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WATER MANAGEMENT SUBSYSTEM SPECIFICATION FOR SPACE FLIGHTS OF EXTENDED TIME PERIODS

64-26211

LIFE SUPPORT SYSTEM FOR SPACE FLIGHTS OF EXTENDED TIME PERIODS

Contract NAS 1-2934

Prepared for

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1/ INTRODUCTION

This subsystem specification accounts for the equipment required in an operational water management subsystem as part of the Life Support System for Space Flights of Extended Time Periods, Contract NAS 1-2934. The recommended water processing techniques resulted from the study described in the Water Management System Evaluation Report (Reference 1).

This report summarizes the requirements of the components making up the water management subsystem and also outlines the operational procedure for normal and emergency situations as well as the integration requirements of this subsystem with other subsystems.

Both a flight and prototype system are discussed in this report. The difference between these two lies chiefly in the limit of effort expended in minimizing the weight, power, and volume of the prototype system. The two systems do not differ in an operational sense except for the fact that the prototype system is designed to operate in a 1-g as well as a 0-g environment. The prototype system is being developed for NASA/LRC under this contract.

2/ WATER MANAGEMENT

2.1 FUNCTIONS

The primary task involved in maintaining a usable water supply in the closed environment of a spacecraft is the necessity of reclaiming waste waters. In addition to waste water reclamation, however, facilities for the following functions must be available:

a. Storage of raw urine, used wash water, and humidity condensate.

b. Collection of reclaimed water for quality analysis (holding tanks)

c. Storage of purified water.

d. Transfer of water to and from tanks and between reclamation systems when necessary.

e. Storage of emergency water supplies.

f. Heating of potable water.

g. Cooling of potable water.

h. Dispensing of water for drinking, food preparation, and washing.

i. Collection of waste waters and water from the CO_2 reduction unit.

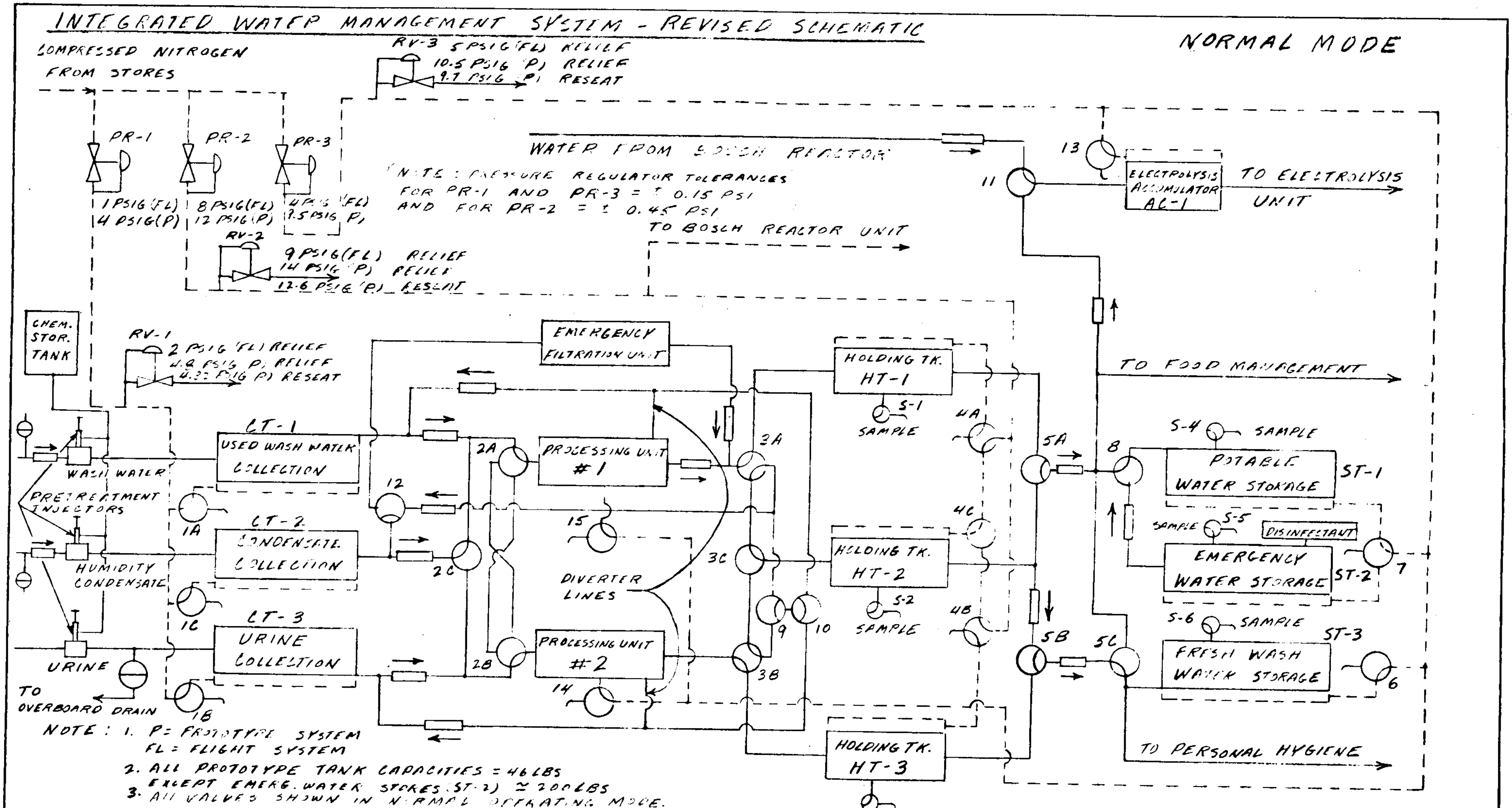
j. Provision of water for electrolysis.

k. Provisions for cleansing and disinfecting of any fresh water tanks that may be contaminated.

Heating, cooling, and dispensing of potable water will be treated as part of the food subsystem. Facilities for dispensing of wash water and collection of used wash water will be included in the personal hygiene subsystem. Facilities for collection of urine will be provided in the waste management subsystem. Humidity condensate is delivered directly from the main cabin air dehumidifier to the water management subsystem.

