N85-29555

CONTAMINATION CONTROL FOR INCREASED CREW PRODUCTIVITY

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Space Station Task Force
Human Productivity Group
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SCOPE OF PRESENTATION

- Contaminant Sources and Loading - Air/Water
- Contaminant Control - Air
- Contaminant Control - Water
- Other Factors Affecting Productivity
- Issues

SPACE STATION CONTAMINANT SOURCES — AIR

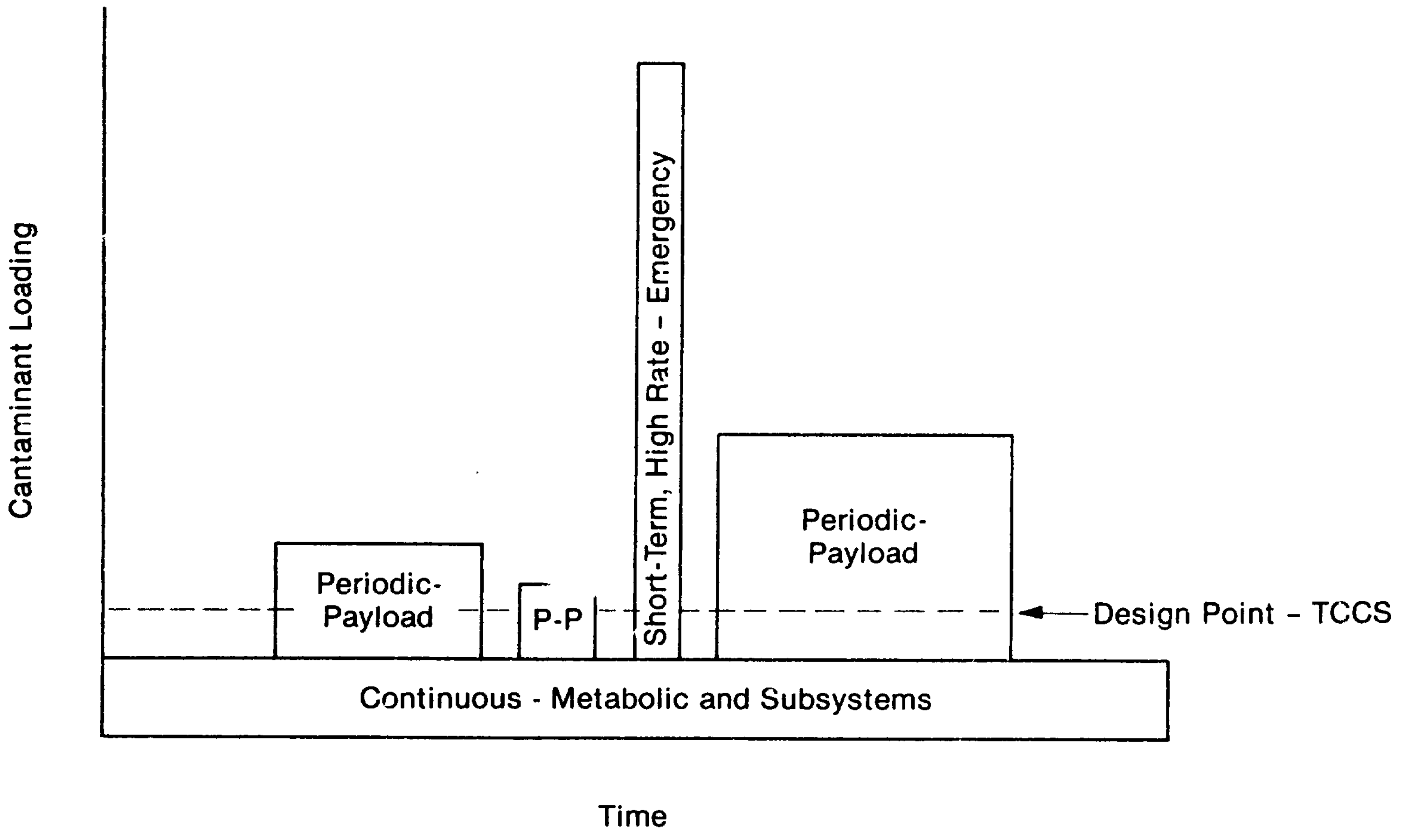
CONTAMINANT	SOURCE	LOADING
Metabolic Products: CO_2, NH_3, CO, H_2S, H_2, CH_4, Organic Acids, Mercaptans, Bacteriological Contaminants.	Crew & Animal	Continuous
Wide Variety of Alcohols, Aldehydes, Aromatics, Esters, Ethers, Chlorocarbons, Fluorocarbons, Halocarbons, Hydrocarbons, Ketones, Acids.	Subsystems & Payloads	Continuous & Periodic
CO, CO_2, Hydrocarbons, Aromatics, Acid Gases, Oxides of N_2, SO_2, NH_3, Alcohols, Formaldehyde.	Emergencies - Spills, Equipment Failures, Fire	Short Term, High Rate

SPACE STATION CONTAMINANT SOURCES — WATER

Water Source	Quantity Per Person-Day (lb)	Suspended Solids (PPM)	Dissolved Solids Inorganics (PPM)	Dissolved Solids Organics (PPM)	Dissolved Solids Total (PPM)	Urea (PPM)	Micro-Organism
Fuel Cell	As required	0(a)	10 to 424	0(a)	10 to 424	0	No
Condensate		0(b)	12(b)	4(b)	16(b)	No	Yes(b)
without SDAS	7.15(e,f,g,h)	10 to 600(a)	20 to 350(a)	25 to 87(a)	45 to 450(a)	0 to 5(a)	Yes
with SDAS	14.15(d,e,f,g,h)						
Shower	5(f),8(g,h)	160(i) 650(j)	90(i) 270(j)	1,030(i) 800(j)	1,120(i) 1,070(j)	15(i) 260(j)	Yes Yes
Handwash	7(f),4(g,h)	110(i)	60(i)	1,020(i)	1,080(i)	10(i)	Yes
Laundry	27.5(f,g,h)	210(i)	180(i)	1,010(i)	1,190(i)	5(i)	Yes
Dish Wash		9,000(i)	580(i)	500(i)	1,080(i)	0	Yes
CO$_2$ Reduction Water	1.80					0	No
EVA Wastewater (lb/8 hr EVA)	9.68(f,g,h)	(Same as Condensate)					
Urine	3.31(f,g,h)	38,000	12,500(k)	29,200(k)	41,700(k)	16,300(k)	Yes
Urinal Flush	1.09(f,g,h)						
Fecal Water	Not identified						
Standard							
Wash Water Standard(l)					≤1.500	≤50	≤10
Potable Water Standard(l)					≤ 500		≤10
Potable Water Standard(m)					14	0	

