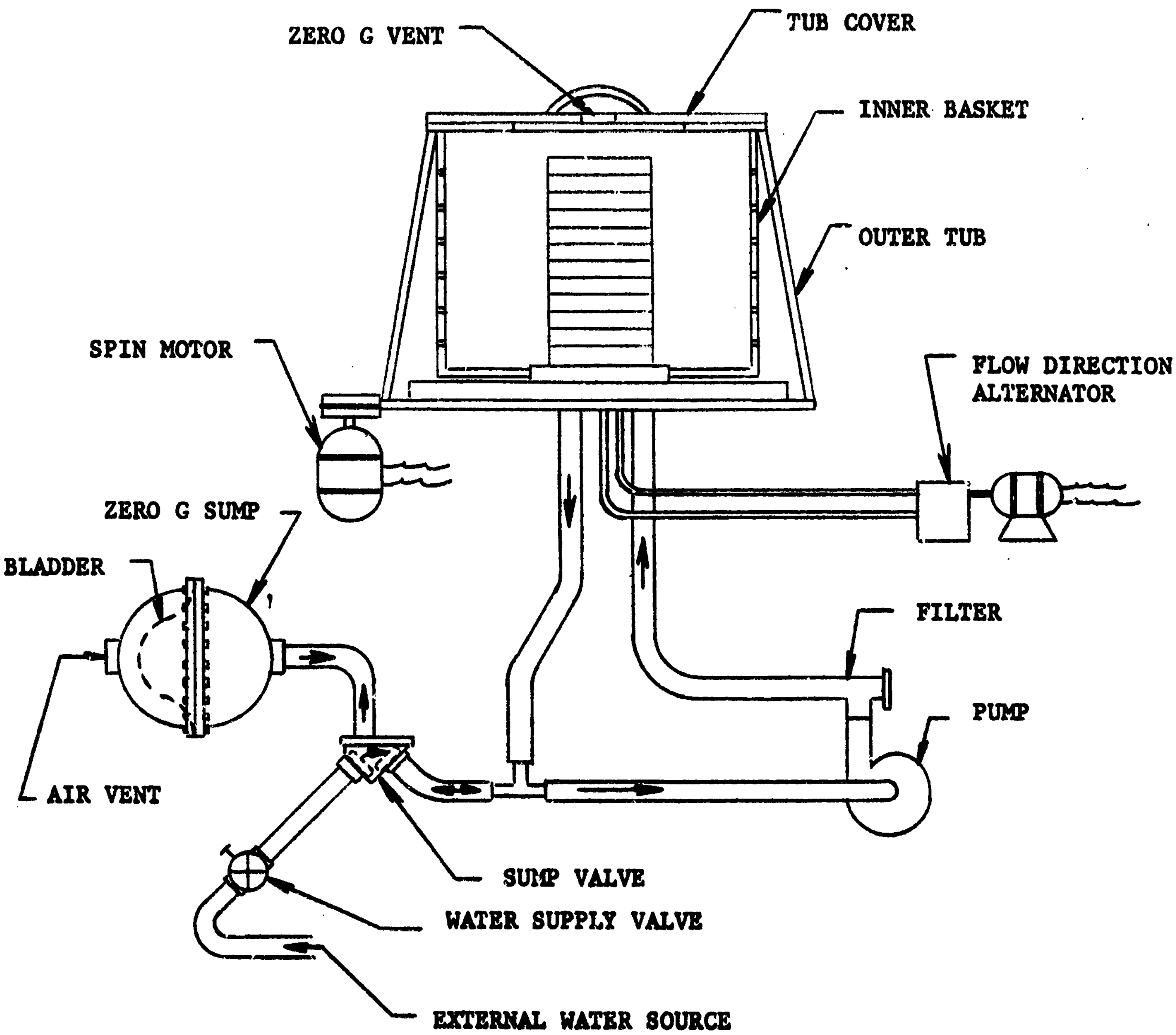


FIGURE 3.0 (A)

3.1 (continued)

2. Remove four machine screws in tub cover.

3. Wrap water-soluble pouch containing detergent and surfactant mixture, and smaller items in laundry load, in the largest item in load, and insert entire bundle in tub, opening lid only sufficiently to permit this operation.

4. Replace and tighten four machine screws in tub cover.

3.2 Fill

1. Connect power cord to 115 volt alternating current power source.

2. a) If zero gravity sump is empty, and a pressurized supply of water is onboard, open water supply valve and admit approximately 2 1/2 gallons of clean water (not over 120°F) to the zero gravity sump. Close water supply valve, move sump valve switch to FILL OR DRAIN (up) position, move spin motor switch to ON (up) position, and move pump switch to ON (up) position. Water will be transferred from sump to tub. The tub must be spinning during filling to permit displaced air in tub to exit through vent. When surface of central air column contacts surface of center post, immediately move sump valve switch to RECIRCULATE (down) position. <u>If switch is not operated at this time, plastic tube or vent may rupture</u>.

   b) If zero gravity sump has been brought aboard filled with 2 1/2 gallons of clean water (not over 120°F), the sump filling operation is deleted, and sump valve, spin motor, and pump switches are operated as described in previous paragraph to initiate wash period.

3.3 **Wash**

1. Move spin motor switch to OFF (down) position.
2. Open clamps on plastic hoses leading to flow direction alternator.
3. Move flow direction alternator switch to ON (up) position.
4. When desired washing time (approximately 15 minutes) has elapsed, initiate extract and drain operation, as described below.

3.4 **Extract and Drain**

1. Tighten clamps on plastic hoses leading to flow direction alternator.
2. Move flow direction alternator switch of OFF (down) position.
3. Move sump valve switch to FILL OR DRAIN (up) position.
4. Move pump switch to OFF (down) position.
5. Move spin motor switch to ON (up) position.
6. When all water has been removed from tub, move spin motor switch to OFF (down) position, and move sump valve switch to RECIRCULATE (down) position to prevent water from moving back into hoses.

NOTE: It is assumed that above procedure will suffice to demonstrate functions of the unit under conditions of zero gravity, and it will not be necessary to perform rinsing operation.

4.0 CARE AND MAINTENANCE

No lubrication of unit is required during normal use. Useful life of unit will be increased, however, by performing the following maintenance operations:

4.0 (continued)

1. Periodically remove and clean filter screen. Proper seating of filter element is required before replacing cover.
2. Flush unit with clean water after each series of usages, spin tub to remove residual water, and do not replace tub cover until interior of tub has dried.
3. If unit is to be stored for extended periods of time, disassemble unit, clean all parts, and coat ball bearing surfaces with SAE 30 oil.