2.2 DESCRIPTION OF SUBSYSTEM

A schematic diagram of the water management subsystem as a whole is shown in Figure 2.1. This schematic shows the valve positions for "normal mode" operation (except that valves 2A, 2B, and 2C would be turned to off position after waste water is transferred to the processing unit "pretreatment tanks"). Zero "g"



NOTE: 1. P = PROTOTYPE SYSTEM
FL = FLIGHT SYSTEM
2. ALL PROTOTYPE TANK CAPACITIES = 46 LBS EXCEPT EMERG. WATER STORES (ST-2) ≃ 200 LBS
3. ALL VALVES SHOWN IN NORMAL OPERATING MODE.

FIGURE 2.1

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tanks required for storage of the waste and recovered waters are shown with connections to a compressed gas source. The pressurized gas will serve to collapse bladders against the water inside the tanks when desired to expel water from these tanks. Design of the tanks will allow for approximate water level measurements. The major components of the subsystem can be summarized as follows:

a. Two waste heat air evaporation units will be provided for recovery of water from the three waste waters. An on-line multi-filtration unit is included in the subsystem for emergencies only. During normal operation, urine is to be processed in one of the air evaporation units and waste wash water and humidity condensate are processed in the second unit.

b. Tanks are provided for collection of waste waters, collection and holding of recovered waters, storage of electrolysis water, storage of reclaimed water , and storage of emergency water supply.

The tank capacities are specified for both the flight system and prototype system. The prototype tank sizes will be standardized rather than providing tanks of minimum required capacity for reasons of economy. Pressures designated for the various tanks are in accordance with requirements for water transfer within the water management system and between other systems. Values are given for both flight and prototype systems. The pressures for the prototype system take into account the hydrostatic head due to differences in level between tanks and equipment according to the location of equipment in the simulator.

2.2.1 WASTE WATER COLLECTION TANKS

a. Urine (CT-3).
Capacity - 46 lbs (prototype - 46 lbs)
Pressure - 1 to 2 psig (prototype - 3.85 to 4.80 psig)
Function - Collection of urine delivered by the collection unit (in the waste management subsystem). Urine from this tank is fed directly to processing unit #2.

b. Used Wash Water (CT-1)
Capacity - 46 lbs (prototype - 46 lbs)
Pressure - 1 to 2 psig (prototype - 3,85 to 4.80 psig)
Function - Collection of used wash water delivered from the personal hygiene subsystem. Used wash water from this tank is fed directly to processing unit #1.

c. Humidity Condensate (CT-2)
Capacity - 40 lbs (prototype - 46 lbs)
Pressure - 1 to 2 psig (Prototype - 3.85 to 4.80 psig)
Function - Water from the main cabin air dehumidier continuously flows to this tank. Waste water from this tank is fed to processing unit #1 during normal operation. In emergency situations, this waste water is processed through the emergency filtration unit.

2.2.2 WASTE WATER PROCESSING UNITS

a. Processing Unit #2
Type - Waste heat air evaporation
Capacity - Capable of processing 32.8 pounds of waste water in 16 hours. Recovery rate of prototype unit in normal operating mode will be 1.25 lb/hr. If Processing Unit #2 fails, recovery rate of Processing Unit #2 will be 1.64 lb/hr.
Function - Processing Unit #2 will reclaim water from urine during the normal mode of operation (other modes of operation will be discussed in Section 3 of this report). The unit delivers recovered water (free of non-condensable gases) to a holding tank which will be vented of pressurized air before filling. The unit is expected to recover at least 95% of the water contained in raw urine.

b. Processing Unit #1
Type - Waste heat air evaporation; identical to processing unit #2.
Capacity - Capable of processing 32.8 pounds of waste water in 16 hours. Recovery rate of prototype unit in normal operating mode will be 32.8 pounds in 20 hours (1.64 lb/hr).
Function - Processing Unit #1 will reclaim water from used wash water and humidity condensate during the normal mode of operation (other modes of operation will be discussed in Section 3 of this report). The unit delivers recovered water (free of non-condensable gases) to a holding tank which will be vented of pressurized air before filling. The unit is expected to recover 97% of the water contained in used wash water and 99% of the water contained in humidity condensate.

c. Emergency Filtration Unit
Type - Multi-filtration (activated charcoal, ion exchange resin and a bacteria filter)
Capacity - Capable of processing 19.6 lbs of humidity condensate in 16 hours for 17 days.
Function - Will purify humidity condensate to produce potable water during periods of emergency operation (breakdown of both air evaporation processing units). A recovery efficiency of 99% is expected from the multi-filtration unit.

2.2.3 HOLDING TANKS

a. Holding Tank #3 (HT-3)
Capacity - 41 lbs (prototype - 46 lbs)
Pressure - 8 to 9 psig (prototype - 11.55 to 14.0 psig)
Function - Under normal operation, recovered urine from processing unit #2 is collected in this tank. The gas side of the tank is vented to ambient during collection of processed waste water so that the internal pressure is 0 psig. While water is collected in this tank, an in-line conductivity probe (within the processing unit) will continuously monitor the chemical purity of recovered water. (In the event of a failure of

processing unit #1, this tank, cycled with holding tank #2, will be used to collect all recovered waste water and will hold the water during an analysis for bacteria.) Water not meeting quality standards is transferred back to one of the waste water collection tanks for reprocessing. Recovered water meeting quality standards is transferred to the wash water storage tank (under normal operating conditions) and to the potable water storage tank (in the back-up mode when processing unit #1 has failed). Water transfer is accomplished by pressurizing the tank to the pressure shown above.

b. Holding Tank #2 (HT-2)
Capacity - 41 lbs (prototype - 46 lbs)
Pressure - 8 to 9 psig (prototype - 11.55 to 14.0 psig)
Function - During normal operation, waste water processed through processing unit #1 (used wash water and humidity condensate) is collected in this tank and analyzed for bacteria at the end of a batch operation. While water is collected in this tank, an in-line conductivity probe (within the processing unit) will continuously monitor the chemical purity of recovered water. The gas side of the tank is vented to ambient during collection of processed waste water so that the internal pressure is 0 psig. (In the event of a failure of either of the processing units, this tank is used for collection of all recovered water, cycled with a second holding tank, and will hold this recovered water for a quality check including analysis for bacteria.) Recovered water not meeting quality standards is transferred back to one of the waste water collection tanks for reprocessing. Recovered water meeting quality standards is transferred to the potable water storage tank. Water transfer is accomplished by pressurizing the tank to the pressure shown above.

c. Holding Tank #1 (HT-1)
Capacity - 41 lbs (prototype - 46 lbs)
Pressure - 8 to 9 psig (prototype - 11.55 to 14.0 psig)
Function - Same as holding tank #2 except that water from processing unit #2 is not collected in this tank when processing unit #1 fails.

d. Electrolysis Accumulator (AC-1)
Capacity - 9 lbs
Pressure - 8 to 9 psig (prototype - 9.35 to 10.5 psig)
Function - Collects and temporarily holds water given off by the Bosch CO_2 reduction unit. The accumulator serves as a constant supply of water for the electrolysis unit. Make-up water required for electrolysis is periodically transferred from the potable water storage tank to the accumulator.