(a) References noted in ( )

CONTAMINANT LOADING PROFILE (TYPICAL)



CONTAMINANT CONTROL — AIR

- CO_2 Removal
  - SDAS vs. EDC
  - EDC vs. LiOH
- H_2O Removal
  - Water Vapor Electrolysis
  - Condensing Heat Exchanger
  - Desiccant
- Trace Contaminant Control
  - Normal, Loading Removal
  - High Contaminant Loading Removal
- Microbial
  - Surface Wipe

REGENERATIVE CO_2 REMOVAL

COMPARISON ELECTROCHEMICAL VS STEAM DESORBED AMINE[a]

PRIOR COMPARISONS

Year	Organization	CO_2 Removal Subsystem Selected
1970	Ham. Std.	EDC equiv. wt. less than half IR-45 amine. Also cited amine problems: bed expansion/contraction, steam/CO_2 separation, steam generation, long term degradation.
1971	Rockwell	EDC selected over amines based on weight, power and heat rejection (⅓ other techniques) and ideally integrates with fuel cell and propulsion system.
1972	NASA JSC/ Ham. Std.	Selected EDC for SSP.
1973	McDonnel Douglas	EDC selected over amine based on lower weight, volume and power.
1976	NASA	Selected EDC for RLSE.
1979	NASA JSC	Selected EDC for Space Operations Center.

ASSUMPTIONS

1. 4-Person Subsystem
2. 2.2 lb CO_2/Person Day
3. Inlet pCO_2 = 3.0 mm Hg
4. Flight Prototype Level
5. Spares Not Included
6. Penalties, lb/W

Power:	0.71 (AC) 0.59 (DC)
Heat Rej:	0.18 (Liq.) 0.44 (Air)

COMPARISON RESULTS

Category	EDC	SDAS	Comments
Fixed Hardware Wt., lb	92	139	All components incld. in both
Power Wt. Penalty, lb	49	577	461 of 577 for steam gen. & heat loss
Heat Rej. Wt. Penalty, lb	145	394	EDC rejects heat to liquid, amine to air
Subtotal	286	1,110	Amine 3.6 times greater than EDC
O_2 Generation Penalty, lb	309	0	EDC integrates with H_2, O_2 & H_2O utilities
Humidity Control Penalty, lb	102	770	Amine dumps 8 x H_2O vapor into cabin
Water Processing Penalty, lb	27	206	Cabin condensate processing penalty
Total Eg. Wt., lb	724	2,086	Difference even greater as pCO_2 spec-dec.
Operation Cont. or Cyclic	Either	Cyclic	Amine continuously cycles cabin RH, T
Vary CO_2 Removal Rate	Yes	No	EDC tolerates crew changes
Maintainability	Cell	Canister	EDC maintainable at lower level
Humidifier Load, lb H_2O/day	4	32	Increases redundant dehumidifiers
Water Recov. Sys. Load, H_2O/day	4	32	Amine 8 times EDC
Noise	Negl.	Large	On/off amine compressor noisy

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a. Details found in Life Systems' TR-604, 7/11/83, and SAE Paper No. 831120.

REGENERATIVE vs. NON REGENERATIVE CO_2 REMOVAL COMPARISON OF ELECTROCHEMICAL vs. LITHIUM HYDROXIDE

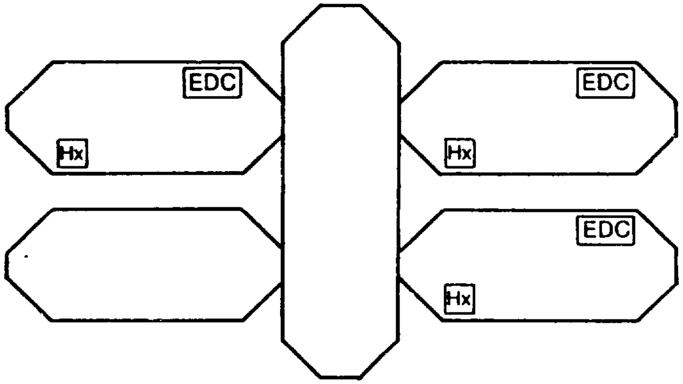
	EDC	LiOH
Weight	724 lbs(1)	3600 lbs(2)
Volume	2.4 ft^3	100 ft^3
Power	0.14 kW	0.03 kW
Crew Time	0	105 hrs.(3)
Resupply Weight	0	1523 lbs
Resupply Volume	0	51.3 ft^3

(1) Weight includes penalty for power, heat rejection, O_2 generation, humidity control, and water processing.

(2) Weight includes penalty for power.

(3) Crew time was calculated assuming changing seven canisters per day requiring ten minutes to locate canister, log out, remove exhausted canister, install new canister and stow old canister.

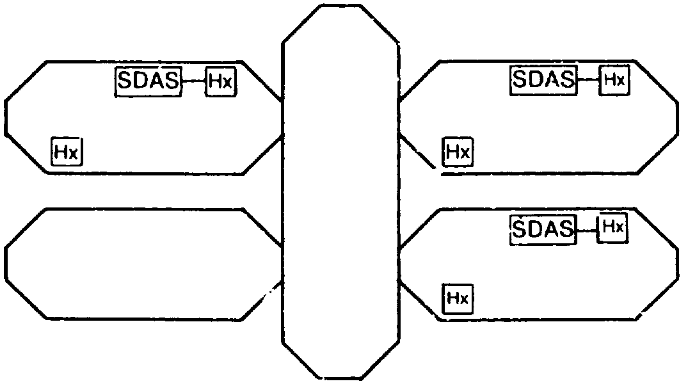
WATER VAPOR REMOVAL — SYSTEMS CONSIDERATION



Water Vapor Loading

	lb/man-day
Metabolic	4.02
Hygiene	0.94
Food Preparation	0.06
Experiments	1.00
Laundry	0.13
Sub-Total	6.15
EDC	1.00
Total	7.15

