**NASA TECHNICAL MEMORANDUM**



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# ENVIRONMENTAL CONTROL AND LIFE SUPPORT SUBSYSTEM (EC/LSS) FOR THE MODULAR SPACE STATION (OPTION IV)

By Hubert B. Wells and Andrew G. Kromis
Program Development

February 15, 1971

**NASA**

*George C. Marshall Space Flight Center*
*Marshall Space Flight Center, Alabama*

# NOTICE

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16. ABSTRACT

This report presents some comparative pre-phase A results of the Environmental Control and Life Support Subsystem (EC/LSS) conceived during the Marshall Space Flight Center in-house Option IV Modular Space Station study. The major parameters selected for comparison were logistics, assembly weights, power, and cost. The EC/LSS used for comparison is capable of supporting a six-man crew continuously over an extended period of time with regular resupply. Nominal crew rotation (6-men) and resupply were considered to be on a 90-day cycle. The EC/LSS must maintain a system life requirement of 10 years through maintenance, spares, and redundancy. The pre-phase A type investigation included open loop, partially closed loops, and full closure of both the oxygen and water cycles. The selected EC/LSS approach is a partially closed water loop (reclamation of condensate and wash) and an open oxygen loop.

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# ENVIRONMENTAL CONTROL AND LIFE SUPPORT SUBSYSTEM (EC/LSS) FOR THE MODULAR SPACE STATION (OPTION IV)

## SUMMARY


This report presents the results of the Environmental Control and Life Support Subsystem (EC/LSS) study for the Option IV Modular Space Station. This pre-phase A investigation stressed low cost as the primary parameter for the study as well as a consideration of logistics, weight, and power. Comparative results were obtained for the open loop, partially closed loop, and full closure of the oxygen and water cycles.

The basic EC/LSS for Option IV consists of a six-man subsystem with independent emergency provisions for 48 hours (Shuttle response time). These emergency provisions will be provided in the form of 30 days of expendables (food, water, nitrogen, and metabolic oxygen) and an additional three-man EC/LSS. Logistics and crew rotation will be accomplished every 90 days with the Space Shuttle vehicle. The basic configuration that was selected for the Option IV Space Station is illustrated in Figure 1.

Various candidates were investigated for all EC/LSS areas to define suitable assemblies to fulfill the EC/LSS requirements. The primary areas compared were atmospheric supply and pressurization, oxygen reclamation, atmospheric purification, water management/water reclamation, waste management, and expendables. The comparative results point to a partially closed water loop and an open oxygen loop as the most economical system.


## I. INTRODUCTION

The Option IV Modular Space Station study was initiated by NASA Headquarters to investigate the practicality of designing a space station with low early peak funding characteristics. The Option IV version is a multidisciplinary research, applications, and operations facility. The basic operational facility consists of a core module and one or more ancillary subsystem modules as required to provide continuous living and working facilities for a six-man crew. The core module is cylindrical with a diameter of approximately 22 feet (the same as an S-IVB stage). It contains complete habitability areas; primary command, control, and communications stations; a biomedical laboratory; general-purpose laboratory facilities; the secondary EC/LSS; and integral experiments. The ancillary subsystem module is a 14-foot cylindrical facility, which is transported in the Space Shuttle payload compartment. This module contains the primary EC/LSS, control moment gyros, and alternate command post.

Atmospheric stores (oxygen and nitrogen) and water are located in the interstage of the core module. These atmospheric gases and water will be piped to the other modules as required. Three separate pressure compartments are maintained onboard the Space Station. A six-man EC/LSS (two interconnected three-man EC/LSS) is located in the subsystem module and a three-man EC/LSS is installed in the core module for emergencies. A thermal control assembly is located in the core and each subsystem module; however, no attempt was made to include this assembly in the EC/LSS comparison.

Regenerative concepts have been under test for some time for application to earth-orbital missions. Several examples are the Integrated Life Support System (ILSS) being evaluated at the Langley Research Center and the 90-day manned test performed at the McDonnell Douglas Astronautics Company (MDAC), Santa Monica, California.

This report presents the results of the pre-phase A effort to utilize suitable assemblies for Option IV to compare the open, partially closed, and closed EC/LSS. Assemblies such as those tested in the ILSS and MDAC simulator were selected for the comparison. Nonrecurring and logistical/operational costs (on a rough order of magnitude) for these assemblies are presented. The nonrecurring costs give consideration to hardware development, spares, launch weight, volume, and power up to the launch date. The logistical/operational costs include such items as 90 days of makeup water plus tankage, metabolic oxygen, nitrogen for leakage, and basic oxygen and nitrogen tankage.

Supercritical cryogenic tanks (AAP type) were selected to contain the oxygen and nitrogen consumables, which are necessary for leakage, repressurization, extravehicular activity (EVA) and metabolic purposes. Atmospheric pressure in the modules will be maintained through a Skylab A two-gas pressure control assembly. If oxygen recovery equipment were utilized, the Sabatier/methane dump and wick-fed electrolysis assemblies would be the primary candidates. A molecular sieve removes carbon dioxide and a nonregenerable/catalytic oxidation assembly controls contaminants. Condensing heat exchangers control humidity, and a multifiltration assembly is utilized to reclaim condensate and wash water. Urine water recovery, if required, could utilize air evaporation. The waste-management selection is Integrated Vacuum Drying. A thermal control assembly, even through it was not included in the comparison, will possibly be an active system (fluid loop, radiators, heat exchangers, fans, etc.). A suit loop, Portable Life Support Systems (PLSS), and chlorate candles can be employed for emergency situations and EVA/IVA. Lists of expendables for the three EC/LSS loops are included in Section IX.

## II. OVERALL EC/LSS GUIDELINES, REQUIREMENTS, AND CANDIDATES SUMMARIZATION

The Modular Space Station must contain all the necessary assemblies to maintain the life and well being of the six-man crew. It was necessary to select a group of candidates for use in the comparison of the open, partially closed, and fully closed EC/LSS loops. These candidates are listed in Table 1, which also shows their functions and a selected candidate for each function. A schematic (Fig. 2) is included to depict the selected EC/LSS assemblies, which are used in the partially closed water and fully open oxygen loops. Some of the basic EC/LSS criteria and requirements established for the comparative study are tabulated in Table 2.

Multifiltration is the assembly approach for reclaiming condensate and wash water in separate loops. The condensate will be reclaimed as potable water, and the wash water as wash water only. Oxygen requirements are satisfied through the use of an open-loop approach. Integrated vacuum drying is the selected approach for waste management.

Overall weights and volumes of the six-man EC/LSS assemblies are given in Table 3. These assemblies weigh 1831 pounds and occupy 155 cubic feet. The overall weight (988 pounds) and volume (77.5 cubic feet) for the three-man EC/LSS are given in Table 4. The total weight of 15 907 pounds for these subsystems plus oxygen, nitrogen, water, and associated tankage are depicted in Table 5.

## III. ATMOSPHERIC SUPPLY AND PRESSURIZATION ASSEMBLY

The major functions of the Option IV atmospheric supply and pressurization assembly are to supply metabolic oxygen to the crew, maintain carbon dioxide partial pressure at a nontoxic level, and maintain suitable partial pressures of oxygen and nitrogen gas in the cabin atmosphere. An atmospheric mixture of 21-percent oxygen and 79-percent nitrogen is maintained at a total pressure of 14.7 psia. Partial pressures are 3.09 psia for oxygen and 11.61 psia for nitrogen. Atmospheric leakage was assumed to be 2.0 pounds per day for the core module and 1.0 pound per day for the subsystem module. This amounts to a leakage of 0.70 pound per day for oxygen and 2.30 pounds per day for nitrogen.

The only storage method considered for the storage of these atmospheric gases ($O_2$ and $N_2$) was supercritical cryogenic. These gases and water will be stored initially for 90 days in the interstage of the core module. Emergency provisions will be provided in the form of 30-day expendables such as food, water, nitrogen, and metabolic oxygen.

Seven AAP type tanks and three water tanks are installed in the interstage of the core module. Three AAP cryogenic tanks contain the oxygen (3320 pounds) to sustain the six-man crew. Nitrogen (3137 pounds) is stored in four AAP cryogenic tanks to satisfy leakage and pressurization purposes. These tanks containing the ($O_2$, $N_2$, and $H_2O$) consumables weigh approximately 2636 pounds and occupy about 220 cubic feet.

The possibility exists that certain emergencies will arise within the Space Station. To offset such a situation, an emergency oxygen supply in the form of chlorate candles can be supplied onboard. Chlorate candles and containers sufficient to supply this emergency for the six-man crew weigh 261 pounds (see Table 6). One spare candle for each crewman is onboard with an additional weight of 156 pounds.

## IV. OXYGEN RECLAMATION ASSEMBLY COMPARISON

Oxygen reclamation assemblies are in various stages of development and will require considerable time, effort, and cost to develop a flight hardware assembly. The four leading contenders for carbon dioxide reduction are the Sabatier, Bosch, Fused Salt, and Solid Electrolyte. The Sabatier and Bosch are the best candidates for the Modular Space Station, which is scheduled to be launched around the year 1977. The Solid Electrolyte and Fused Salt assemblies are well into the research stage; however, fully qualified assemblies will not be available by the 1977 Modular Space Station launch date. The carbon problem in the Bosch is generally solved; however, the Sabatier reactor is somewhat ahead of the Bosch in development status; also, the Sabatier assembly has undergone testing in the MDAC test simulator. If the oxygen loop were closed, the Sabatier/methane dump would be the selected approach for the Space Station.

Water electrolysis is required with both the Sabatier and Bosch assemblies. The electrolysis assembly selected for operation with the Sabatier reactor would be a wick-fed concept, which also underwent testing in the MDAC simulator. Development is well into the prototype stage and can possibly be developed for flight as early as 1974.

Detailed weight breakdowns of a three-man wick-fed electrolysis and the Sabatier and Bosch reactor are listed in Tables 7, 8, and 9. Two three-man oxygen reclamation assemblies would have to be interconnected to acquire the desired six-man assembly.

A comparison was made of the open versus closed oxygen loop utilizing the logistics, weight, power, and cost parameters mentioned in Section I. Closure of the oxygen loop with the Sabatier and electrolysis assemblies would be very profitable for interplanetary missions, but not for earth-orbit missions with low-cost resupply capability. The addition of these assemblies increases EC/LSS dry weight, power, cost, and maintenance.

Logistic requirements for oxygen recovery are illustrated in Figure 3. By addition of oxygen recovery equipment (Sabatier plus electrolysis), 994 pounds of metabolic oxygen could be reclaimed every 90 days. An additional 42 pounds of oxygen leakage could be reclaimed from electrolysis makeup water. The total minimum logistic penalty every 90 days would be 1036 pounds of oxygen and one AAP tank (334 pounds).

Figure 4 represents the comparison of the dry assembly weights for the open and closed oxygen loops. The dry weight for either loop requires six AAP type tanks (four for nitrogen) to contain the oxygen and nitrogen reserves (pressurization, EVA, $N_2$ leakage, etc.). One oxygen tank (334 pounds) to contain the 1036 pounds of cryogen for metabolic and leakage purposes is the only addition to the open-loop dry weight. Closure of the open loop requires additional Sabatier and electrolysis assemblies, which are the most advanced in development of all the oxygen recovery assemblies.

The dry assembly weights of both the open and closed loops (2338 pounds versus 2306 pounds) are practically the same.

The addition of Sabatier and electrolysis assemblies to close the oxygen loop results in considerable increase in power, especially the peak loads for the electrolysis. These assemblies require an average power of 7 and 1276 watts, respectively. Peak loads are 27 and 2356 watts for these assemblies. These power requirements (Fig. 5) influenced the decision to select an open oxygen loop.

Cost, as well as power, also influenced the decision to select an open loop. The cost to develop the Sabatier with methane dump is approximately \$3.58 million. Electrolysis development will cost about three times the amount of the Sabatier (≈\$11.4 million). These development costs are reflected in Figure 6.

## V. ESSENTIAL EC/LSS ASSEMBLIES

Certain assemblies, which include atmospheric purification and suit loop or PLSS, must be included in the open, partially closed, or closed EC/LSS. These assemblies maintain the carbon dioxide and trace contaminants continuously within acceptable limits and provide for emergency situations such as meteorite punctures. Carbon dioxide will be removed with a molecular sieve, and contaminants will be controlled through a nonregenerable charcoal/catalytic oxidation process. Emergency situations will be handled with a suit loop or PLSS.

The weights of these assemblies for six men are approximately 410 pounds for the molecular sieve, 52 pounds for nonregenerable charcoal/catalytic oxidation, and 71 pounds for the suit loop. Tables 10 and 11 contain a detailed weight breakdown for a three-man capacity molecular sieve and nonregenerable charcoal/catalytic oxidation assemblies. Two three-man assemblies are interconnected to provide the six-man capacity. Peak powers for these assemblies in the same order as above are 854, 226, and 246 watts, respectively. Their nonrecurring costs in the same order are \$8.6, \$5.6, and \$9.9 million. An additional nonrecurring cost of \$10.3 million and \$0.90 million operational cost will be incurred if PLSS units are required onboard. Figure 7 is a bar graph depicting the nonrecurring costs of these assemblies. Operational costs will amount to \$0.72 and \$0.93 million.