2.2.4 FRESH WATER STORAGE TANKS

a. Wash Water (ST-3)
Capacity - 28 lbs (prototype - 46 lbs)
Pressure - 4 to 5 psig (prototype - 9.35 to 10.5 psig)
Function - Storage of water recovered from urine to be used for washing.

b. Potable Water (ST-1)
   Capacity - 66 lbs (prototype - 46 lbs)
   Pressure - 4 to 5 psig (prototype - 9.35 to 10.5 psig)
   Function - Storage of recovered wash water and humidity condensate. Water from this tank is used for food reconstitution, drinking, and electrolysis make-up.

c. Emergency Potable Water (ST-2)
   Capacity - 205 lbs (prototype 184 lbs)
   Pressure - 4 to 5 psig (prototype - 9.35 to 10.5 psig)
   Function - Storage of emergency water supply. A sample port is attached to this tank so that samples can periodically be taken and analyzed for purity.

2.3 WATER UTILIZATION AND PURITY

2.3.1 **WATER BALANCE.** Recovered waste waters will be used for drinking, food preparation, washing, and for electrolysis. Table 2.1 gives a breakdown of the water sources and uses. The water allowance shown for consumption is maximum; the quantities shown for urine and fecal waste waters are average. Some water is lost in discarded food. An estimate of this loss, based on an estimated food waste of 0.20 lbs/man-day and a 1% loss of water in beverages, is included in the water balance.

Some water will evaporate into the cabin atmosphere during washing. This water would be removed from the air as humidity condensate. The amount of water that would evaporate should be small and it is therefore assumed that all the water used for washing will be collected as used wash water. The fact that some of the wash water will appear as humidity condensate instead of used wash water will not affect the water balance, except for the slight difference expected for recovery efficiencies. Some water is lost in air leaking from the cabin but this is a negligible loss (estimated to amount to less than 0.005 lbs/man-day).

Recovery efficiencies used to determine the amount of water recovered are those believed to be obtainable in each of the waste water processing units. Purities and usage of each of the recovered waste waters are discussed in the following paragraphs.

2.3.2 **RECOVERED URINE WATER.** Recovered urine water (along with some make-up potable water when required) will be used for washing.

Although under normal conditions recovered urine water will not be used for human ingestion (for psychological reasons), and bacteriological tests will not be made in the normal operating mode, the urine processing equipment will be capable of producing potable water from urine. Tentative potable water standards for recovered urine water are as follows.

pH	6-8
Conductivity, max. Micromhos/cm	100
Total solids, max. ppm	100
NH_3	Less than 20 ppm
Cl^-	Less than 10 ppm
$SO_4^=$	Less than 10 ppm
Urea	Less than 0.5 ppm
Bacteria	Less than 1 colony per ml
Organoleptic Test	
a	No visible turbidity
b	No observable color
c	No unpleasant odor
d	No unpleasant taste

The water recovered from urine is used as wash water and will be post-treated with Benzalkonium Chloride (BAC) to provide a cleansing agent which has both bactercide and detergent properties. The BAC is essentially an ammonium salt and is removed from the waste wash water by any of the following techniques: activated charcoal, ion exchange, or phase change.

2.3.3 **RECOVERED WASH WATER.** Water reclaimed from used wash water will be analyzed to check for potability according to the tentative standards shown above in Paragraph 2.3.2. All the reclaimed wash water, after determined to be potable, will be transferred to the potable water storage tank where reclaimed humidity condensate will also be stored The potable water will be used as described in the following paragraph.

2.3.4 **RECOVERED HUMIDITY CONDENSATE.** Water reclaimed from humidity condensate shall meet the following tentative potable water standards:

pH	6-8
Conductivity, max. Micromhos/cm	100
Total solids, max. ppm	100
Bacteria	Less than 1 colony per ml
NH_3	Less than 20 ppm
Cl^-	Less than 10 ppm
$SO_4^=$	Less than 10 ppm
Urea	Less than 0.5 ppm
Organoleptic Tests	
a	No visible turbidity
b	No observable color
c	No unpleasant odor
d	No unpleasant taste

The recovered humidity condensate and recovered wash water meeting potable water standards will be held for use in the potable water storage tank. Of the average total potable water supply of 8.04 lbs/man-day (recovered condensate and wash water), 7.65 will be used for drinking and food preparation, 0.20 will be used as electrolysis make-up and 0.17 will be required for washing.

TABLE 2.1

WATER BALANCE (Basis: 1 Man-day)

WATER TO AND FROM ASTRONAUT

Water Consumed and Produced:		Waste Waters:	
In Food	0.23 lbs	Urine Water	3.30 lbs
For Drinking and Food Preparation	7.65	Fecal Water (Discarded)	0.25
		Discarded in Food	0.16
Metabolically Produced	0.72	Humidity Condensate	4.89
Subtotal	8.60	Subtotal	8.60
Wash Water	3.30	Used Wash Water	3.30
Total	11.90	Total	11.90

RECOVERED WATER FOR RE-USE

Amount Recovered:			Use of Recovered Water:	
From Urine	0.95(3.30) =	3.13 lbs	For Drinking and Food Preparation	7.65 lbs
From Condensate	0.99(4.89) =	4.84	For Washing	3.30
From Wash Water	0.97(3.30) =	3.20	For Electrolysis	2.10
From Bosch Reactor		1.90	Excess	0.02
Total		13.07	Total	13.07

2.3.5 **BOSCH REACTOR WATER.** Bosch reactor water averaging 1.9 lbs/man-day will flow to an accumulator and will be used for electrolysis along with make-up from potable water storage.

3/ SUBSYSTEM OPERATION

3.1 RELIABILITY CONSIDERATIONS

3.1.1 GENERAL. To achieve the reliability required, the subsystem is designed to operate in three separate modes as follows:

a. Normal Mode - The two air evaporation units operate according to design specifications and purify waste water as required (design continuous level).

b. Back-up Mode - A breakdown of one of the air evaporation processing units requiring operation of the other unit at the minimum continuous level. Operation at the minimum continuous level is defined as follows:

   1. The surviving air evaporation unit operates 25% longer than under normal operation.(13% longer for the prototype system).