Heat Exchangers Required 1 per Module



Water Vapor Loading

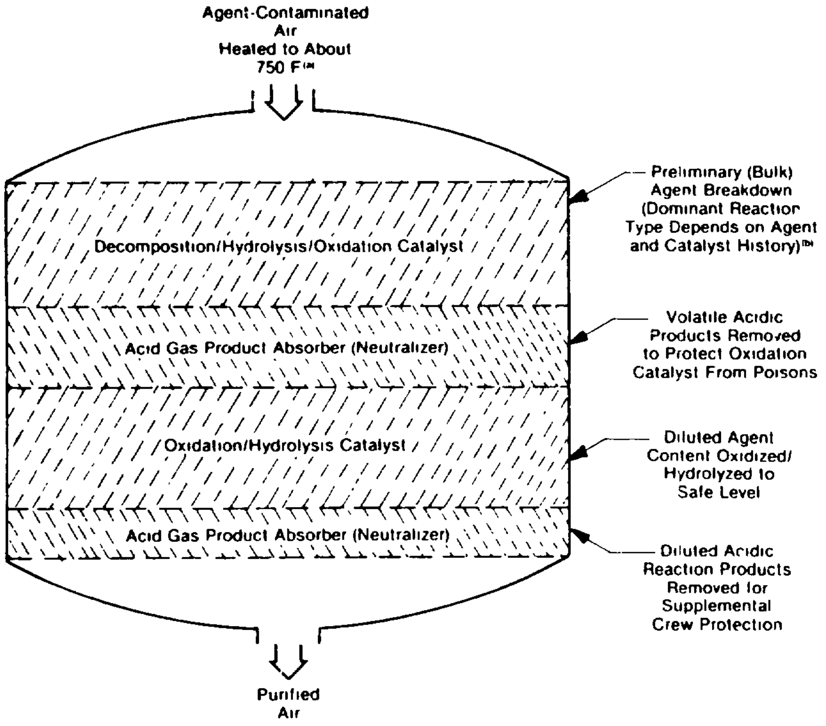
	lb/man-day
Metabolic	4.02
Hygiene	0.94
Food Preparation	0.06
Experiments	1.00
Laundry	0.13
Sub-Total	6.15
SDAS	8.00
Total	14.15

Heat Exchangers Required 1 per Module plus
1 per SDAS

CONTAMINANT CONTROL TECHNIQUES EVALUATED BY LIFE SYSTEMS

- Catalytic Oxidation
- Corona Discharge
- Regenerative Adsorption
- Thermal Decomposition
- Laser Decomposition
- Combustion
- Chemical Decomposition
- Microwave/Plasma Decomposition
- Membranes

BASELINE SEQUENTIAL CATALYTIC OXIDATION CONCEPT



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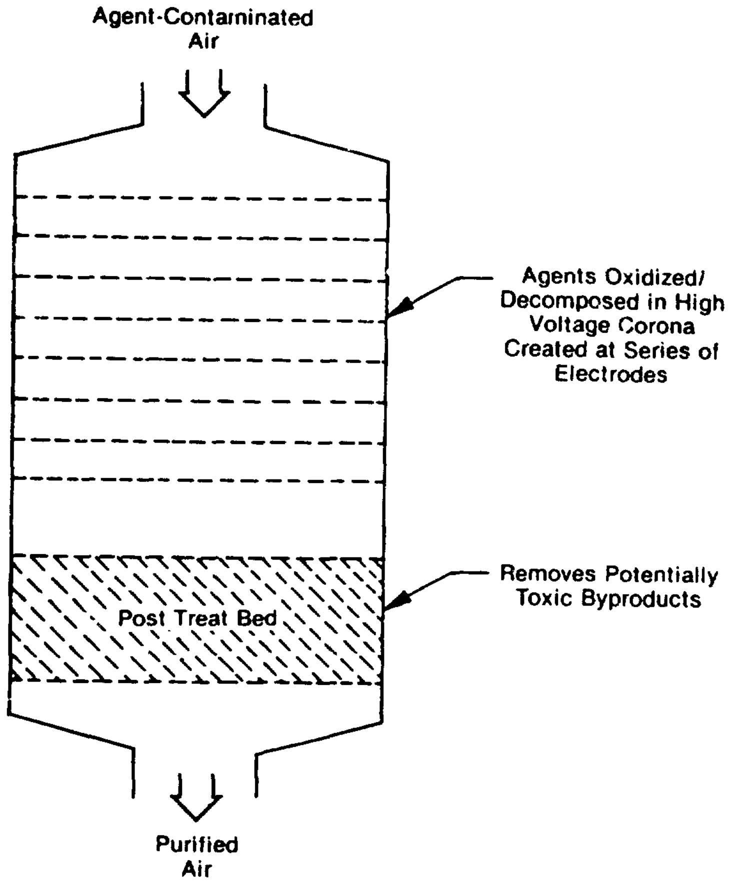
(a) Some agent breakdown will occur during heatup. Potentially installing a portion of the absorber material upstream of the first bed will further improve longevity.

(b) First catalyst bed expected to provide alternate decomposition modes even after primary mode (oxidation) is destroyed.