# VI. WATER MANAGEMENT/WATER RECLAMATION ASSEMBLY COMPARISON

The water management/water reclamation assembly's functions are to collect and purify water, and to store and deliver potable water for use on demand. Potable water must be provided for drinking and food reconstitution and wash water for showers, clothes washing, and dishwashing. Closure of the loop means reclaiming water from the wash, condensate, and urine sources. Water from the feces is usually dumped overboard. Partial closure of the loop can be accomplished by reclaiming separately the wash, condensate, or urine, or a combination of these.

The total daily amount of water required for the six-man crew is approximately 207.5 pounds per day, which includes 158.4 pounds of wash water, 36.78 pounds for food and drink, 6.21 pounds for water electrolysis (closed loop only), 3.96 pounds for water of oxidation, and 2.16 pounds for urinal rinse. These water requirements are illustrated in Figure 8 as a function of mission duration for the six-man crew. Approximately 18 680 pounds of water are required every 90 days to support the Space Station. Table 12 summarizes the Space Station water balance for the six-man crew.

If water reclamation techniques are not utilized, one Shuttle launch would be required every 90 days only to satisfy the water requirements. Figure 9 depicts the total water requirements for the six-man crew as a function of mission duration, while employing various water reclamation techniques. Reclamation equipment to recover urine, condensate, and wash water can reduce the total requirements to approximately 1000 pounds of makeup water every 90 days. Since urine water is the most difficult to recover, only the wash and condensate will be recovered, which would require approximately 3000 pounds of water every 90 days. Figure 10 illustrates the logistics requirements for the various degrees of water-loop closures considered.

The best possible choices of candidates for water recovery are air evaporation, vacuum distillation/compression, vapor diffusion/compression, multifiltration, and reverse osmosis. An air evaporation assembly could be used to reclaim urine or wash water separately or together. Condensate or wash water can be reclaimed by multifiltration either separately or together. The air evaporation and multifiltration assemblies underwent the 90-day test in the MDAC simulator. Urine water recovery for Option IV is rejected because of the effort and expense to develop flight-tested hardware. Multifiltration, which is the selected mode, is used to reclaim the condensate and wash water separately. The multifiltration process is simple, requires very low power, and is inexpensive. Detailed assembly weight breakdowns of the air evaporation and multifiltration assemblies are shown in Tables 13 and 14.

Figure 11 reflects the assembly weights to accomplish the various degrees of water closures. If no reclamation is used, 1600 pounds of tanks (16 in all) are required to contain the 18 680 pounds of water for 90 days. The weight of the multifiltration assemblies to recover wash and condensate water is 230 pounds. If the loop were fully closed using the air evaporation for urine recovery, an additional 174 pounds must be added to the dry weight for this assembly.

The average- and peak -load requirements to accomplish the various degrees of water closures are shown in Figure 12. It shows the approximate power required to individually close the wash and condensate loop by multifiltration. Closure of the urine or wash loop by air evaporation will be considerably more, especially the peak loads. These peak loads can be reduced if thermal energy is available.

Preliminary data have been generated to compare the cost of developing flight hardware for the various degrees of water closures. Comparable costs are shown in Figure 13 for the development of the assemblies to accomplish these tasks. Costs of multifiltration for reclamation of wash and condensate water range between $2 and $2.5 million. If an air evaporation is developed for urine recovery, the cost increases to about $9 to $15 million.

## VII. WASTE MANAGEMENT ASSEMBLY COMPARISON

There are approximately 12 different methods or candidates for waste management. Four of the leading candidates for Option IV appear to be bag/storage, integrated vacuum drying, integrated vacuum decomposition, and integrated vacuum decomposition with partial oxidation. The last two candidates were rejected because of the high SRT cost requirements. The first candidate (bag/storage) is rejected because of crew acceptability (manual transfer of the collection bag several times per day).

The integrated vacuum drying concept seems to be the most acceptable candidate although the tank liner has to be replaced once a week. It has been tested in the 60- and 90-day tests of MDAC's Space Station simulator. This concept was selected because of the low development risks, least overall cost, and crew acceptability. The facts above are summarized with power, weight, and cost for the selected candidate in Table 15.

## VIII. WEIGHT, POWER, AND COST COMPARISON SUMMARIZATION

Figure 14 summarizes the operational and logistical weights, peak powers, and costs on a pre-phase A basis for the open-, selected, and closed-loop EC/LSS. The open-loop dry assembly weight includes $CO_2$ removal, trace contaminant, pressure control, water and waste management, and suit loop assemblies. The selected dry assembly weight includes the above assemblies plus multifiltration for condensate and wash water recovery. The closed-loop dry assembly weight includes the assemblies of the selected loop plus oxygen and urine recovery equipment.

The power values reflected on the chart are the total operational power values for each loop. These values amount to 1930 watts for the open loop, 1955 watts for the selected loop, and 5980 watts for the closed loop.

The nonrecurring and logistical/operational costs for the three loops are shown in millions of dollars. The nonrecurring costs give consideration to hardware development, spares, launch weight, volume, and power up to the launch date. The logistical/operational costs include such items as 90 days of makeup water plus tankage, metabolic oxygen, nitrogen for leakage, and basic oxygen and nitrogen tankage.

## IX. EXPENDABLE REQUIREMENTS

Sufficient quantities of oxygen and nitrogen must be maintained onboard the Space Station to allow independent operations with a full crew of six for 120 days. This amounts to a normal 90-day supply plus a 30-day contingency for emergency metabolic and leakage needs. Cryogenic consumables ($O_2$ and $N_2$) are required for various activities such as EVA, initial and emergency pressurizations, metabolic and leakage purposes, and pumpdown and maintainability losses and reserves. These activities (Table 16) require 3320 pounds of oxygen and 3137 pounds of nitrogen plus tankage for the open loop. The initial pressurization gases (346 pounds of oxygen and 1140 pounds of nitrogen) are located in the Core and Subsystem Module compartments, thus eliminating the need to contain this initial atmosphere supply in the storage tanks. Logistically, only 1036 pounds of oxygen and 138 pounds of nitrogen plus tankage must be resupplied by the Space Shuttle every 90 days.

The Option IV guidelines state that the EC/LSS must be considered for eventual replacement with a fully closed loop. Closure of the oxygen loop requires the addition of Sabatier ($CO_2$ reduction) and electrolysis (water disassociation) assemblies. Addition of these assemblies would eliminate the logistic requirement of transporting the 1036 pounds of oxygen (994 pounds metabolic and 42 pounds leakage) every 90 days. Nitrogen recovery was not considered in this study; however, certain recovery techniques are under study. Nitrogen must be resupplied for leakage (138 pounds) every 90 days.

Table 17 reflects the revised oxygen and nitrogen requirements if the oxygen loop is closed. Since no recovery equipment is used in the nitrogen loop, the nitrogen requirements (3137 pounds) remain the same for open and closed loops. The overall weight of the oxygen needed for the closed loop is approximately 2070 pounds.

Table 18 summarizes some of the necessary expendables plus containers required to support the six-man basic crew for a 90-day operation. These expendables include oxygen, nitrogen, water, food, and their respective packages or containers.

The total water complement is quite large and would require a Space Shuttle flight every 90 days. For an open loop it requires 16 tanks (approximately 40 inches I. D.) filled to capacity, weighing 21 383 pounds, and would occupy 317 cubic feet. Seven AAP type tanks are required to contain the oxygen (3320 pounds) and nitrogen (3137 pounds) for the open oxygen loop. The total weight of the expendables and containers amounts to 31 669 pounds. A 30-day reserve supply of food and water is stored onboard to be used in emergencies.

Closure of the Option IV EC/LSS loop would save considerable weight, volume, and logistic transport of the required expendables. Full closure of the oxygen loop would result in a savings of 994 pounds of metabolic oxygen, 42 pounds of oxygen leakage, and one $O_2$ tank. To accomplish this, Sabatier and electrolysis assemblies must be installed for a slight weight penalty. Full closure of the water loop demands recovery from three water sources: namely, condensate, urine, and waste water. The necessary expendables plus containers for the closed loop are given in Table 19. The total weight of these expendables and containers amounts to 11 045 pounds.

Water recovery from urine is very difficult and will require considerable effort and expense to develop flight-tested hardware. Air evaporation is perhaps one of the best techniques for urine water recovery. Reclamation of condensate and wash water is much easier, and can be accomplished with multifiltration, which can be done at low cost, weight, and power.

The summarization given in Table 20 provides some of the necessary expendables required for the selected EC/LSS, which consists of a partially closed water loop and an open oxygen loop. The partially closed water loop will recover water from the condensate and wash water. Urine water will not be recovered because of the development and expense involved.

The condensate and wash water will be reclaimed by multifiltration through separate water loops. Wash water is to be reclaimed only as wash water and not potable water. Urine will be dumped overboard. Water reclaimed from the condensate is almost pure water and will be used as potable water. Partial closures of these water loops will require only 2890 pounds of water hauled logistically every 90 days. The total weight of expendables, which includes oxygen and nitrogen for the open loop plus tankage, is 14 579 pounds.

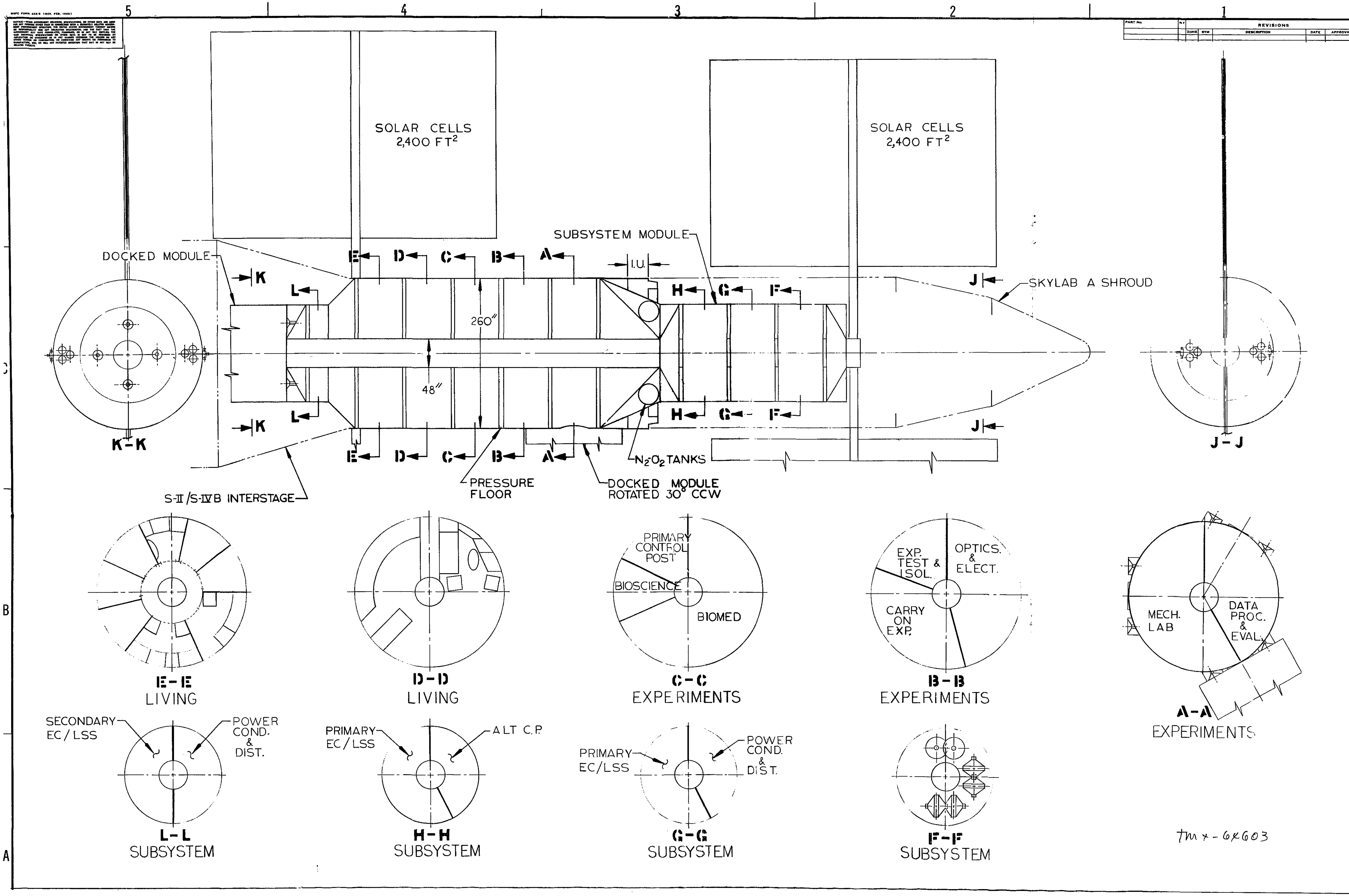



Figure 1. Option IV Modular Space Station.