   2. Water allocated for washing is reduced by 50%.(reduced by 2/3 for prototype system).

   3. There is no reduction in electrolysis water make-up.

   4. Water allocated for drinking and food rehydration remain normal.

   5. Water allocated for washing comes from potable supply.

c. Emergency Mode - Breakdown of both air evaporation processing units. Emergency operation is defined as follows:

   1. Humidity condensate is processed in the emergency filtration unit. Water requirements are derived from the recovered condensate and emergency stores.

   2. Water allocated for drinking and food rehydration remain normal.

   3. There is no reduction in electrolysis water make-up.

   4. No water is allocated for washing.

3.1.2 DESIGN REQUIREMENTS. Equipment must be designed to assure successful operation of the water management subsystem under any of the three modes of operation described above. The following criteria must be adhered to in order to achieve this assurance of reliable performance:

a. No failure of the primary mode shall prevent initiation of the secondary (back-up) mode.

b. No single inadvertent manual switching sequence results in irreversible component failure, i.e., initiates a loss of function which cannot be regained by correction of the procedural error if accomplished in a reasonable sequence period.

c. The equipment must be amenable to maintenance demands of the mission. Minimizing the requirement for servicing and preventive maintenance combined with maximizing the potential for corrective maintenance is a major contributor to subsystem reliability. Subsystem down-time is the major parameter involved in the design analysis. Assumptions concerning the in-flight availability of spare parts and repair materials or special tools must be reflected in the weight estimates for the operational item(s).

The restrictions imposed on the design with respect to servicing and preventive maintenance should be followed as far as practicable in the design for repair by the operational crew.

The matching of estimated down-times in the maintainability analyses with the stated allowable down-times is a key to the operational reliability of the subsystem. It can be noted that the degree of independence between management functions has a marked effect on the allowable down-times for each function.

d. The switching functions for any given sequence or mode of operation must be minimized to the extent possible. In so doing, care must be extended to avoid: (1) compromising the integrity of the equipment items and processes involved, and (2) increasing the equipment complexity of the subsystem.

3.1.3 OPERATIONAL RELIABILITY, MAINTAINABILITY AND SAFETY. Reliability of the subsystem is defined as the probability of successfully performing its basic function for the specified life without producing failures which require a shutdown of the basic function for periods exceeding the allowable maintenance down-times.

Safety is defined as the probability that the primary back-up and emergency modes of attaining subsystem functions will operate so as not to endanger the life of the crew during the normal mission during "emergency" or alternate mode periods specified.

Attention must be given to the design of simple and functional components, processes and process controls whose failure probabilities are inherently low, characteristically independent of other failures within the subsystem, and which produce high assurance of repair upon failure. From the safety standpoint, no single failure can directly create a crew safety hazard.

Couples with these considerations are those involved with design approaches which increase the direct and continuous monitoring capability of the crew with respect to each function and its processes and which by so doing allow for timely corrective action.

The subsystem shall be designed to operate under the conditions stated herein with a reliability of 0.990.

The types and frequency of failure together with the repair capability of the crew and the repair potential of the equipment system will be such that subsystem availability of 0.982 is attainable. Availability is defined as the fraction of total desired operating time that the equipment is actually operable.

The maximum allowable down-time of the subsystem for the execution of servicing and preventive maintenance is two hours (continuous). The maximum allowable down-time for corrective maintenance is six hours with an average down-time not to exceed one hour.

Typical Maintenance Tasks: Typical tasks required for servicing and preventive maintenance as applicable to the water management subsystem are changing of filters and wick cartridges, replenishment of pretreatment chemicals, cleansing of surfaces exposed to "spillage" and process materials, and possible inspection of exposed seals subject to wear.

Malfunctions requiring corrective maintenance are:

a. Clogging of feed lines or a feed metering device

b. Leakage of air from an air evaporation unit

c. Failure of an air circulation fan

d. Failure of liquid-gas separator

e. Clogging in evaporator

f. Instrumentation or control failures

g. Clogging in heat exchangers

Routine maintenance of the emergency filtration unit would consist of replacement of charcoal, ion exchange and bacteria filters if required. Corrective maintenance would be required in cases of the following malfunctions:

a. Clogging of feed lines or feed metering pump

b. Breakdown of metering pump.

Other repair maintenance requirements would arise in the water management subsystem if any of the following defects occurred:

a. Leakage of waste or reclaimed waters from fittings or valves or tanks

b. Clogging of liquid lines

c. Air leakage from pressurized tanks or air lines

d. Contamination of holding tanks or potable water storage tanks with impure water (requiring cleansing of the tanks)

3.2 NORMAL MODE OPERATION

Operation of the water management subsystem centers about the purification of the waste waters. The processing of the waste waters can be approached in either of two ways, i.e., processing of each of the waste waters can be sequenced to start at a given time each day or processing of each waste water can begin only after a set quantity of waste water is collected. The advantages of sequencing the processing operations are:

a. Can schedule commencement of processing of each waste water at a convenient time so that the tasks of start-up and shut-down of each of the units do not coincide with other routine tasks required of the crew.

b. Can schedule operation of processing units so that usage of power, waste heat, etc., is optimized within the life support system.

The advantages of the alternate approach are:

a. The length of time for operation of each processing unit would be the same for each batch.

b. It might be easier to handle (or transfer) the same quantity of water for each batch than it would be to handle differing quantities for each batch which would result from sequencing.

The advantages of setting a fixed time for processing each of the waste waters seem to outweigh the advantages for the latter approach. It will thus be assumed here that the processing of the waste waters will be a scheduled function.

Operation of the water management subsystem will be described in the paragraphs below by following the paths of the various waste waters and reclaimed waters (See Figure 2.1).

3.2.1 URINE WATER. Urine collected in the waste management subsystem is delivered to the urine collection tank which is held at 1-2 psig (3.85 - 4.80 psig in prototype system). Liquid disinfectant solution is periodically sprayed into the urine collector to keep it sanitary. This disinfectant passes into the urine collection tank where it, plus additional pretreatment chemicals (injected into the dilution chamber), prevent bacterial growth. When it is time to start the processing of urine, the content of the urine collection tank is transferred to the pretreatment tank in processing unit #2 where the operation of the unit is initiated. Recovered urine water is transferred to holding tank #3 which is vented of pressurized air during processing. The recovered water quality is continuously monitored by an in-line conductivity probe. An alarm and diverter valve will operate in case water of high conductivity passes from the unit. At the end of a batch operation, the recovered urine water is sampled and checked for impurities. Water meeting standards is transferred to the wash water storage tank where BAC is added to prevent bacterial growth and to provide detergent qualities. Reclaimed water not meeting standards is transferred back to the urine collection tank for reprocessing.