CORONA DISCHARGE REACTOR/ POST-TREAT CONCEPT

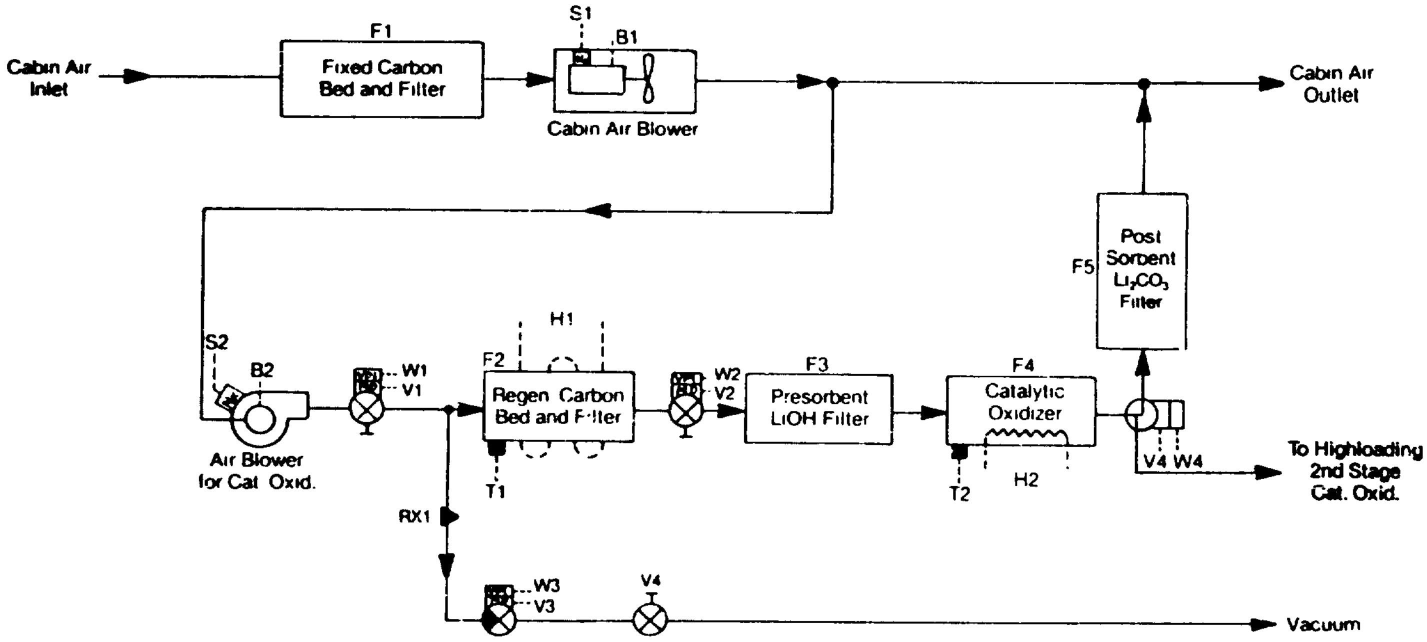


FOCUS OF CORONA DISCHARGE INVESTIGATIONS

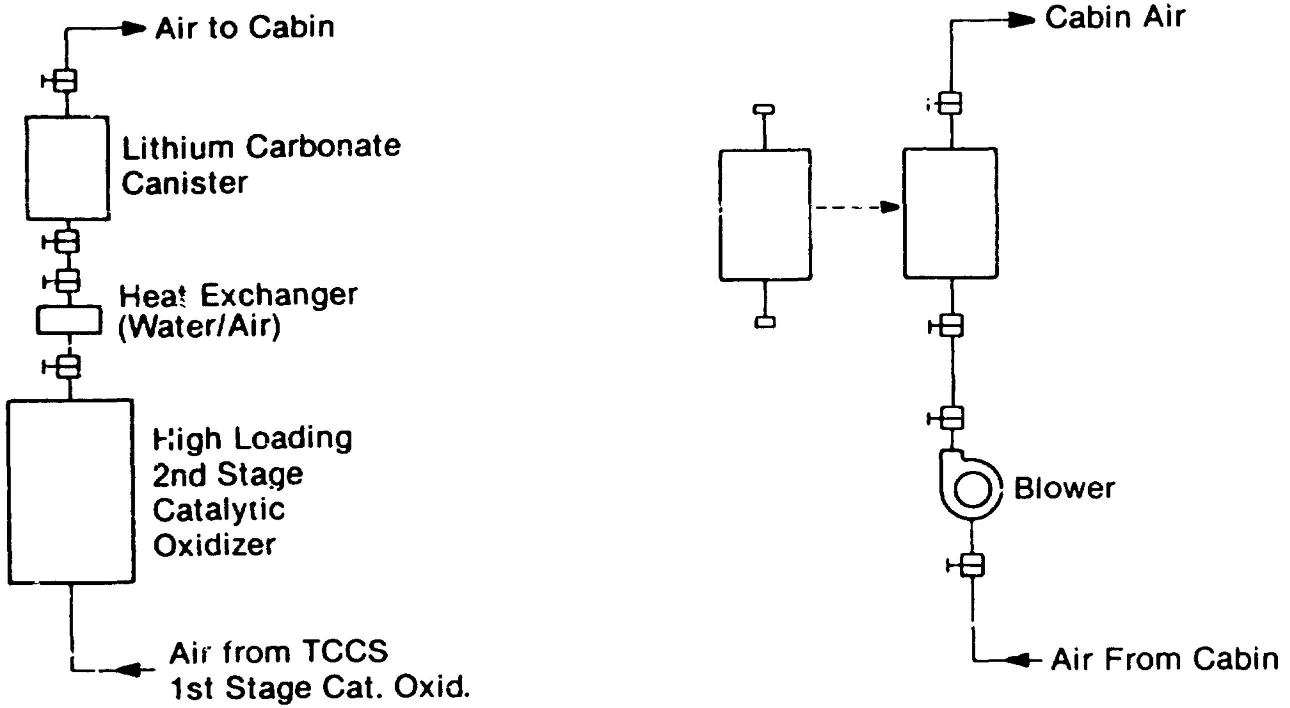
- Available Data
    - Very Little Data Available
    - Currently Existing Laboratory Reactors Not Amenable to Scaleup
    - Post-Treat Concept Not Explored to Date

- Focus of Present Work
    - Design Lab Scale Breadboard Reactor Compatible With Scaleup
    - Expand Data Base Considerably
    - Improve Process Performance
    - Investigate Post-Treat Concept(s)

TRACE CONTAMINANT CONTROL SUBSYSTEM
FOR NORMAL LOADING REMOVAL



TRACE CONTAMINANT CONTROL FOR HIGH LOADING REMOVAL



TCCS SIZING FOR SPACE STATION

Subsystem	Normal	High Loading Canister	High Loading Catalytic Oxidation
Weight, lb	105	TBD	26
Power, W (continuous)	165	100	140
Volume, ft^3	8.3	TBD	0.8
Resupply (90 days)			
Weight, lb	250	TBD	TBD
Volume, ft^3	9.8	TBD	TBD

CONTAMINANT CONTROL — WATER

- Biocide Addition
- Microbial Checkvalve
- UV/Ozonation
- Phase Change Water Recovery
- Filtration Water Recovery
- Open Loop Regenerative Fuel Cell

WATER CONTAMINANT CONTROL OPTIONS

Sources	Treatment	Quality
Fuel Cell	Biocide Addition	Potable
Condensate CO_2 Reduction EVA CO_2 Reduction	Multifiltration, Biocide Addition	Potable
Shower Handwash	Filtration Water Recovery, Microbial Check Valve, Biocide Addition	Reuse
Laundry Dishwash Urine Urinal Flush	Phase Change Water Recovery, Multifiltration, Biocide Addition	Reuse
Reuse	UV/Ozonation, Biocide Addition	Potable
Reuse	Open Loop Regenerative Fuel Cell, Biocide Addition	Potable