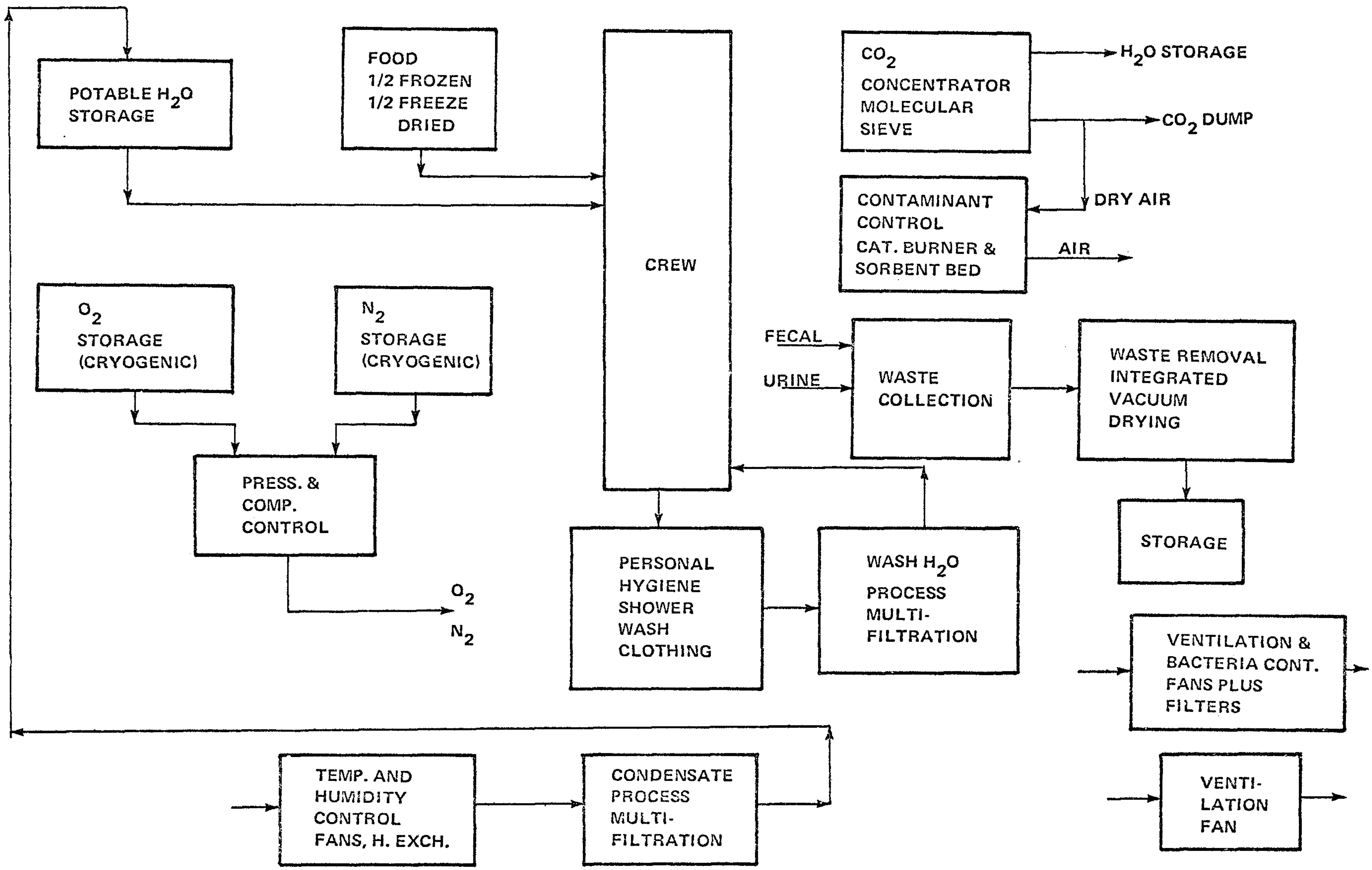
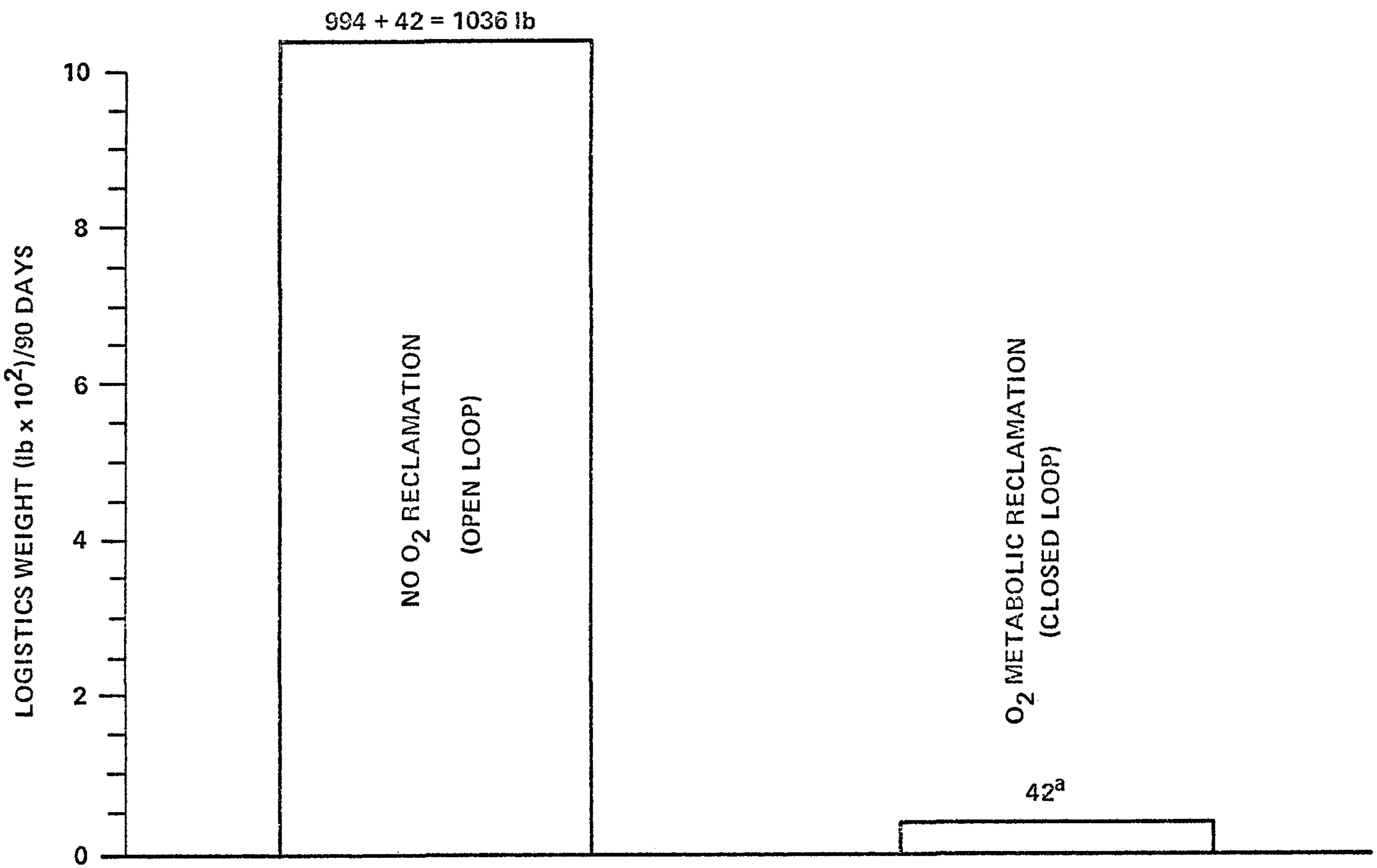
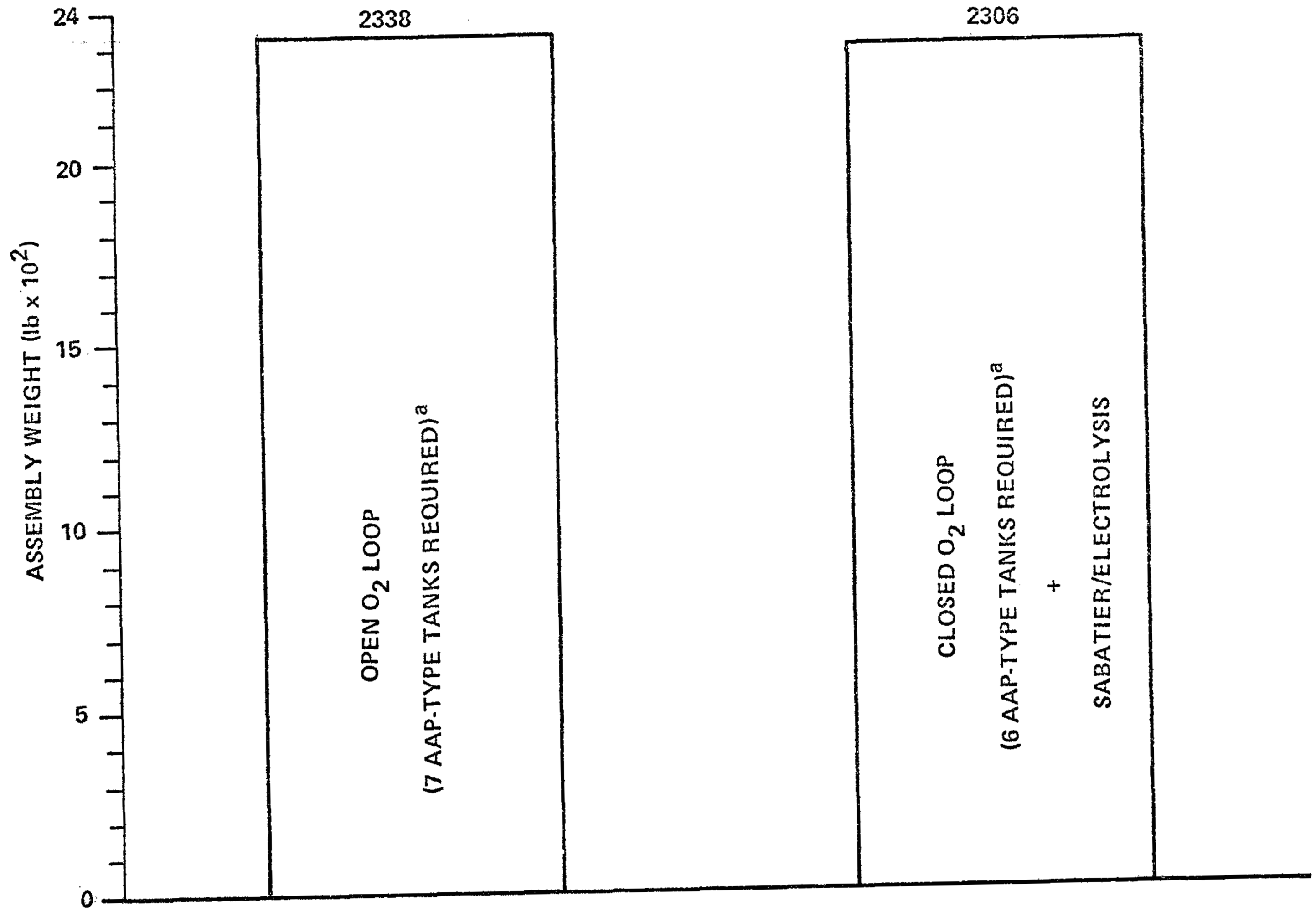



Figure 2. EC/LSS schematic.



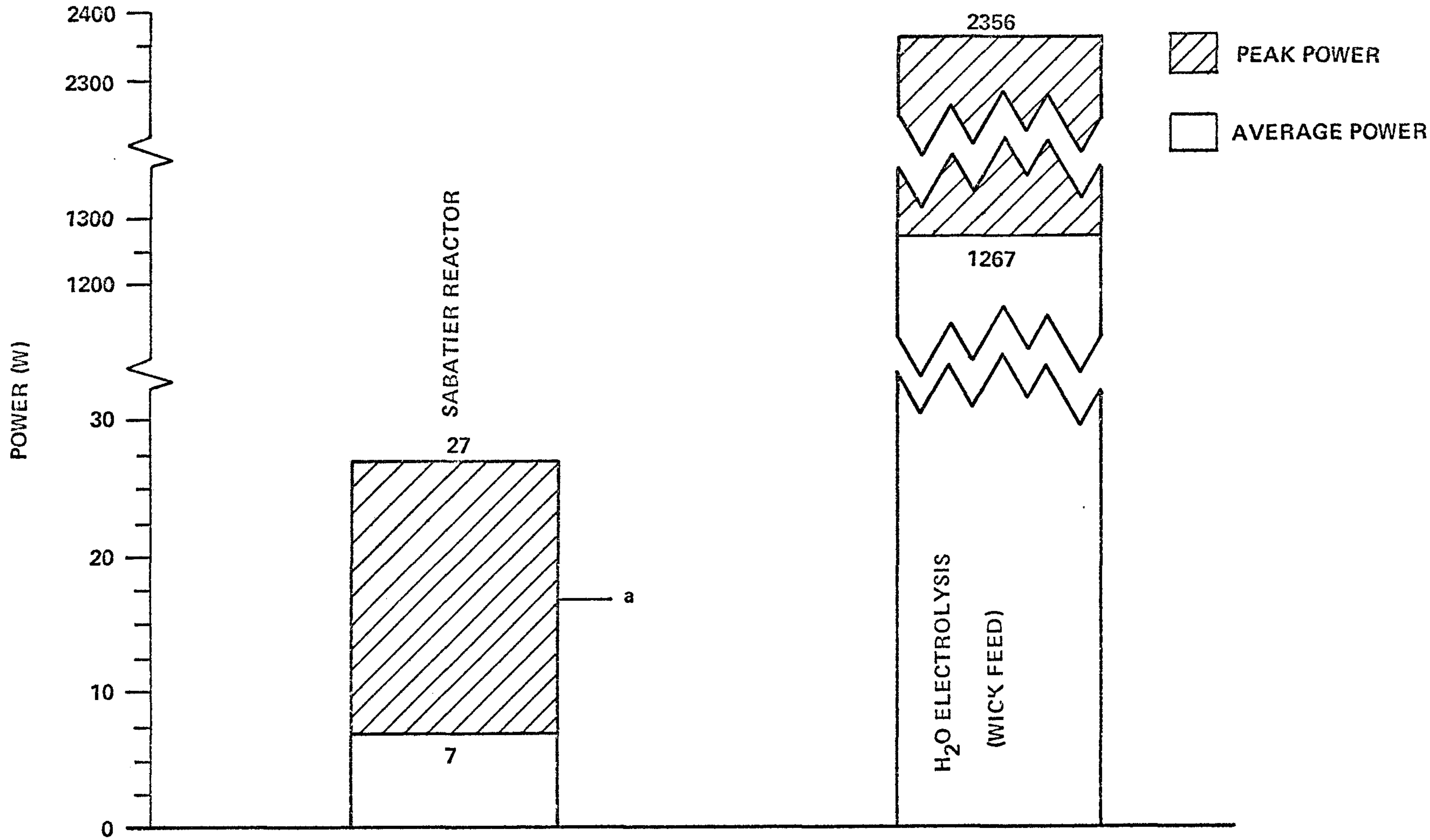

a. LEAKAGE RECLAIMED BY ELECTROLYSIS OF MAKEUP $H_2O$

Figure 3. Oxygen recovery logistics requirements, open versus closed loop (six-man, 90-day resupply).