3.2.2 BOSCH REACTOR WATER. Water produced in the Bosch reactor is transferred to the electrolysis accumulator which is held at 8-9 psig (9.35 to 10.5 in prototype system). This Bosch reactor water along with electrolysis make-up water from potable water storage is available to the electrolysis unit on demand.

3.2.3 USED WASH WATER. Used wash water originating in the personal hygiene subsystem is transferred to the used wash water collection tank which is held at a pressure of 1-2 psig (3.85 - 4.80 psig in prototype system). A pretreatment disinfectant is added by injecting it into a dilution chamber. When it is time to purify the used wash water, the contents of the collection tank is transferred to the pretreatment tank in processing unit #1 and the operation of the unit is initiated. Recovered wash water (along with recovered humidity condensate) is transferred to holding tank #2 or #1. As in processing unit #2, the recovered water quality is continuously monitored by an in-line conductivity probe. An alarm and diverter valve will operate in case water of high conductivity passes from the unit. A batch of recovered water is checked for bacteria (requiring about 24 hours during which time the second holding tank is available for use). Recovered water meeting purity standards is transferred to the potable water storage tank. Water not meeting purity standards is transferred back to the used wash water collection tank for reprocessing.

3.2.4 HUMIDITY CONDENSATE. Condensate from the main cabin air dehumidifier is delivered continuously to the condensate collection tank which is held at a pressure of 1-2 psig (3.85 - 4.80 psig in prototype system). Disinfectant is injected upstream of the tank to prevent bacterial growth. Humidity condensate is recovered in processing unit #1 in the same manner as is used wash water. Recovered condensate is passed to the same holding tank as the recovered wash water and is sampled and checked for bacteria after being mixed with the recovered wash water.

3.2.5 RECOVERED WATERS. Recovered urine water is stored in the wash water storage tank where it is available at 4-5 psig to the personal hygiene subsystem. The prototype storage tank will be pressurized at 9.35 to 10.5 psig.

Recovered wash water and humidity condensate are stored in the potable water storage tank where it is available at 4-5 psig to the food management subsystem for drinking and food preparation. The prototype storage tank will be pressurized at 9.35 to 10.5 psig. Some of the potable water is periodically transferred to the electrolysis accumulator and wash water storage tank as make-up. The quantity of fresh water required for initial system start-up (to achieve steady state) amounts to approximately 133 lbs (See Appendix A).

3.2.6 MAINTENANCE REQUIREMENTS FOR THE NORMAL MODES OF OPERATION. Determination of the appropriate servicing and preventive maintenance by the operational crew will be restricted to visual inspection of readily accessible and directly interpretable indications of condition or to procedural compliance with a scheduled operation.

Performance of such activity will not require more than one crew member and will be restricted to simple manual operations employing a minimum of tools and equipment. Operations requiring removing and replacing of components will not involve precision in the matching of surfaces, in the alignment or torqueing of connectors, or in the handling of waste or consumed materials.

Execution of these activities shall require a minimum of interference with the availability of the subsystem.

Processing unit #1 and #2 are identical air evaporation systems and require routine maintenance including replacement is wick canisters and filters and replenishment of pretreatment chemicals. The technique for wick replacement is designed to prevent leakage of odorous gases into the cabin atmosphere.

3.3 BACK-UP MODE OPERATION

The two air evaporation units are sized and interconnected so that breakdown of either processing unit will allow operation at the minimum continuous level in the working unit (see Section 3.1.1). The alternate source of recovery processing provides additional time for repairs in addition to reducing the seriousness of the failure which in turn increases the probability that normal resupply will be adequate.

Detail equipment design must assure that servicing and maintenance demands on the crew are not excessive and that potential safety problems associated with servicing and maintenance are minimized.

Repair or replacement of critical components under weightless conditions is a specific maintenance requirement and will be included in its reliability rating. It is a design objective that such maintenance be possible while the operator is wearing a pressurized suit. Such considerations must be balanced against design approaches which assure high confidence for performance with respect to the primary (basic) water recovery management functions.

3.3.1 BREAKDOWN OF PROCESSING UNIT #1. Figure 3.1 shows the valve settings required to initiate the back-up mode. (Valve 2B would be set to "dead-end" position after a batch of waste water is transferred to the processing "pretreatment tank" and before processing is initiated). All three waste waters are processed in processing unit #2 to maintain the minimum continuous level of operation.

3.3.2 BREAKDOWN OF PROCESSING UNIT #2. The back-up mode for this failure is initiated as illustrated in Figure 3.2. (Valve 2A would be set to a "dead end" position after a batch of waste water is transferred to the processing uni #1 "pretreatment tank" and before processing is initiated.) The three waste ..ers are processed in processing unit #1 to maintain minimum continuous level operation.

3.3.3 EMERGENCY SITUATION. An emergency condition is considered to occur when both air evaporation units fail. Water storage and the emergency unit processing capacity is such that minimum subsistance levels for water will be obtained for a maximum period of 17 days. This time is considered sufficient to allow for the repair of failing units and/or receive water and equipment from resupply.

The emergency mode of operation is defined in Section 3.1.1. This mode of operation is illustrated in Figure 3.3. During the emergency situation, urine would be stored until the capacity of the urine and wash water collection tanks is exceeded. The urine would then be vented overboard.

In addition to st..ed water, water available during the emergency conditions consists of 4.84 lbs/man-day of recovered humidity condensate and 1.90 lbs/man-day of Bosch reactor water. Water consumed (other than that contained in food) would be 7.65 lbs for drinking and food rehydration plus 2.10 lbs/man-day for electrolysis. Table 3.1 shows the emergency water balance for 17 days. From this balance it can be seen that a total 205 lbs of water is required for emergency storage.