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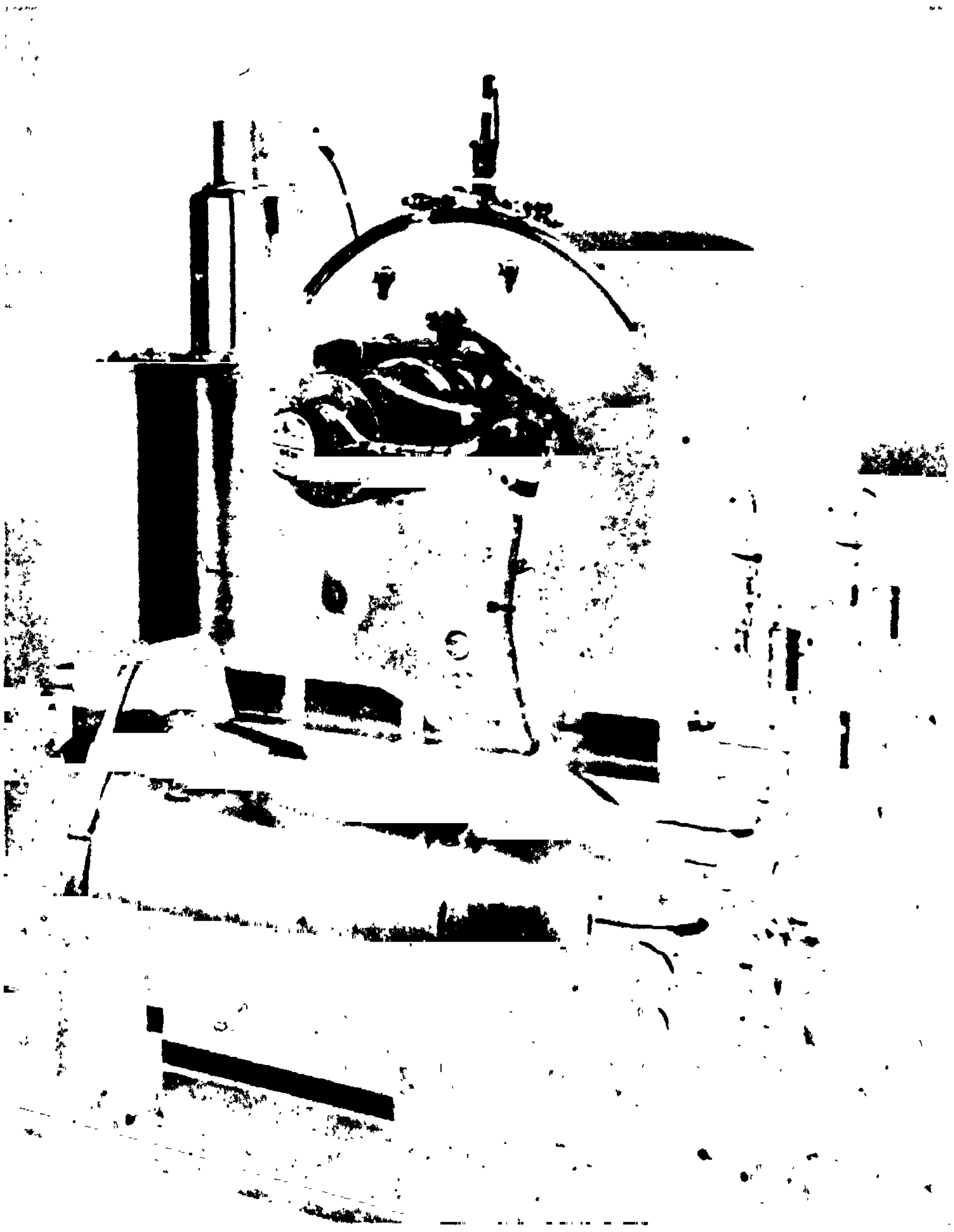
PHASE CHANGE WATER RECOVERY — VAPOR COMPRESSION DISTILLATION SUBSYSTEM



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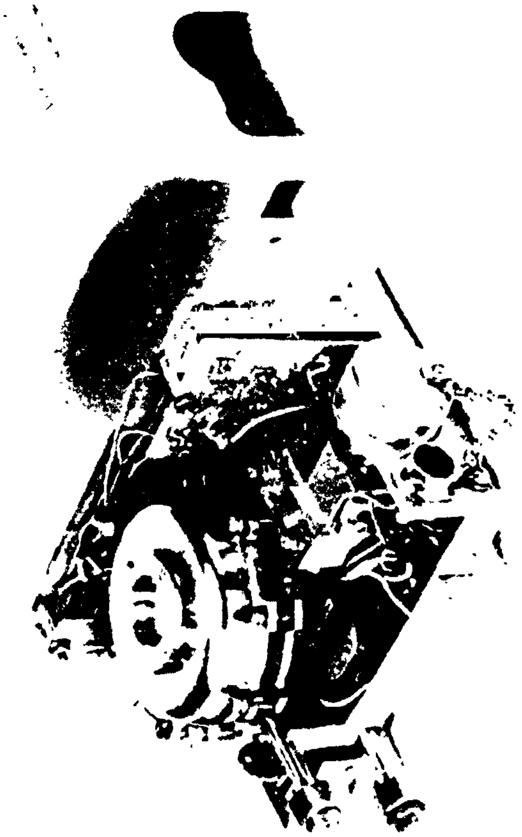
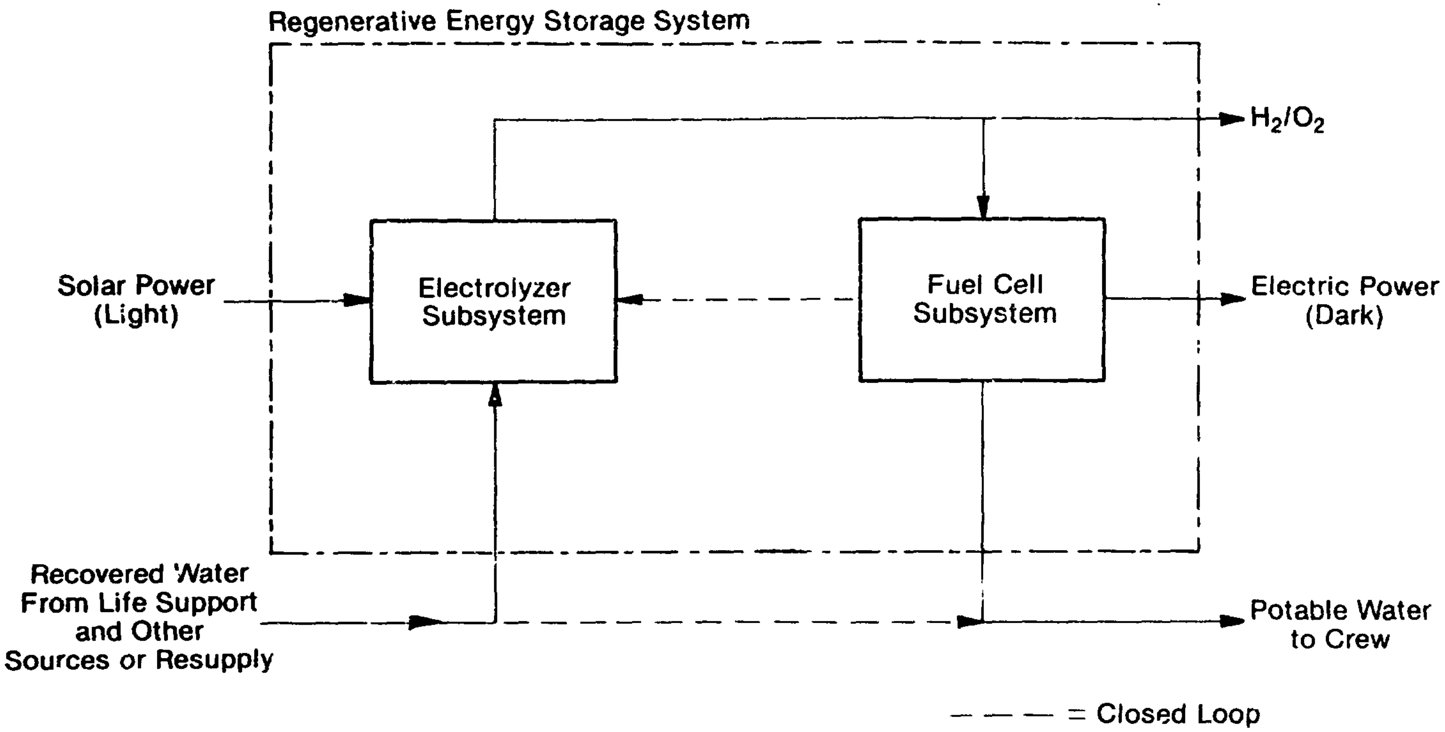
BIOCIDE ADDITION AND MONITORING UNIT