a. FOR OXYGEN AND NITROGEN STORAGE

Figure 4. Oxygen reclamation assembly weight comparisons, open versus closed loop (six-man, 90-day resupply).




a. SABATIER REACTOR START-UP ONLY

Figure 5. Oxygen reclamation power comparison, closed loop (six-man, 90-day resupply).

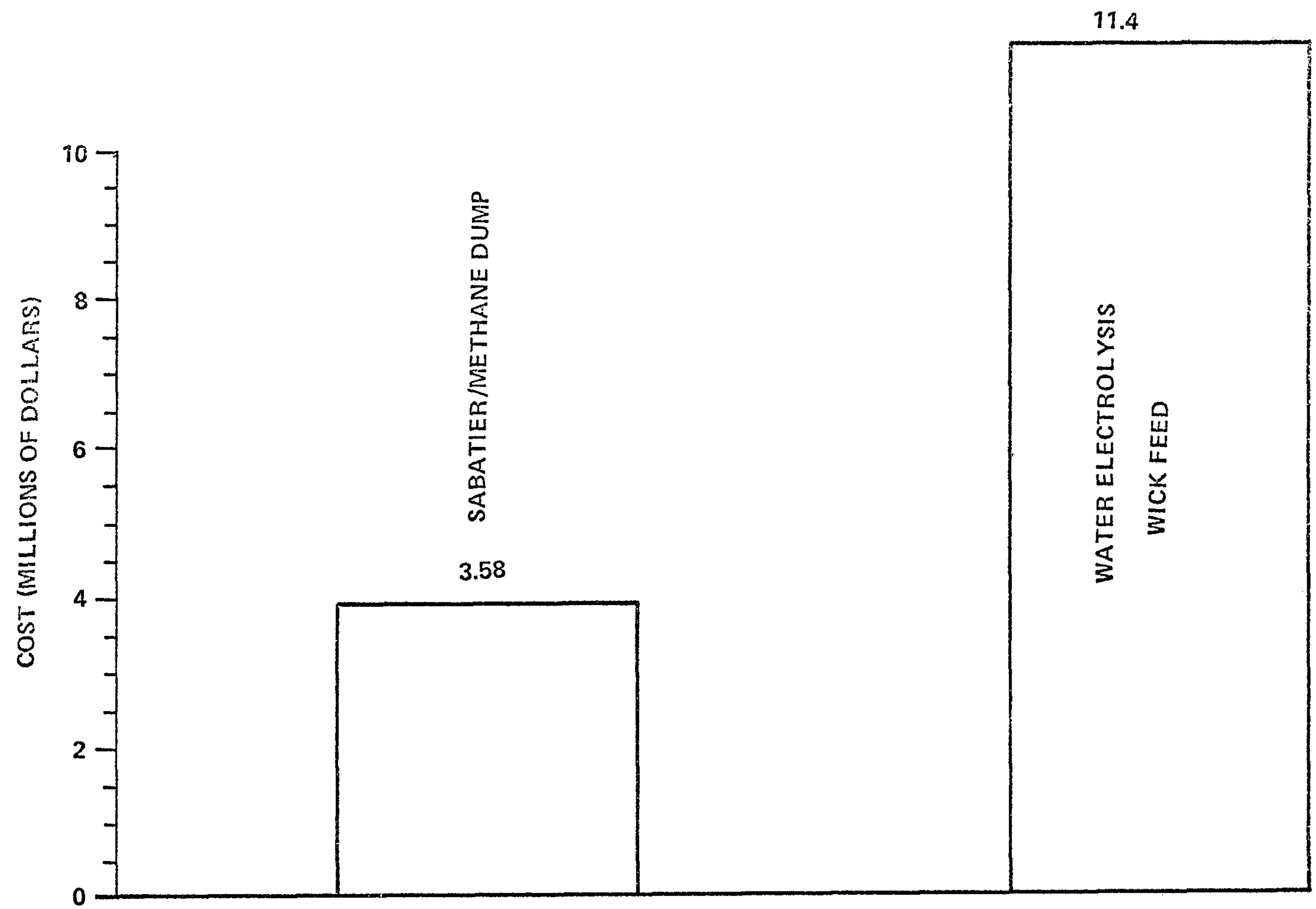



Figure 6. Oxygen reclamation assembly costs (six-man, 90-day resupply).

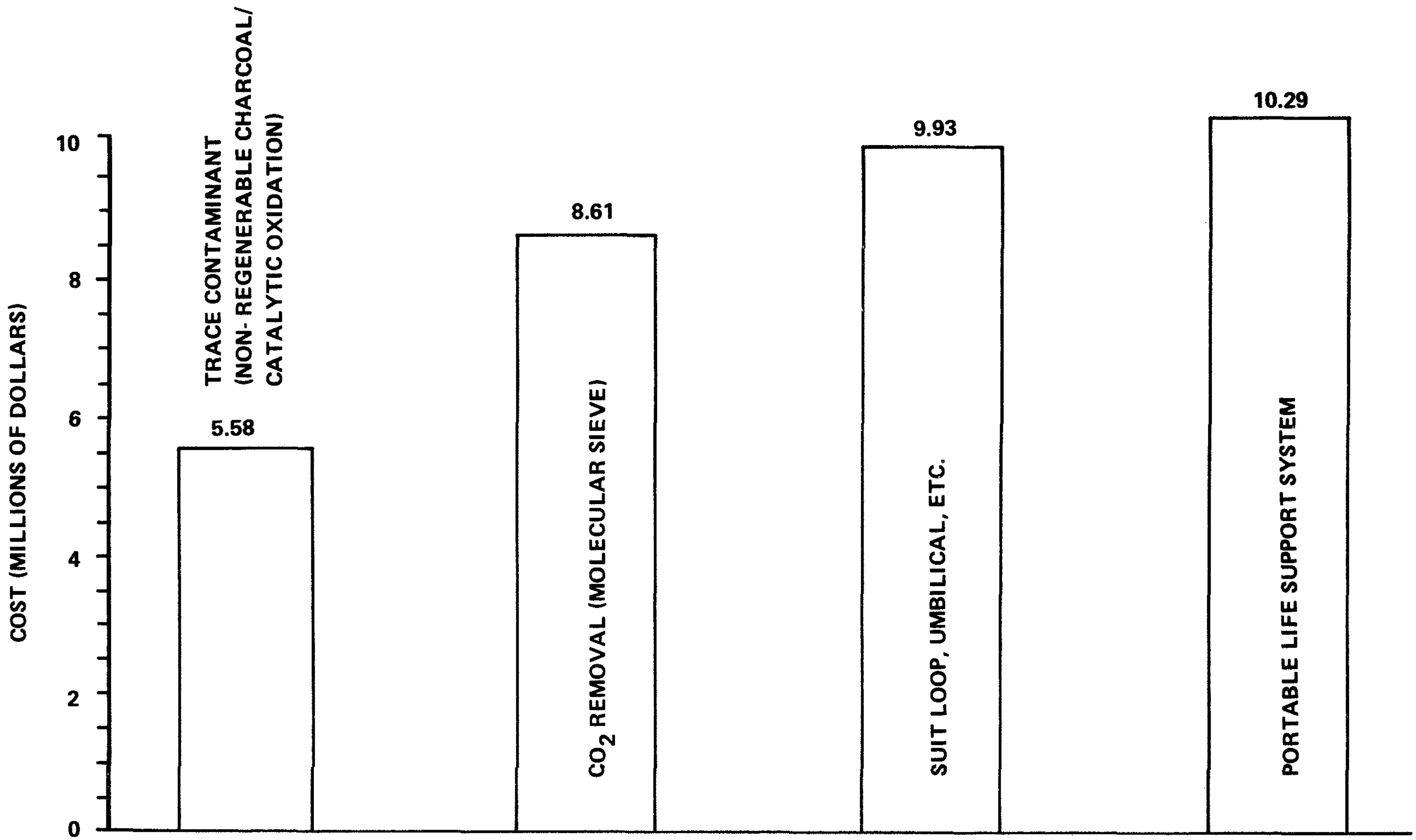



Figure 7. Miscellaneous EC/LSS cost comparisons.

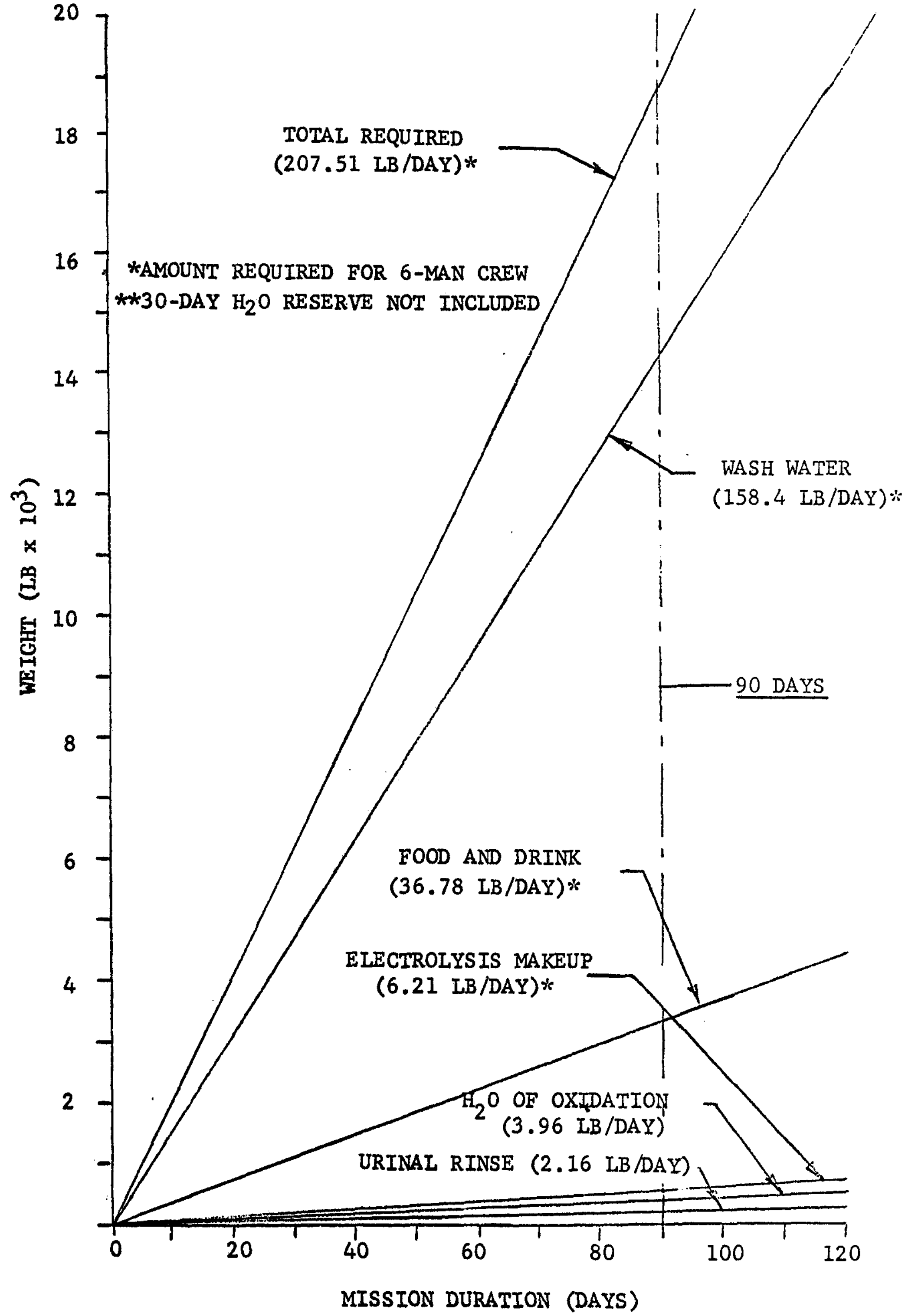



Figure 8. Option IV water requirements (six-man EC/LSS).