TABLE 3.1

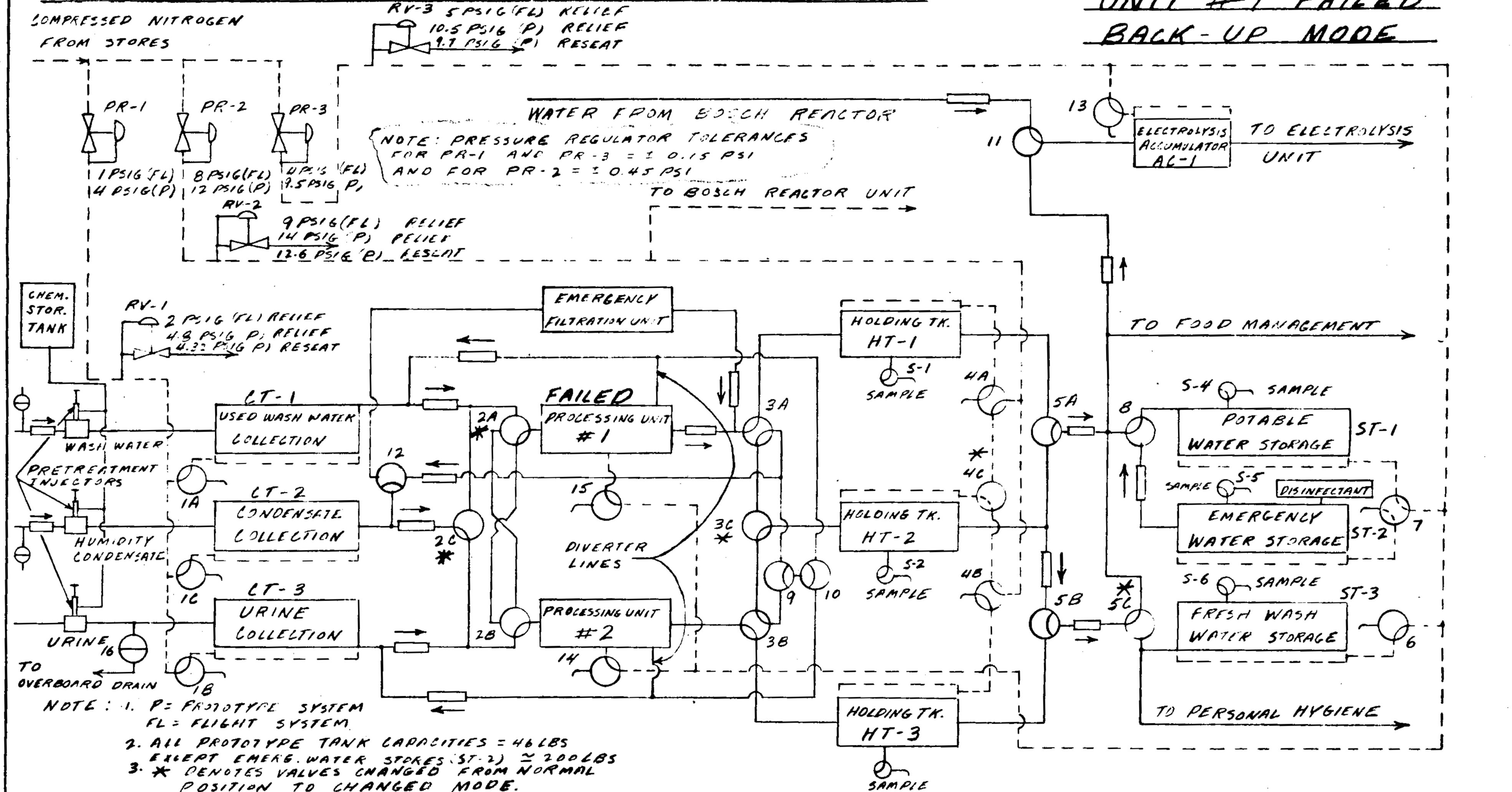
EMERGENCY WATER BALANCE

Source or Use	Water Consumed, lbs.	Water Available, lbs.
Drinking and food preparation	520	
For electrolysis	143	
Recovered humidity condensate		329
From Bosch reactor		129
Emergency storage		205
	663	663

An additional emergency consideration involves the contamination of the emergency water storage supply. A sample port is provided on the emergency storage tank so that periodic bacteria checks can be made. In the event that the emergency stores have been contaminated with bacteria, BAC will be added so that the final concentration is 1:100,000. At this concentration the BAC cannot be detected by organoleptic tests. Test on ingestion of water with BAC have been made on animal colonies at concentrations of 1:1000 without cumulative toxic effects (Reference 2).

INTEGRATED WATER MANAGEMENT SYSTEM - REVISED SCHEMATIC

UNIT #1 FAILED BACK-UP MODE



NOTE: 1. P = PROTOTYPE SYSTEM
FL = FLIGHT SYSTEM
2. ALL PROTOTYPE TANK CAPACITIES = 46 LBS EXCEPT EMERG. WATER STORES (ST-2) ≃ 200 LBS
3. * DENOTES VALVES CHANGED FROM NORMAL POSITION TO CHANGED MODE.