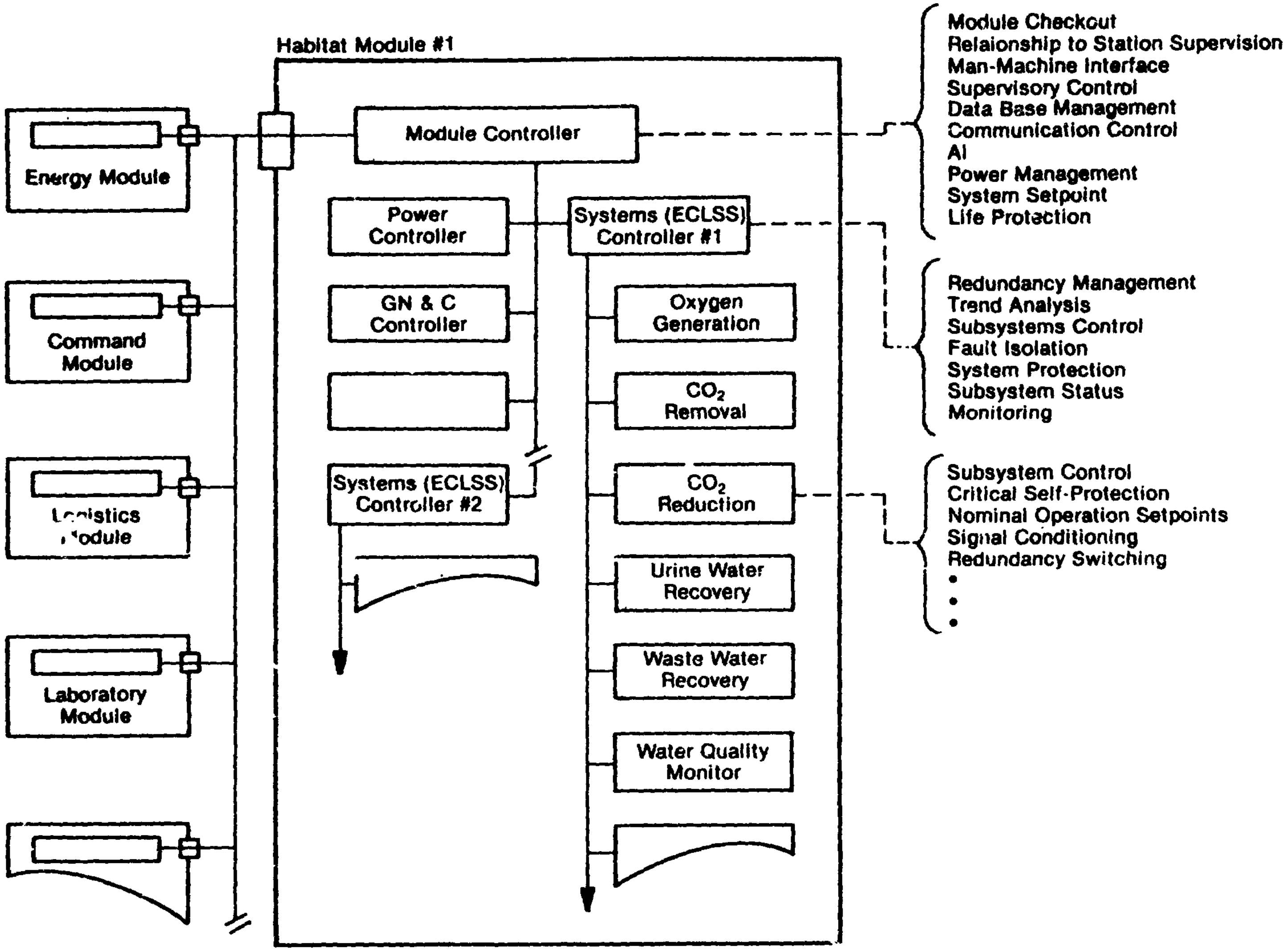
OPEN LOOP REGENERATIVE FUEL CELL — FOR SECONDARY WATER TREATMENT



OTHER FACTORS AFFECTING PRODUCTIVITY

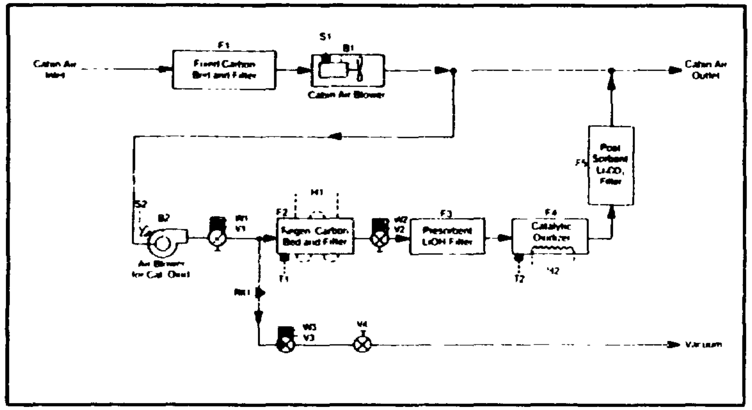
- Automation
  - Subsystem Interaction
  - Man in Loop
- Mechanical Integration
  - Subsystem
  - System
- Crew Time
  - LiOH
  - TCCS Cannister Design