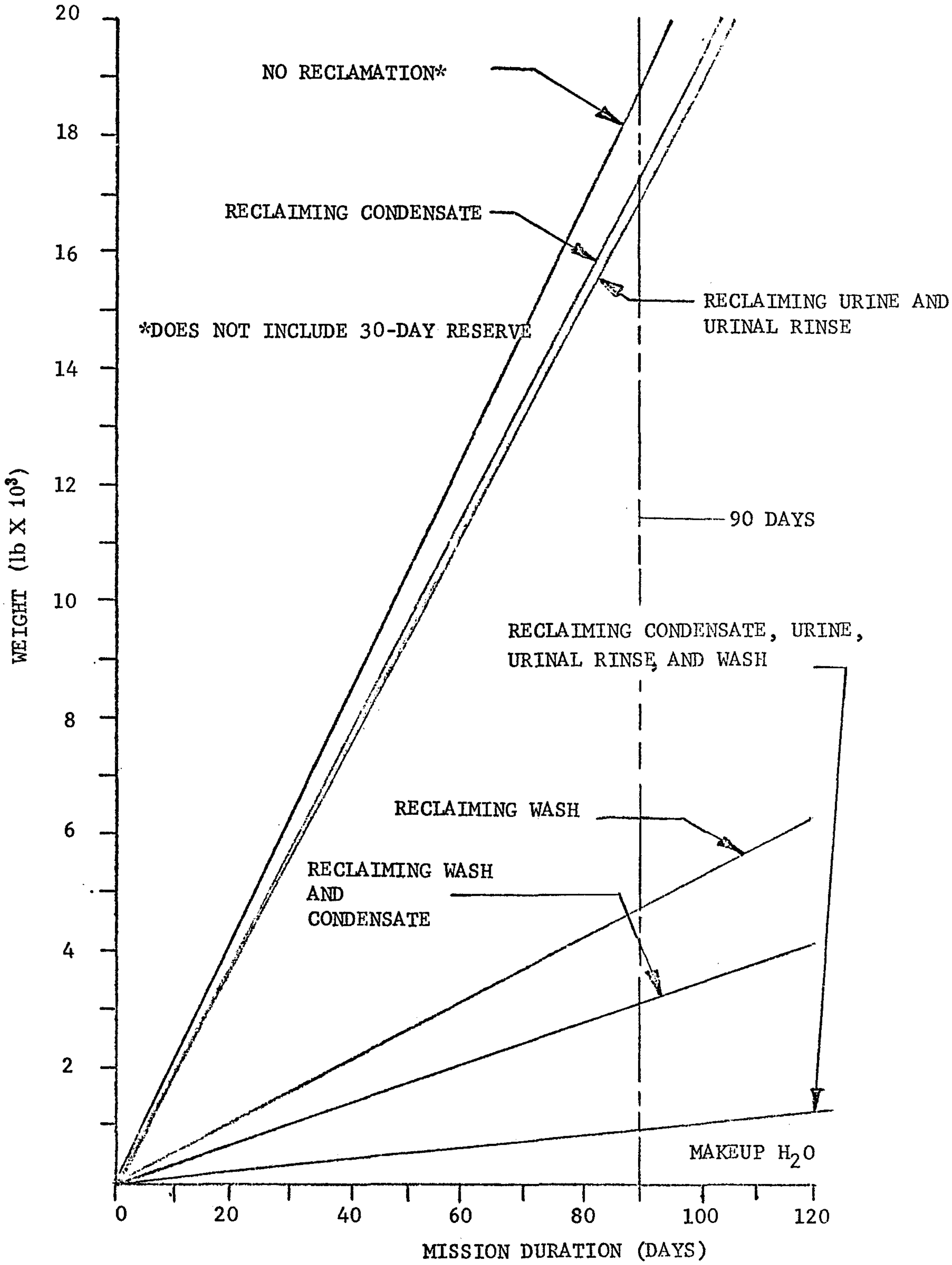



Figure 9. Total water requirements (six-man EC/LSS).

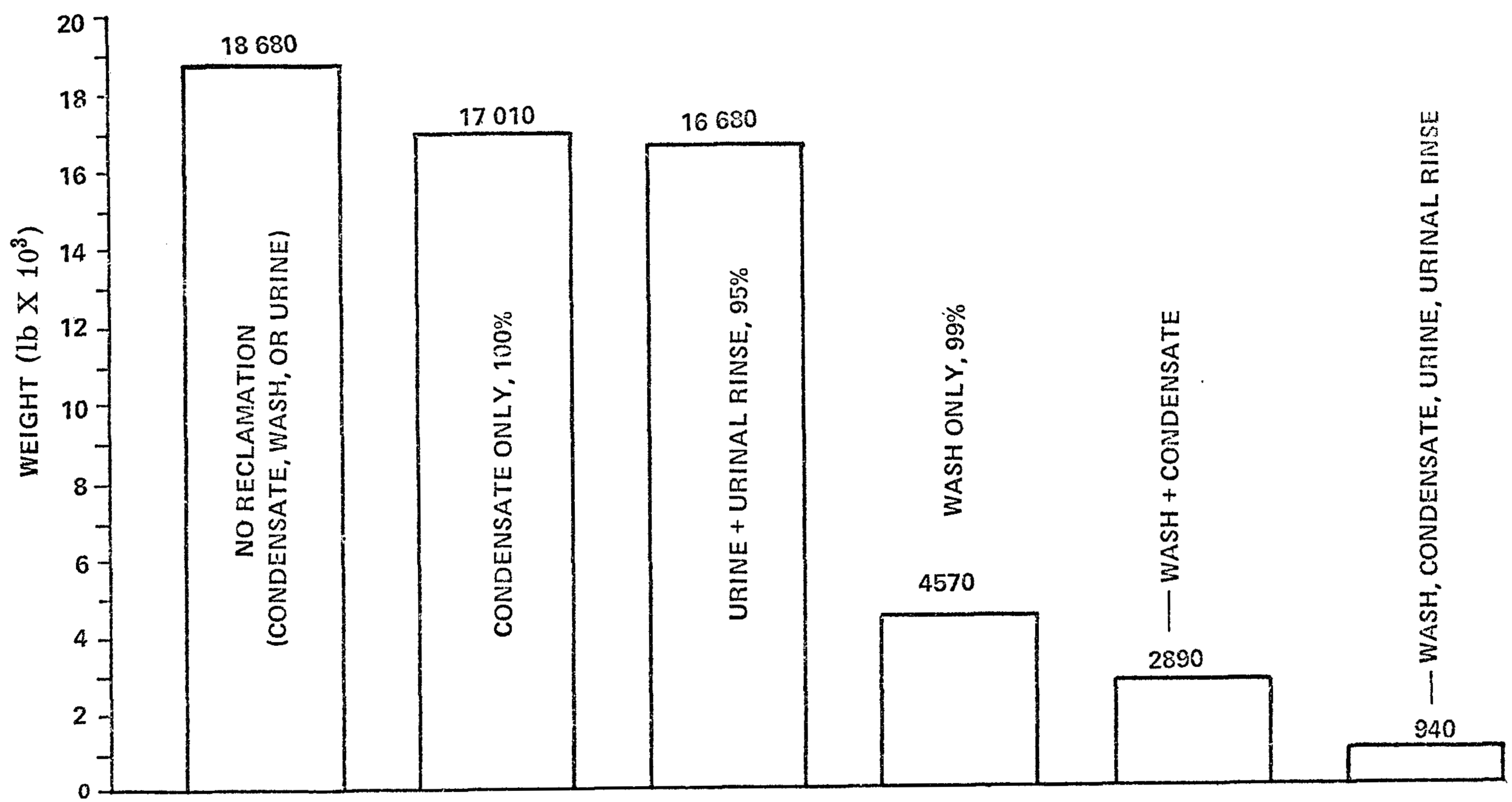
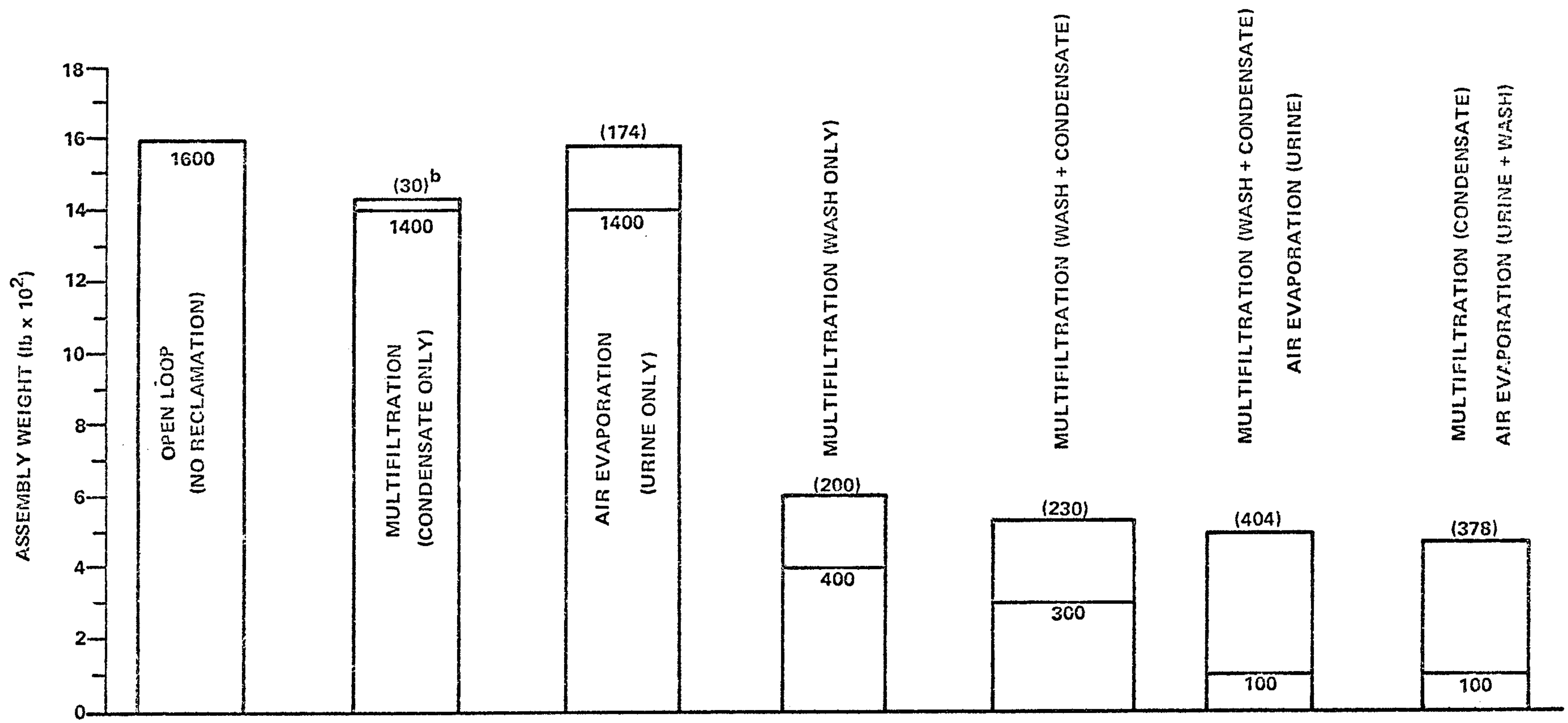
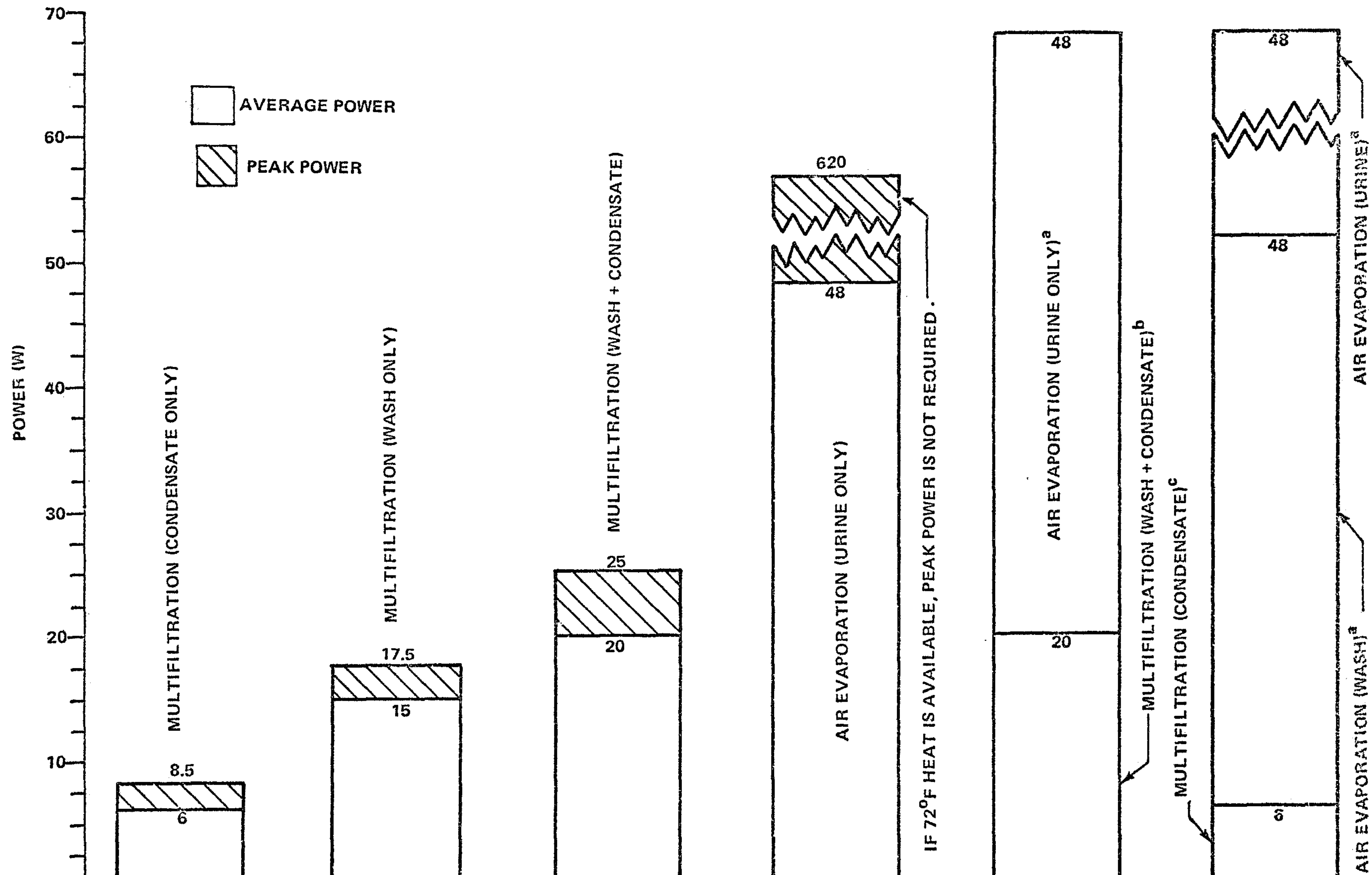