FIGURE 3.1

PREPARED BY	DATE	CHECKED BY	DATE	REVISED BY	DATE
W.W.	4/10/64				3/28/64

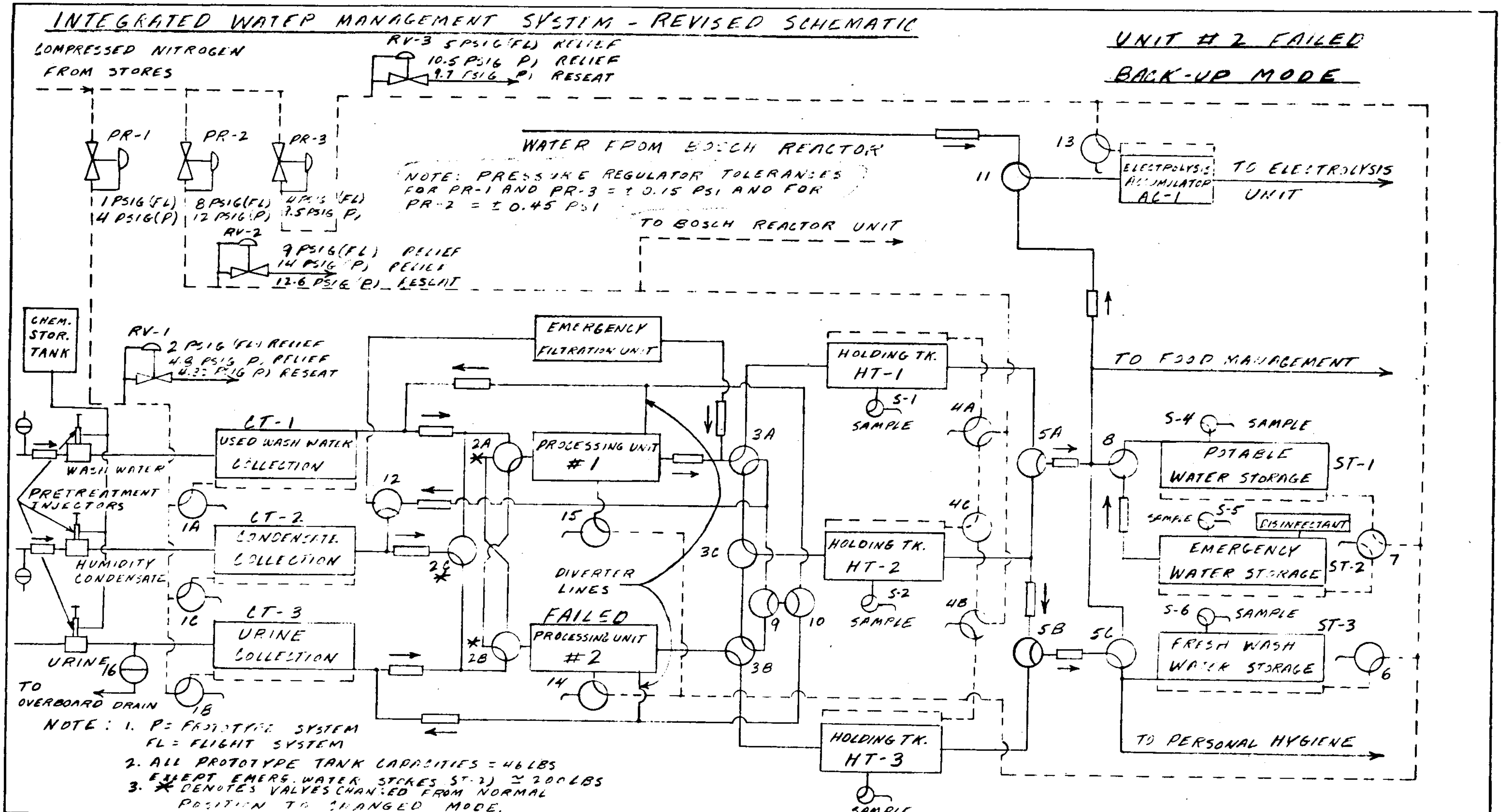


FIGURE 3.2

PREPARED BY	DATE	CHECKED BY	DATE	REVISED BY	DATE
W.W.	4/10/64				9/30/64

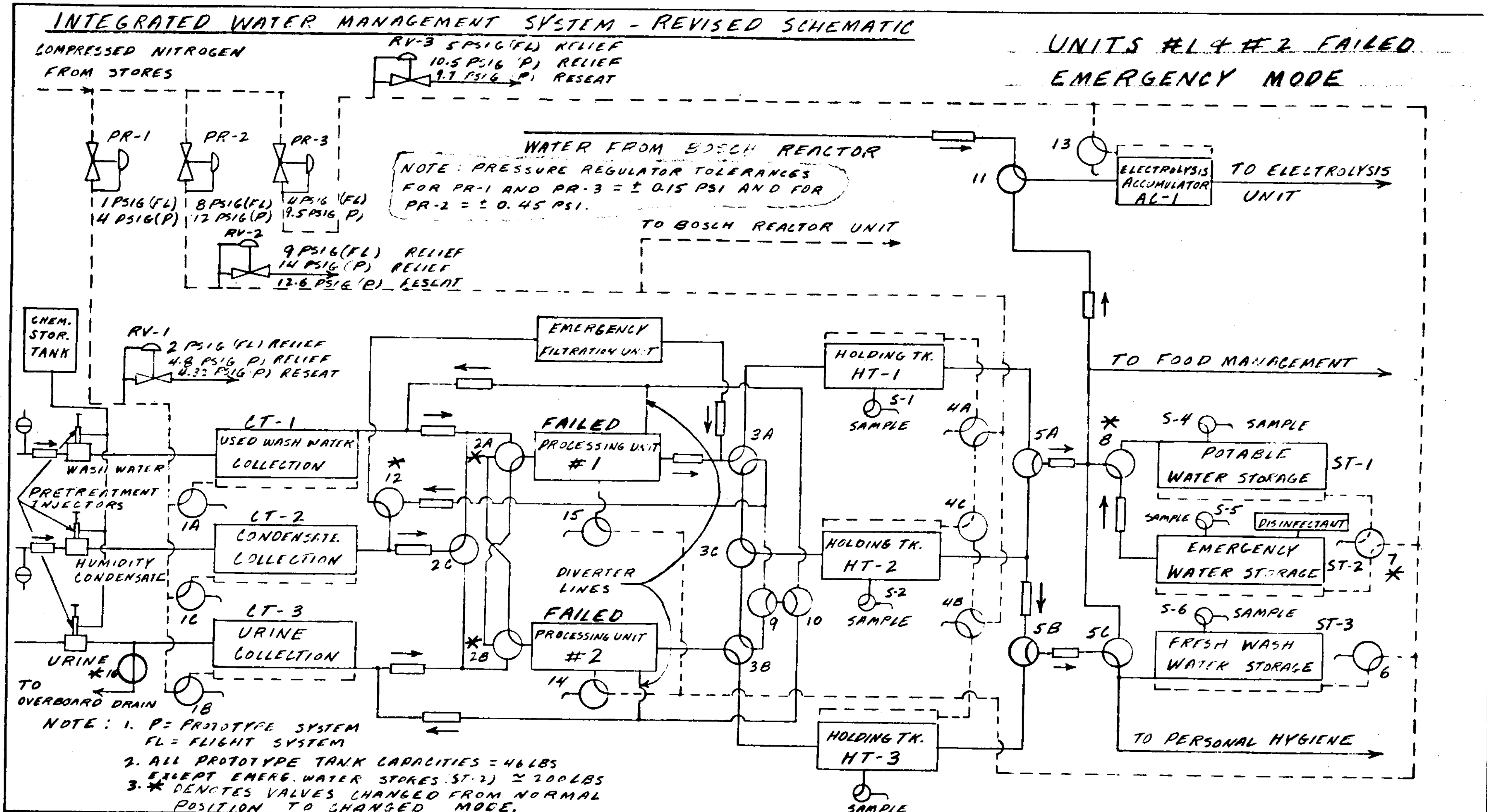


FIGURE 3.3

PREPARED BY	DATE	CHECKED BY	DATE	REVISED BY	DATE
W. W.	4/10/64			[illegible]	7/28/64

4/ INTEGRATION

Integration of the water management subsystem within the life support system involves several subsystems. These integration requirements are discussed in the following paragraphs.