SPACE STATION AUTOMATION CONCEPT



SUBSYSTEM INTEGRATION

Trace Contaminant Control Subsystem



Sensors

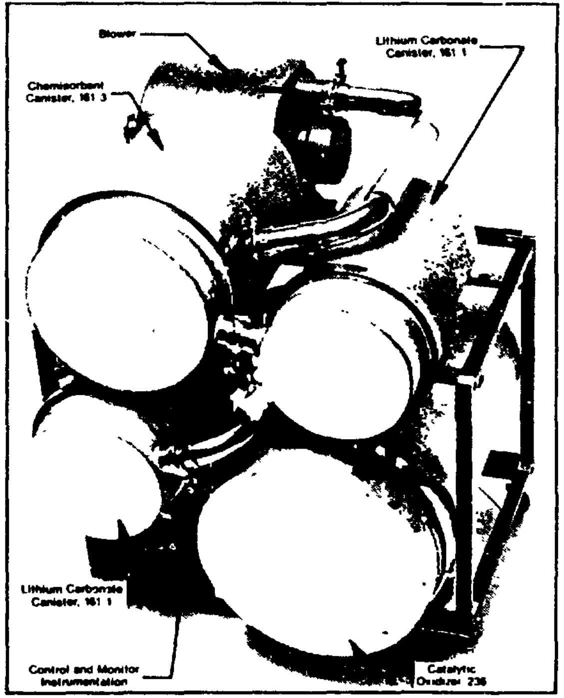
Description	Qty	Subsystem Symbol
Speed Sensor for Fixed Carbon Blower	1	S1
Speed Sensor for Regen. Carbon Blower	1	S2
Regen. Carbon Bed Temperature	2	T1
Catalytic Oxidizer Temperature	2	T2
Total	6	

Actuators

Description	Qty	Symbol
Blower, Cabin Air	1	B1
Blower, Cat. Oxid	1	32
Heater, Regen. Carbon	1	H1
Heater, Cat. Oxid.	1	H2
Valves, Carbon Bed Isolation	2	V1,V2
Valve, Vacuum	1	V3
Total	7	

MECHANICAL ENGINEERING INTEGRATION

Packaging



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MECHANICAL COMPONENTS INTEGRATION PROGRAM

Sponsored By:
Ames, Lewis,
JSC: Crow & Power,
Life Systems

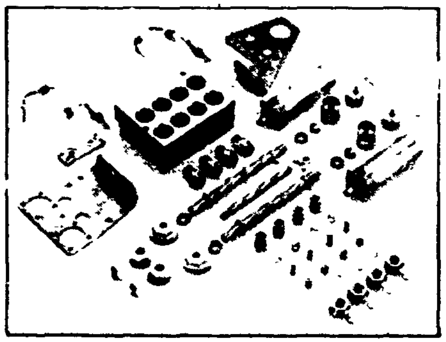
PURPOSE: Save Money By
1. Decreasing Subsystem Complexity
2. Decreasing Wt, Vol., Power,...
3. Increasinng Reliability

STATUS:
- 5 - Completed
- 1 - In Development
- 3 - Planned

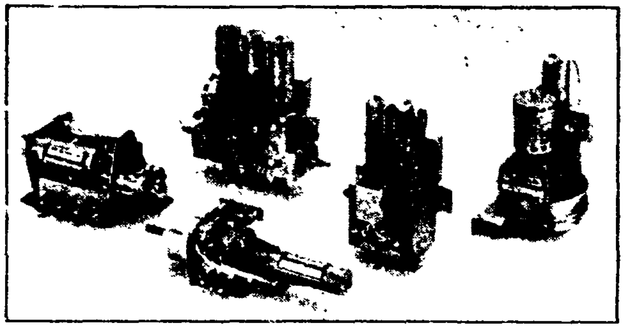
Avg. Results	% Red:
No. Components	83
Power	68
Weight	83
Volume	83
No. Connections	64

No.	Mechanical Integration	Units Produced	Testing Hours	Testing Cycles
1	3-Fluids Pressure Controller	7	15,000	11,800
2	Coolant Control Assembly	7	11,500	8,600
3	Fluids Control Assembly (EDC)	3	20,000	14,000
4	Fluids Control Assembly (SFE)	8	2,400	1,000
5	2-Fluids Pressure Controller	1	0	0

- 18 Components → 1
  - 7 - Two-way Valves
  - 2 - Check Valves
  - 4 - Filters
  - 3 - Orifices
  - 2 - Press. Trans.
- 24 W → 2
- 11.4 lb → 4
- 400 in³ → 200



Assembled: 4.8 x 3.0 x 3.5 In



Next Steps:
1. Applicability of Super Plastics
   - Injection Molding To Save $
   - Considerably Lighter Weight
2. Increase Maintainability
   - Onboard Replacement Unit

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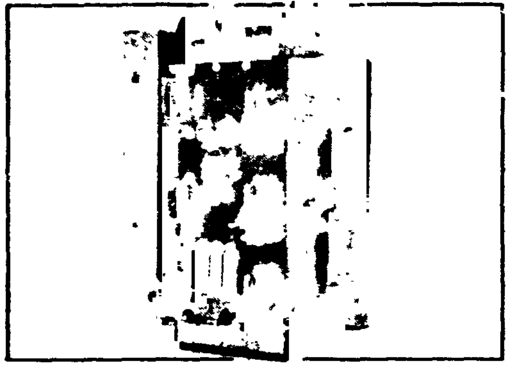
12 YEARS OF CONTINUOUS INTEGRATED ARS EXPERIENCE

Air Revitalization System Development	Timeframe 73	74	75	76	77	78	79	80	81	82	83	84	85	86	CO_2 Rem.	CO_2 Red.	O_2 Gen.	Dehumidification	N_2 Gen.	Capacity
Lab. Breadboard	—	—													EDC	Sab.	SFE	-	-	1
Lab. Breadboard		—	—												EDC	Bos.	-	-	-	4
Flight Breadboard (EARS)			—	—											EDC	-	WVE	WVE	-	1
Lab. Breadboard			—	—	—										EDC	Bos.	SFE	-	-	4
Lab. Breadboard					—	—									EDC	Sab.	SFE	-	-	1
✓ Flight Breadboard (ARX-1)						—	—	—	—	—	—				EDC	Sab.	SFE	Slupper	N_2H_4	1
✓ RLSE Preprototype (IARS)						—	—	—	—	—					EDC	-	WVE	WVE	-	3
✓ Flight Experiment Mockup								—	—						EDC	Sab.	SFE	Slupper	-	1
✓ Engineering Model										—	—	—	—		EDC	Sab.	SFE	Slupper	-	1
✓ Flight Demonstration												- -	- -	- -	EDC	Sab.	SFE	-	-	1

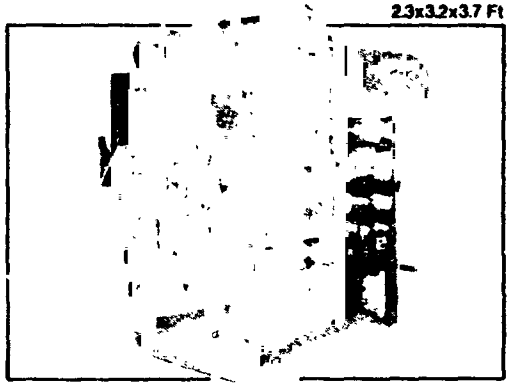
✓ = Subsystems no longer retained as separate entities.