Figure 10. Logistics requirements for varying degrees of water loop closures (six-man, 90-day resupply).



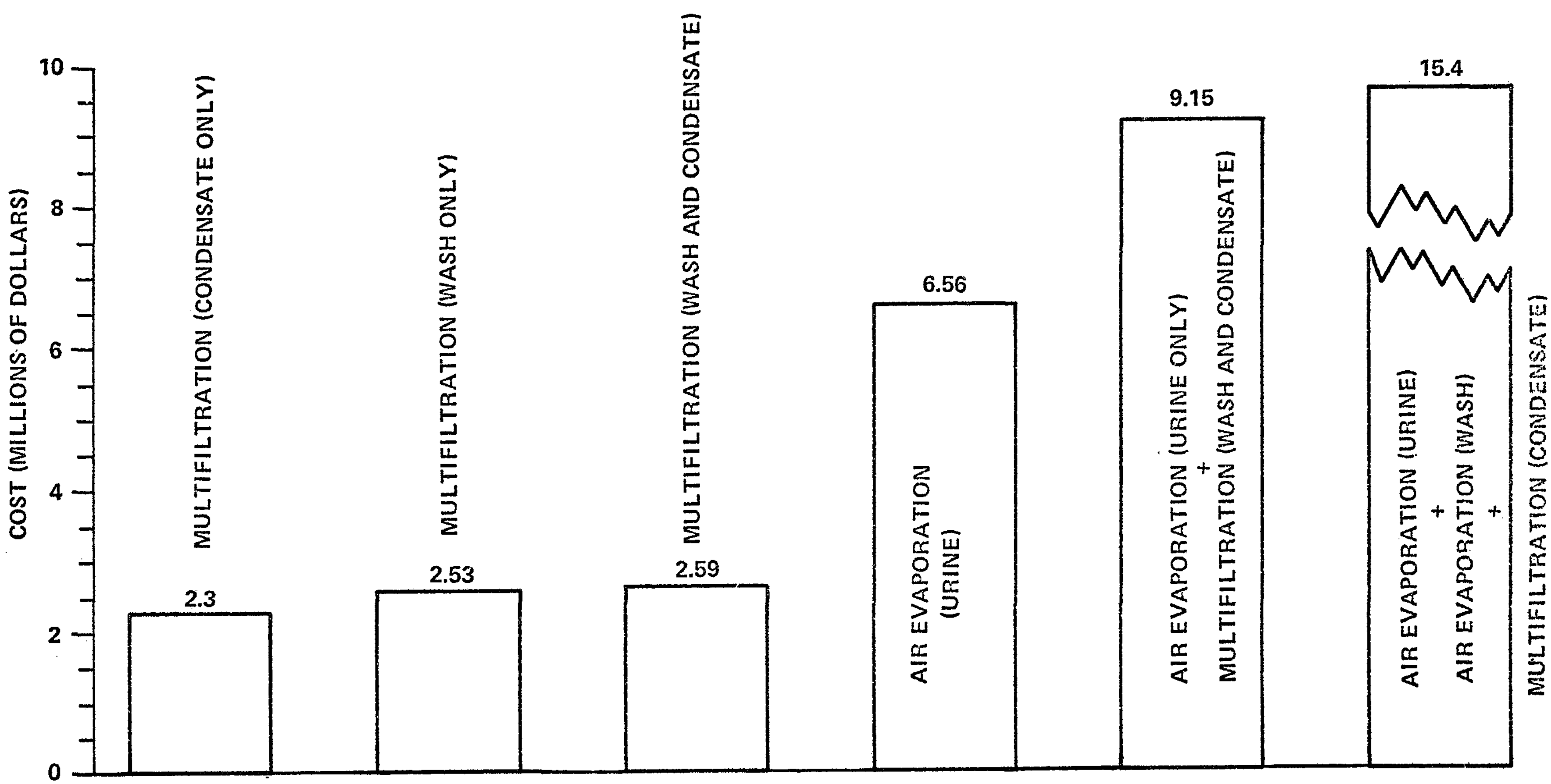

a. WATER STORAGE TANK WEIGHT INCLUDED.
b. ( ) REFERS TO RECLAMATION ASSEMBLY WEIGHT.

Figure 11. Water management assembly weight comparisons (six-man, 90-day resupply).



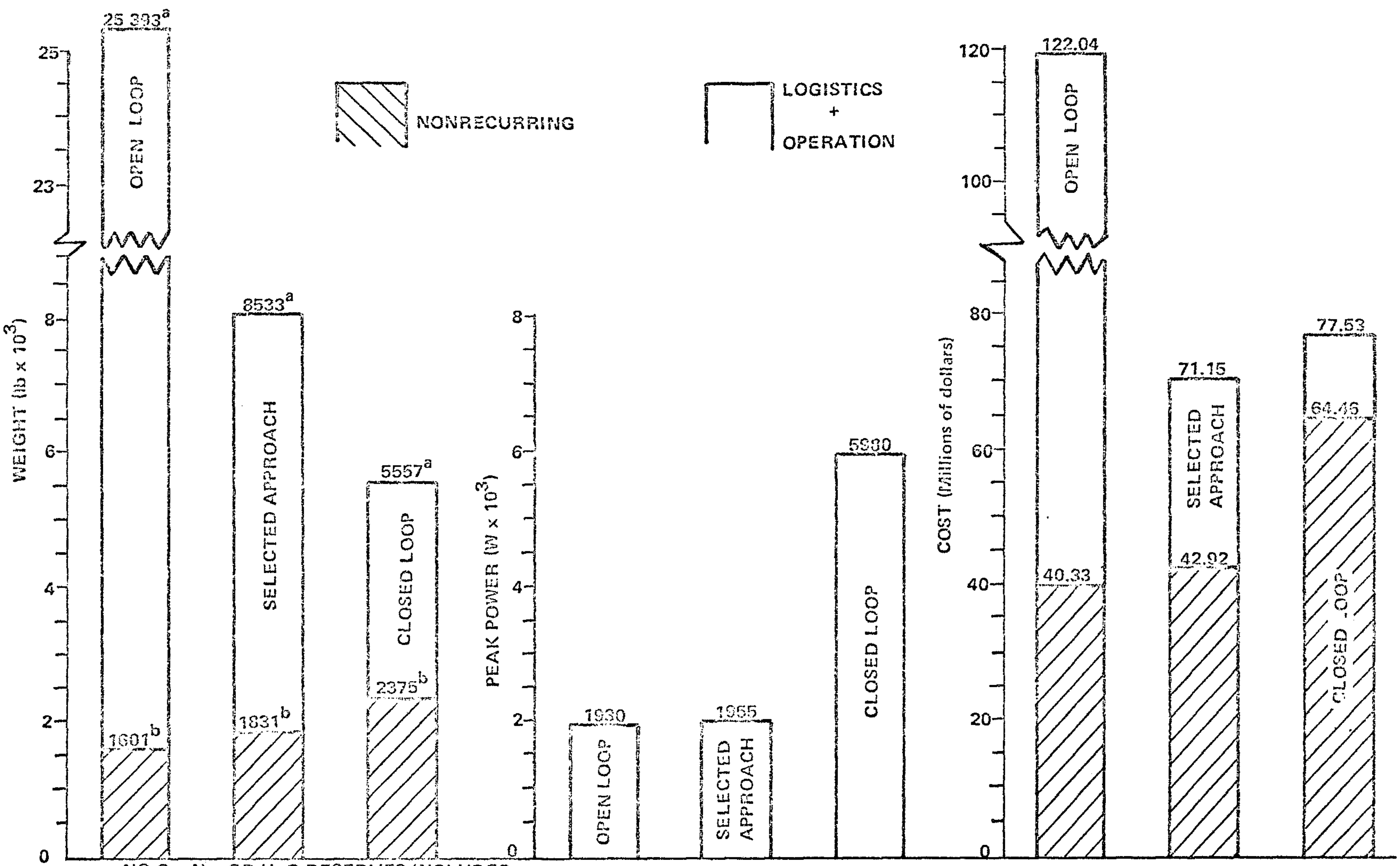

a. ADDITIONAL PEAK POWER OF 572 WATTS REQUIRED.
b. ADDITIONAL PEAK POWER OF 5 WATTS REQUIRED.
c. ADDITIONAL PEAK POWER OF 2.5 WATTS REQUIRED.

Figure 12. Water reclamation assembly power requirements (six-man, 90-day resupply).




a. INCLUDES HARDWARE, SPARES, POWER, LAUNCH WEIGHT AND VOLUME COSTS

Figure 13. Water reclamation assembly cost comparisons (six-man, 90-day resupply).




a. NO $O_2$, $N_2$, OR $H_2O$ RESERVES INCLUDED.

b. DRY ASSEMBLY WEIGHT (NO-SPARES, $O_2$, $N_2$, OR $H_2O$ TANKAGE).

Figure 14. Overall EC/LSS weight, power, and cost comparisons (six-man, 90-day resupply).

TABLE 1. EC/LSS FUNCTIONS AND EQUIPMENT APPROACHES.

| Function | Approaches | Selected Candidate | Selected Approach |
|---|---|---|---|
| Oxygen Storage | Gaseous Tanks (Skylab A)<br>Cryogenic Tanks | Cryogenic Tanks (Supercritical) | AAP Type |
| Nitrogen Storage | Cryogenic Tanks<br>Gaseous Tanks (Skylab A) | Cryogenic Tanks (Supercritical) | AAP Type |
| Pressure Control | Two-Gas | 14.7 psia-$N_2$ Diluent | Skylab A |
| Airlock Repressurization | Gas Replacement | Gas Replacement | Skylab A |
| $CO_2$ Removal | Molecular Sieve | Molecular Sieve | Resize Simulator |
| $CO_2$ Conversion (if ever used) | Sabatier - Bosch | Sabatier | |
| $O_2$ Generation (if ever used) | Electrolysis | Wick Feed | |
| Trace Contaminant | Nonregenerable Charcoal/Catalytic Oxidation<br>Regenerable Charcoal/ Catalytic Oxidation | Nonregenerable Charcoal/Catalytic Oxidation | Resize Simulator |
| Trace Contaminant Monitoring | Hybrid Gas Chromatograph/Mass Spectrometer | | Resize Simulator |
| Atmosphere Temperature Control | Air/Fluid $H_x$ | Air/Fluid $H_x$ | Resize Simulator |
| Humidity Control | Air/Fluid $H_x$ | Air/Fluid $H_x$ | |
| Ventilation | Fans, Ducts, Diffusers | Fans, Ducts, Diffusers | |
| Thermal Control<br>Internal Loop<br>External Loop | Active<br>Water<br>R-21 (Freon) | Active<br>Same<br>Same | Resize MOL<br>Modify and<br>Resize MOL |
| Urine $H_2O$ Recovery (if ever used) | Closed Air Evaporation<br>Vapor Compression | Closed Air Evaporation | Resize and Modify Simulator |
| Wash $H_2O$ Recovery | Multifiltration<br>Reverse Osmosis | Multifiltration | |
| Condensate $H_2O$ Recovery | Multifiltration<br>Reverse Osmosis | Multifiltration | |
| Potable $H_2O$ Storage | Heated Tanks | Same | Skylab A |
| Urine Collection | Integrated and Automatic Air Entrainment | Same | Skylab A |
| Fecal Collection and Processing | Integrated Vacuum Drying<br>Bagging/Dehydration | Integrated Vacuum Drying | Skylab A |
| EVA/IVA | Umbilical | Umbilical | Skylab A |
| Emergency $O_2$ Assemblies | Chlorate Candles/PLSS | Chlorate Candles/ PLSS | |