4.1 POWER

Table 4.1 shows the estimated power requirements for the water management subsystem. Operation of the air evaporation units requires power for the recirculating fans. The prototype units will be smaller than the units specified for flight and will consume somewhat less theoretical power as shown in Table 4.1. In addition to power for the fans, some power will be required for instrumentation and control (estimated as 15 watts).

TABLE 4.1

ESTIMATED POWER FOR THE WATER MANAGEMENT SUBSYSTEM

	Flight		Prototype	
Component	Power, watts	Nominal Oper. Time, hrs/day	Power, watts	Nominal Oper. Time, hrs/day
Processing Unit #2	87	6.5	73	8
Processing Unit #2	87	16	73	20

4.2 THERMAL REQUIREMENTS (Heating and Cooling)

Heat from the process heat fluid loop (Dow Corning 331) is utilized in the air evaporation units. In addition, the cooling fluid loop (Minnesota Mining and Manufacturing FC-75) must be used for heat rejection in the processing units. Table 4.2 summarizes the estimated heating and cooling requirements of the water management subsystem.

The flow rates and temperatures of the heating and cooling fluids are subject to change as the designs of the air evaporation units are more firmly established.

There will be some heat lost from the air evaporation units to the cabin atmosphere. The loss should be small.

TABLE 4.2

ESTIMATED HEATING AND COOLING REQUIREMENTS - WATER MANAGEMENT SUBSYSTEM

FLIGHT SUBSYSTEM	Heat to Fluid Btu/hr	Temp. of Fluid °F	Flow Rate of Fluid lbs/hr	Nominal Oper. time hrs/day
Heating:				
Processing Unit #1	2385	---	---	16
Processing Unit #2	2385	---	---	6.5
Cooling:				
Processing Unit #1	2525	---	---	16
Processing Unit #2	2525	---	---	6.5
PROTOTYPE SUBSYSTEM				
Heating:				
Processing Unit #1	1932	345-385	20-50 (30)	20
Processing Unit #2	1417	345-385	20-50 (30)	8
Cooling:				
Processing Unit #1	2248	34	250-350 (250)	20
Processing Unit #2	1657	70	250-350 (250)	8

4.3 WATER TRANSFER

A summary of the water transfer requirements is given in Table 4.3.

TABLE 4.3

WATER TRANSPORT REQUIREMENTS

Subsystem From	Subsystem To	Source or Use	Water Wt., lbs/day
Waste Management	Water Management	Urine	13.2
Personal Hygiene	Water Management	Used Wash Water	13.2
Atmospheric Control	Water Management	Humidity Condensate	19.6
Atmospheric Control	Water Management	Bosch CO_2 Reduction	7.6
Water Management	Food Management	Drinking & Food Prep'n	30.6
Water Management	Atmospheric Control	Electrolysis	8.4
Water Management	Personal Hygiene	For Washing	13.2

4.4 INSTRUMENTATION AND CONTROL

For operation of the two air evaporation units, automatic control of the following parameters is required:

a. Feed rate

b. Air temperature downstream of the evaporator

In addition, the following parameters must be monitored for assurance of operation according to processing requirement:

a. Water conductivity

b. Water contamination

c. Pretreatment tank level

d. Water output rate

The emergency filtration system requires control of the flow rate only. One other control requirement comes from the use of pressurized tanks which require continuous control of air pressures.

4.5 WASTE DISPOSAL

Residues, in wick canisters, and charcoal filters from the processing units must be stored. Storage facilities within the waste management system are designed to prevent escape of any undesirable odors. Urine residues amount to approximately 0.7 lbs/day; wash water and condensate residues amount to approximately .035 to 0.1 lbs/day.

4.6 VACUUM SOURCE AND PLUMBING

A vacuum vent to the urine storage tank will be provided to vent urine overboard in case of operation in the emergency mode. (See Paragraph 3.3.3) Fluid lines between the thermal control system for heating and cooling fluids are required. Water lines between various subsystems as indicated in Table 4.3 are also required.

4.7 RESUPPLY

Charcoal filters, wick cartridges and pretreatment chemicals will have to be replenished at the end of each 90 day resupply period. The filters of the emergency filtration unit will also have to be resupplied if they are used.

APPENDIX A

In order to achieve initial start-up of the water management recovery systems, an analysis of the recovery unit time constants along with the crew use rates and production rates was made. The results of the study are summarized in the schedule shown in Table A.

It is assumed that the crew does not wash on the first day of the mission. It should be noted that after four days of operation, steady state is achieved. On the third day, the water reclaimed from urine (processed on the second day) is passed to fresh storage for use after a check for impurities. Water reclaimed from humidity condensate and wash water requires holding an additional day for completion of a bacteria check.

TABLE A

SCHEDULE

START-UP WATER REQUIREMENTS (lbs)
(4 men)

Day	Use	Collect	Process	Hold	Fresh Storage	Water Deficit
1	30.6D 0.8E	19.6C 13.2U				31.4
2	30.6D 0.8E 13.2W	19.6C 13.2U 13.2W	19.6C 13.2U			44.6
3	30.6D 0.8E 13.2W	19.6C 13.2U 13.2W	19.6C 13.2U 13.2W	19.36C	12.54UW	32.1
4	30.6D 0.8E 13.2W	19.6C 13.2U 13.2W	19.6C 13.2U 13.2W	19.36C 12.80W	19.36C 12.54UW	12.7
5	30.6D 0.8E 13.2W	19.6C 13.2U 13.2W	19.6C 13.2U 13.2W	19.36C 12.80W	19.36C 12.54UW 12.80W	0
					Subtotal	120.8
					Add 10%	12
						132.8

NOTE: D - H_2O for drinking and food prep'n
E - H_2O for electrolysis make-up
W - Wash H_2O
C - Humidity condensate
U - Urine
UW - Urine water

REFERENCES

1. Steele, J. A. and J. R. Burnett, Water Management System Evaluation for Space Flights of One Year Duration, GD/Astronautics Report No. 64-26206; NASA Contract NAS 1-2934, (December 1963). Revised December 1964.

2. Alfredson, B. B. et al, Journal American Pharmaceutical Association, Vol. 40, p. 263-276, 1951.