1.5x2.8x1.5 Ft



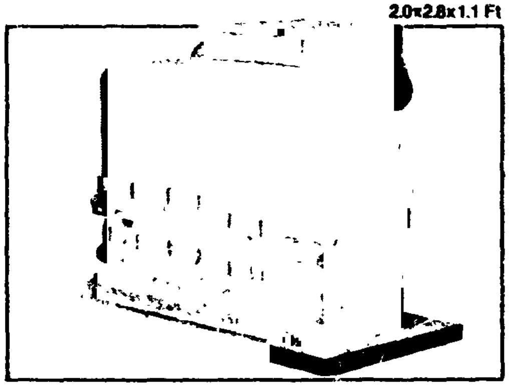
- CO_2 Removal
- O_2 Generation
- Dehumidification

2.3x3.2x3.7 Ft



- CO_2 Removal
- O_2 Generation
- Dehumidification
- CO_2 Reduction
- N_2 Generation

2.0x2.8x1.1 Ft

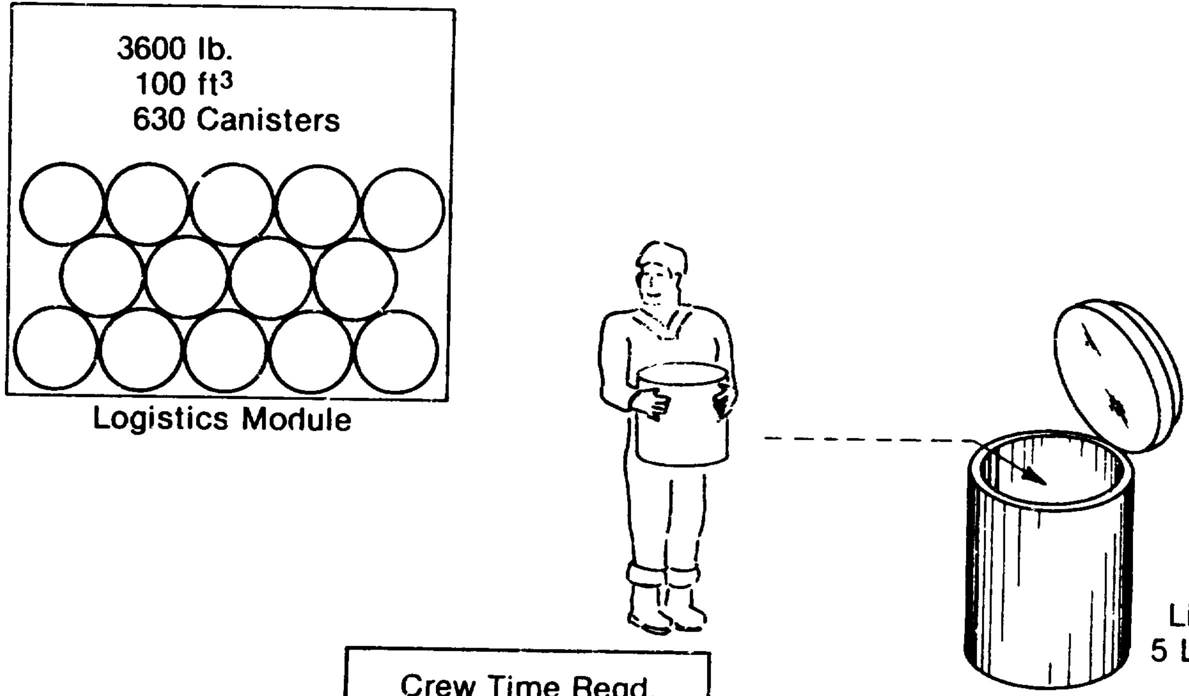


- CO_2 Removal
- O_2 Generation
- Dehumidification
- CO_2 Reduction

Result: Life Systems Has Indepth Knowledge Of:
- ARS Functional & Component Performances
- Process Dymanics
- Water Handling: Feed & Condensate
- Interactions Between Controllers
- Importance of Simplifying
- Software Requirement & Development Times

ALSO: WE ARE INTEGRATING THE SFE AND SHUTTLE ORBITER FUEL CELL INTO RFCS BREADBOARD

CONTAMINANT CONTROL TECHNIQUE AFFECTS CREW PRODUCTIVITY



LiOH Canister
Storage (90 Days)

3600 lb.
100 ft^3
630 Canisters

Logistics Module

LiOH Use
5 Locations

Crew Time Reqd.
10 min/Canister 7 Canister/Day 105 hr/90 Days

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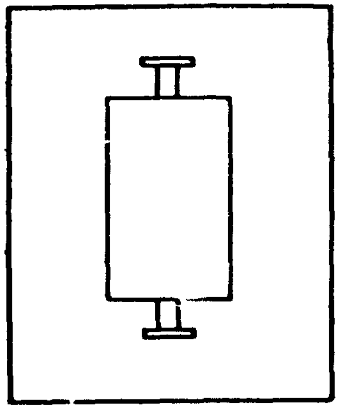
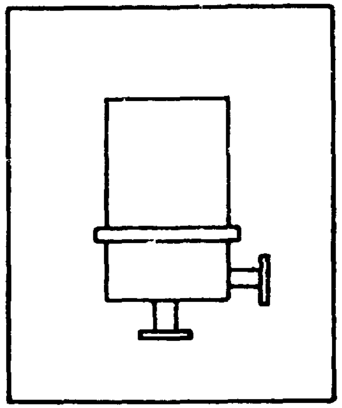
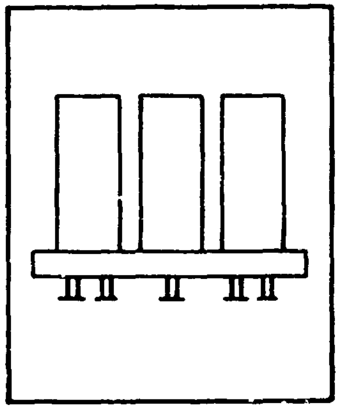
CANISTER OPTIONS VS. CREW TIME



Canister With
2 Clamps



Canister With
1 Clamp



Multiple Canisters
With Common
Manifold

ISSUES REGARDING CONTAMINATION CONTROL

Sources	—	Space Station Design and Selection of Materials and Subsystems
Loading	—	Multiple Capacity Equipment for Normal and High Loading
Control Techniques	—	Additional Studies, Evaluation and Testing
Productivity Factors	—	Automation, Mechanical Integration, Crew Time