TABLE 2. EC/LSS REQUIREMENTS/GUIDELINES

| | | | |
|---|---|---|---|
| A. | Crew Data | | |
| | 1. | Number of Crew (continuous) | 6 Men |
| | 2. | Intermittent for 48 Hours Maximum Duration | 12 Men |
| | 3. | Metabolic Heat Generation (Btu/man-day) | 11 200 |
| | 4. | $O_2$ Consumption (lb/man-day) | 1.84 |
| | 5. | $CO_2$ Produced (lb/man-day) | 2.12 |
| B. | Baseline Mission Data | | |
| | 1. | Resupply Interval (days) | 90 |
| | 2. | Systems Life Requirement with Maintainability Spares, Redundancy (years) | 10 |
| | 3. | Crew Duty Tour (days) | 90 |
| | 4. | Crew Replacement Rate/90 Days | 6 |
| | 5. | Onboard Reserves, Expendables (days) | 30 |
| C. | Space Station | | |
| | 1. | Atmosphere - Total Pressure (psia) | 14.7 |
| | 2. | Atmospheric Mixture (by volume) | 21% $O_2$<br>79% $N_2$ |
| | 3. | $O_2$ Partial Pressure (psia) | 3.09 |
| | 4. | $N_2$ Partial Pressure (psia) | 11.61 |
| | 5. | $CO_2$ Partial Pressure, Nominal Maximum | 7.6 mm Hg<br>1.00%<br>(0.147 psia) |
| | 6. | $CO_2$ Emergency, Maximum | 15 mm Hg<br>1.97%<br>(0.290 psia) |
| | 7. | Leakage (lb/day for subsystem module) | 1 |
| | | Leakage (lb/day for core module) | 2 |

TABLE 3. SUBSYSTEM MODULE ASSEMBLIES—SIX-MAN EC/LSS
($PARTIALLY CLOSED H_2O$/OPEN $O_2$)

| Assembly | Major Component or Type | Weight (lb) | Volume ($ft^3$) |
|---|---|---|---|
| $CO_2$ Removal | Molecular Sieve | 410<br>56 (s) | 24<br>6.0 (s) |
| $O_2/N_2$ Pressure Control | Standard | 145<br>45 (s) | ?<br>0.6 (s) |
| Contaminant Control | Nonregenerable/Catalytic Oxidation | 52<br>12 (s) | 10<br>1.0 (s) |
| Water Management | Plumbing, Valves, etc. | 400<br>? (s) | ?<br>? (s) |
| Condensate Loop | Multifiltration | 30<br>4 (s) | 2<br>0.4 (s) |
| Wash Loop | Multifiltration | 200<br>53 (s) | 9.3<br>2.1 (s) |
| Waste Management | Integrated Vacuum Drying | 252<br>68 (s) | 64<br>3 (s) |
| Suit Loop | | 142<br>12 (s) | 30<br>0.4 (s) |
| Contingency | | 200<br>23 (s) | 16<br>2 (s) |
| | Total | 1831[c]<br>273 (s)[b] | 155.3<br>15.5 (s)[b] |

a. Two three-man EC/LSS interconnected.
b. Indicated total spares weight or volume.
c. Does not include $O_2$, $N_2$, and $H_2O$ tankage.

TABLE 4. CORE MODULE ASSEMBLIES—THREE-MAN EC/LSS (PARTIALLY CLOSED $H_2O$/OPEN $O_2$)

| Assembly | Major Component or Type | Weight (lb) | Volume ($ft^3$) |
|---|---|---|---|
| $Co_2$ Removal | Molecular Sieve | 205<br>28 (s) | 12<br>3.0 (s) |
| $O_2/N_2$ Pressure Control | Standard | 145<br>45 (s) | ?<br>0.6 (s) |
| Contaminant Control | Nonregenerable/Catalytic Oxidation | 26<br>6 (s) | 5<br>0.5 (s) |
| Water Management | Plumbing, Valves | 200<br>? (s) | ?<br>? (s) |
| Condensate Loop | Multifiltration | 15<br>2 (s) | 1<br>0.2 (s) |
| Wash Loop | Multifiltration | 100<br>26 (s) | 4.5<br>1 (s) |
| Waste Management | Integrated Vacuum Drying | 126<br>34 (s) | 32<br>0.5 (s) |
| Suit Loop | Plumbing, Supply Valves, etc. | 71<br>6 | 15<br>0.2 (s) |
| Contingency | ? | 100<br>14 (s) | 8<br>1 (s) |
| | Total | 988[a]<br>161 (s)[b] | 77.5<br>7.0 (s)[b] |

a. Does not include $O_2$, $N_2$, and $O_2O$ tankage.
b. Indicates total spares weight or volume.

TABLE 5. TOTAL EC/LSS SUBSYSTEM WEIGHT SUMMARY[a]

| Components | Location | Weight (lb) |
|---|---|---|
| Six-Man EC/LSS | Subsystem Module | 1 831 |
| Three-Man EC/LSS | Core Module (Aft End) | 988 |
| $O_2$ + Tankage | Core Module (Interstage) | 4 322 |
| $N_2$ + Tankage | Core Module (Interstage) | 4 473 |
| $H_2O$ + Tankage | Core Module (Interstage) | 4 293 |
| | Total EC/LSS Weight plus Fluids | 15 907 |

a. Initial pressurization gases excluded.

TABLE 6. CHLORATE CANDLE (EMERGENCY OXYGEN SUPPLY)[a]

| Components | No. Required | Weight (lb) | Estimated Volume or Size |
|---|---|---|---|
| Chlorate Candles (Primary) | 6 | 156 | 6.25-inch dia. by 11 3/8-inch length |
| Chlorate Cylinders (0.137#/ft.$^3$ of $O_2$) | 6 | 100 | |
| Fixed Weight | | 5 | |
| Total | | 261 | |
| Spares | | | |
| Chlorate Candles | 6 | 156 | |

a. Burn time is 50 + 5 minutes for 121.8 cubic feet of $O_2$/candle.

TABLE 7. OXYGEN RECOVERY ASSEMBLY (BOSCH) DETAILED DRY WEIGHT BREAKDOWN (THREE-MAN EC/LSS)

| Component | No. Required | Weight (lb) |
|---|---|---|
| Reactor and Cartridge | 2 | 8.0 |
| Master Control | 1 | 1.8 |
| Heater Controller | 2 | 3.6 |
| Heat Exchanger | 1 | 7.5 |
| Water Separator | 1 | 6.0 |
| Fan | 1 | 3.0 |
| Pump | 1 | 2.0 |
| Manual Shut-Off Valve | 1 | 0.3 |
| $CO_2$ Regulator Valve | 1 | 1.2 |
| $H_2$ Regulator Valve | 1 | 1.2 |
| Solenoid Diverter Valve | 2 | 3.0 |
| $CO_2$ Sensor | 1 | 2.6 |
| Check Valve | 2 | 0.4 |
| | Total | 40.6 |

TABLE 8. OXYGEN RECOVERY ASSEMBLY (SABATIER) DETAILED WEIGHT AND POWER BREAKDOWN (THREE-MAN EC/LSS)

| Component | No. Required | Weight (lb) |
|---|---|---|
| Sabatier/Methane Dump | | |
| Sabatier Reactor | 1 | 5.0 |
| Pressure Transducer | 3 | 1.5 |
| $CO_2$ Orifice | 1 | 0.05 |
| Pressure Ratio Regulator | 1 | 1.25 |
| $H_2$ Orifice | 1 | 0.05 |
| Flow Transducer | 2 | 2.0 |
| $CH_4$ Orifice | 1 | 0.05 |
| Shutoff Valve | 6 | 1.80 |
| Cycle Accumulator | 2 | 6.0 |
| $O_2$ Warning Sensor | 1 | 0.1 |
| Signal Conditioner | 1 | 0.5 |
| Temperature Transducer | 2 | 0.4 |
| Signal Conditioner | 2 | 0.6 |
| Solenoid Valve | 2 | 0.5 |
| Timer, Electrical | 1 | 0.2 |
| Condenser/Water Separator | 1 | 6.0 |
| Temperature Control Valve | 1 | 1.0 |
| Temperature Controller | 1 | 0.9 |
| Installation Provisions | | 11.1 |
| | Total | 39.0 |

TABLE 9. WATER ELECTROLYSIS ASSEMBLY
DETAILED DRY WEIGHT BREAKDOWN
(THREE-MAN EC/LSS)

| Component | No. Required | Weight (lb) |
|---|---|---|
| Check Valve | 2 | 0.6 |
| Shut-Off Valve | 4 | 4.8 |
| Electrolysis Module | 1 | 48.0 |
| Condenser/Separator | 1 | 6.0 |
| Hydrogen Regulator | 1 | 1.2 |
| Oxygen Regulator | 1 | 1.2 |
| Circulation Pump | 1 | 1.5 |
| Gas/Liquid/Solids Separator | 1 | 6.0 |
| Controller | 1 | 1.8 |
| Solenoid S. O. Valve | 1 | 1.5 |
| Cold Plate | 1 | 4.0 |
| Instrumentation | | 10.0 |
| Plumbing and Wiring | | 9.0 |
| Insulation | | 3.0 |
| Mounting | | 3.0 |
| Contingency | | 10.4 |
| Total | | 112.0 |

TABLE 10. NONREGENERABLE CHARCOAL/CATALYTIC OXIDATION ASSEMBLY DETAILED DRY WEIGHT BREAKDOWN (THREE-MAN EC/LSS)

| Component | No. Required | Weight (lb) |
|---|---|---|
| Fan | 1 | 1.3 |
| Charcoal Bed | 1 | 3.0 |
| Manual Shut-Off Valve | 1 | 1.2 |
| Catalytic Burner | 1 | 10.4 |
| Post Sorbent Bed | 1 | 1.0 |
| Heater Controller (Catalytic Burner) | 1 | 3.0 |
| Installation Hardware | 1 | 6.1 |
| | Total | 26.0 |

TABLE 11. MOLECULAR SIEVE ASSEMBLY
DETAILED DRY WEIGHT BREAKDOWN
(THREE-MAN EC/LSS)

| Component | No. Required | Weight (lb) |
|---|---|---|
| Fan | 1 | 6.5 |
| Heater | 1 | 1.5 |
| Silica Gel Canister | 2 | 48.0 |
| Molecular Sieve Canister | 2 | 48.0 |
| Regenerative H/X | 1 | 20.0 |
| Coolant Diverter Valves | 6 | 9.0 |
| Canister Diverter Valves | 4 | 6.0 |
| Start-Up Valve | 1 | 1.5 |
| Shut-Off Valves | 3 | 1.2 |
| Vacuum Pump | 1 | 22.0 |
| $CO_2$ Cooler | 1 | 1.5 |
| $CO_2$ Accumulator | 1 | 13.4 |
| $CO_2$ Compressor | 1 | 6.5 |
| $CO_2$ Diverter Valve | 1 | 1.5 |
| Valve Sequence Controller | 1 | 6.0 |
| $CO_2$ Sensor | 2 | 5.2 |
| Heater/Controller | 1 | 1.8 |
| Humidity Sensor | 2 | 0.5 |
| Pressure Sensor | 3 | 2.1 |
| Speed Sensor | 3 | 1.2 |
| Temperature Sensor | 6 | 1.2 |
| Total | | 204.6 |

TABLE 12. SPACE STATION WATER BALANCE (SIX-MAN)

| Water Sources | Quantity (lb/day) |
|---|---|
| <u>Water Requirements</u> | |
| Food and Drink (6.13 lb/man-day) | 36.78 |
| Water of Oxidation (0.66 lb/man-day) | 3.96 |
| Wash Water (26.4 lb/man-day) | 158.4 |
| Urinal Rinse Water (0.36 lb/man-day) | 2.16 |
| Electrolysis (Makeup $H_2O$) | 6.21 |
| Total Required | 207.51 |
| <u>Human</u> | |
| Urine (95% efficiency) | 19.67 |
| Perspiration and Respiration (100% efficiency) | 18.54 |
| Water in Food Waste | 0.84[a] |
| Water in Feces | 1.50[a] |
| <u>Equipment and Processes</u> | |
| Wash Water (99% efficiency) | 156.82 |
| Urinal Flush Water (95% efficiency) | 2.05 |
| Reclamation Inefficiencies (stored) | 2.73 |
| Stored Makeup $H_2O$ | 7.71 |
| Total | 209.86 |
| Unrecovered | 2.34 |
| Total available | 207.52 |

a. Unrecovered

TABLE 13. AIR EVAPORATION ASSEMBLY
DETAILED DRY WEIGHT BREAKDOWN
(THREE-MAN EC/LSS)

| Component | No. Required | Weight (lb) |
|---|---|---|
| Chemical Storage Tank Connector | 2 | 1.0 |
| Pre-Treat Tank | 2 | 8.6 |
| Manual, 3-Way Valve | 1 | 0.5 |
| Evaporator | 2 | 15.0 |
| Condenser/Separator | 1 | 7.5 |
| Manual, 4-Way Valve | 2 | 0.1 |
| Fan | 1 | 1.5 |
| Heater | 1 | 1.5 |
| Heater Control | 1 | 1.8 |
| Charcoal Filter Canister | 1 | 1.8 |
| Chemical Injector | 2 | 7.2 |
| Solenoid, 4-Way | 1 | 1.0 |
| Solenoid, 3-Way | 1 | 0.7 |
| Shut-Off Valve | 17 | 4.3 |
| Feed Valve | 4 | 2.0 |
| Pumps | 2 | 3.0 |
| Controller | 1 | 3.0 |
| Conductivity Sensor | 1 | 2.8 |
| Heat Exchanger | 1 | 7.0 |
| Bacteria Filter | 1 | 2.6 |
| Controls | | 2.7 |
| Structure | | 4.0 |
| Plumbing | | 5.0 |
| Wiring | | 2.0 |
| Total | | 86.6 |

TABLE 14. MULTIFILTRATION ASSEMBLY
DETAILED DRY WEIGHT BREAKDOWN
(THREE-MAN EC/LSS)

| Component | No. Required | Weight (lb) |
|---|---|---|
| Diverter Valve, 4-Way | 1 | 1.8 |
| Multifiltration Bed | 1 | 1.8 |
| Bacteria Filter | 2 | 3.6 |
| Conductivity Sensor | 1 | 1.2 |
| Solenoid Valve, 3-Way | 1 | 1.8 |
| Pump | 1 | 1.5 |
| Manual Shut-Off Valve | 6 | 1.8 |
| Controller | 1 | 1.5 |
| Total | | 15.0 |

TABLE 15. WASTE MANAGEMENT ASSEMBLY COMPARISON

| Candidate Concepts | Flight Availability | Development Risk |
|---|---|---|
| a. Bag/Storage | 1973 | Least - (MOL & Skylab) |
| b. Integrated Vacuum Drying | 1975 | Low - MDAC 60/90 SSS Runs |
| c. Integrated Vacuum Decomposition | 1976 | High - Adv. SRT Required |
| d. Integrated Vacuum Decomposition With Partial Oxidation | 1977 | High - Adv. SRT Required |

Crew Acceptability

a. Poor - Manual Transfer of Collection Bag Several Times Per Day
b. Fair - Removal and Replacement of Tank Liner Once Per Week
c. Good - Ash Removal Only
d. Good - Ash Removal Only

- Selected Concept - Integrated Vacuum Drying
  - Low Development Risk
  - Least Overall Cost (Devel. + Resupply)
  - Crew Acceptability

| Weight (lb) | Power (W) | Cost ($) |
|---|---|---|
| 126 | 170 | 5.92M |

TABLE 16. ONBOARD OPEN LOOP CONSUMABLES AT INITIAL LAUNCH MODULAR SPACE STATION (SIX-MAN, 90-DAY RESUPPLY)

| Requirement | Fluid Weight (lb) | |
|---|---|---|
| | $O_2$ | $N_2$ |
| Space Station Leakage (90 days - 2 lb/day) | 42 | 138 |
| Space Station Leakage Reserve (30 days) | 14 | 46 |
| Subsystem Module Leakage (90 days - 1 lb/day) | 21 | 69 |
| Subsystem Module Leakage (30 days) | 7 | 23 |
| Metabolic Oxygen (90 days) | 994 | |
| Thirty-Day Reserve (metabolic for 12 men) | 662 | |
| Crew Rotation (6 men - 5 days) | 55 | |
| Crew Rotation (4 men - 5 days) | 37 | |
| EVA (120 manhours @ 0.25 lb/hr) | 30 | |
| Initial Space Station Pressurization | 280 | 923 |
| Emergency Space Station Pressurization (1 required) | 280 | 923 |
| Initial Subsystem Module Pressurization | 66 | 217 |
| Emergency Subsystem Module Pressurization (1 required) | 66 | 217 |
| Airlock Pressurization | 70 | 229 |
| Pump-Down Gas Losses | 90 | 79 |
| Experiment Chamber Pressurization | 74 | 245 |
| Loss from Molecular Sieve | 66 | 202 |
| Gas Losses for Maintainability | 641 | 762 |
| Contingency | 171 | 204 |
| Overall Requirements | 3666 | 4277 |
| Less Initial Pressurization Gases | -346 | -1140 |
| Cryogen Storage | 3320 | 3137 |

TABLE 17. ONBOARD CLOSED LOOP CONSUMABLES AT INITIAL LAUNCH MODULAR SPACE STATION (SIX-MEN ~ 90-DAY RESUPPLY)

| Requirement | Fluid Weight (lb) | |
|---|---|---|
| | $O_2$ | $N_2$ |
| Space Station Leakage (90 days - 2 lb/day) | 42 | 138 |
| Space Station Leakage Reserve (30 days) | 14 | 46 |
| Subsystem Module Leakage (90 days - 1 lb/day) | 21 | 69 |
| Subsystem Module Leakage (30 days) | 7 | 23 |
| Initial Startup (1-day metabolic for 6 men) | 11 | |
| Thirty-day reserve (metabolic for 12 men) | 662 | |
| Crew Rotation (6 men - 5 days) | 55 | |
| Crew Rotation (4 men - 5 days) | 37 | |
| EVA (120 manhours @ 0.25 lb/hr) | 30 | |
| Initial Space Station Pressurization | 280 | 923 |
| Emergency Space Station Pressurization (1 required) | 280 | 923 |
| Initial Subsystem Module Pressurization | 66 | 217 |
| Emergency Subsystem Module Pressurization | 66 | 217 |
| Airlock Pressurizations | 70 | 229 |
| Pump-Down Gas Losses | 90 | 79 |
| Experiment Chamber Pressurization | 74 | 245 |
| Loss from Molecular Sieve | 66 | 202 |
| Gas Losses for Maintainability | 430 | 762 |
| Contingency | 115 | 204 |
| Overall Requirements | 2416 | 4277 |
| Less Initial Pressurization Gases | -346 | -1140 |
| Cryogen Storage | 2070 | 3137 |

TABLE 18. OPTION IV MODULAR SPACE STATION EXPENDABLE SUMMARY (OPEN LOOP)[a] (6-MAN, 90-DAY RESUPPLY)

| Expendable | Weight (lb) |
|---|---|
| Freeze-Dried Food Reserve (3 days)[b] | 28 |
| Frozen Food Reserve (2 days)[b] | 36 |
| Freeze-Dried Food Reserve (3 days)[c] | 19 |
| Frozen Food Reserve (2 days)[c] | 24 |
| Freeze-Dried Food (1.58 lb/man-day)[d] | 426 |
| Frozen Food (3.0 lb/man-day)[d] | 810 |
| $H_2O$ (initially stored) | 18 680 |
| $H_2O$ Reserve (30 days) | 1 103 |
| $O_2$ (metabolic) | 1 778 |
| $O_2$ Leak, Press., Reserve, etc.[e,f] | 1 542 |
| $N_2$ Leakage, Press., Reserve, etc.[e,f] | 3 137 |
| Total | 27 583[g] |

| Containers for | Type and Size | No. | Wt. Per Container (lb) | Total Container Weight (lb) | Total Container & Expendables (lb) |
|---|---|---|---|---|---|
| Freeze-Dried Food | ? | ? | ? | 61 | 534 |
| Frozen Food | ? | ? | ? | 87 | 957 |
| $H_2O$ | New Tanks (40.0 in. I.D.) | 16 | 100 | 1600 | 21 383 |
| $O_2$ Cryogenic | AAP Type (39.0 in. I.D.) | 3[h] | 334 | 1002 | 4 322 |
| $N_2$ Cryogenic | AAP Type (39.0 in. I.D.) | 4[h] | 334 | 1336 | 4 473 |
| | | | Total | 4086 | 31 669 |

a. Open $H_2O$ and $O_2$ loops.
b. 5 days of unpackaged food for six-man turnaround crew.
c. 5 days of unpackaged food for four-man supplementary crew.
d. 45 days of unpackaged food for six-man continuous crew.
e. Leakage rate assumed = 1.0 lb/day for subsystem module.
f. Leakage rate assumed = 2.0 lb/day for Space Station.
g. 320 lb (30-day reserve) of additional freeze-dried food required.
h. 280 lb of $O_2$ and 263 lb $N_2$ can be added.

TABLE 19. OPTION IV MODULAR SPACE STATION EXPENDABLE SUMMARY, CLOSED LOOP [a] (6-MAN, 90-DAY REQUPPLY)

| Expendable | Weight (lb) |
|---|---|
| Freeze-Dried Food Reserve (3 days)[b] | 28 |
| Frozen Food Reserve (2 days)[b] | 36 |
| Freeze-Dried Food Reserve (3 days)[c] | 19 |
| Frozen Food Reserve (2 days)[c] | 24 |
| Freeze-Dried Food (1.58 lb/man-day)[d] | 426 |
| Frozen Food (3.0 lb/man-day)[d] | 810 |
| $H_2O$ (initially stored) | 940 |
| $H_2O$ Reserve (30 days) | 1103 |
| $O_2$ (metabolic) | 795 |
| $O_2$ Leak, Press., Reserve, etc.[e,f] | 1275 |
| $N_2$ Leakage, Press., Reserve, etc.[e,f] | 3137 |
| Total | 8593[g] |

| Containers for | Type and Size | No. | Wt. Per Container (lb) | Total Container Weight (lb) | Total Container & Expendables (lb) |
|---|---|---|---|---|---|
| Freeze-Dried Food | ? | ? | ? | 61 | 534 |
| Frozen Food | ? | ? | ? | 87 | 957 |
| $H_2O$ | New Tanks (40.0 in. I.D.) | 3 | 100 | 300 | 2 343 |
| $O_2$ Cryogenic | AAP Type (39.0 in. I.D.) | 2[h] | 334 | 668 | 2 738 |
| $N_2$ Cryogenic | AAP Type (39.0 in. I.D.) | 4[h] | 334 | 1336 | 4 473 |
| | | | Total | 2452 | 11 045 |

a. Closed $O_2$ and $H_2O$ Loop.
b. 5 days of unpackaged food for six-man turnaround crew.
c. 5 days of unpackaged food for four-man supplementary crew.
d. 45 days of unpackaged food for six-man continuous crew.
e. Leakage rate assumed = 1.0 lb/day for subsystem module.
f. Leakage rate assumed = 2.0 lb/day for Space Station.
g. 320 lb (30-day reserve) of additional freeze-dried food required.
h. 330 lb of $O_2$ and 263 lb $N_2$ can be added.

TABLE 20. OPTION IV MODULAR SPACE STATION EXPENDABLE SUMMARY, PARTIALLY CLOSED LOOP[a] (6-MAN, 90-DAY RESUPPLY)

| Expendable | Weight (lb) |
|---|---|
| Freeze-Dried Food Reserve (3 days)[b] | 28 |
| Frozen Food Reserve (2 days)[b] | 36 |
| Freeze-Dried Food Reserve (3 days)[c] | 19 |
| Frozen Food Reserve (2 days)[c] | 24 |
| Freeze-Dried Food (1.58 lb/man-day)[d] | 426 |
| Frozen Food (3.0 lb/man-day)[d] | 810 |
| $H_2O$ (initially stored) | 2890 |
| $H_2O$ Reserve (30 days) | 1103 |
| $O_2$ (metabolic) | 1778 |
| $O_2$ Leak, Pressure, Reserve, etc.[e,f] | 1542 |
| $N_2$ Leakage, Pressure, Reserve, etc.[e,f] | 3137 |
| Total | 8903[g] |

| Containers for | Type and Size | No. | Wt. Per Container (lb) | Total Container Weight (lb) | Total Container & Expendables (lb) |
|---|---|---|---|---|---|
| Freeze-Dried Food | ? | ? | ? | 61 | 534 |
| Frozen Food | ? | ? | ? | 87 | 957 |
| $H_2O$ | New Tanks (40.0 in. I.D.) | 3 | 100 | 300 | 4 293 |
| $O_2$ Cryogenic | AAP Type (39.0 in. I.D.) | 3[h] | 334 | 1002 | 4 322 |
| $N_2$ Cryogenic | AAP Type (39.0 in. I.D.) | 4[h] | 334 | 1336 | 4 473 |
| | | | Total | 2786 | 14 579 |

a. Partially closed $H_2O$/Open $O_2$.
b. 5 days of unpackaged food six-man turnaround crew.
c. 5 days of unpackaged food for four-man supplementary crew.
d. 45 days of unpackaged food for six-man continuous crew.
e. Leakage rate assumed = 1.0 lb/day for subsystem module.
f. Leakage rate assumed = 2.0 lb/day for Space Station.
g. 320 lb (30-day reserve) of additional freeze-dried food required.
h. 280 lb of $O_2$ and 263 lb $N_2$ can be added.

# APPROVAL

# ENVIRONMENTAL CONTROL AND LIFE SUPPORT SUBSYSTEM (EC/LSS) FOR THE MODULAR SPACE STATION (OPTION IV)

By Hubert B. Wells and Andrew G. Kromis

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