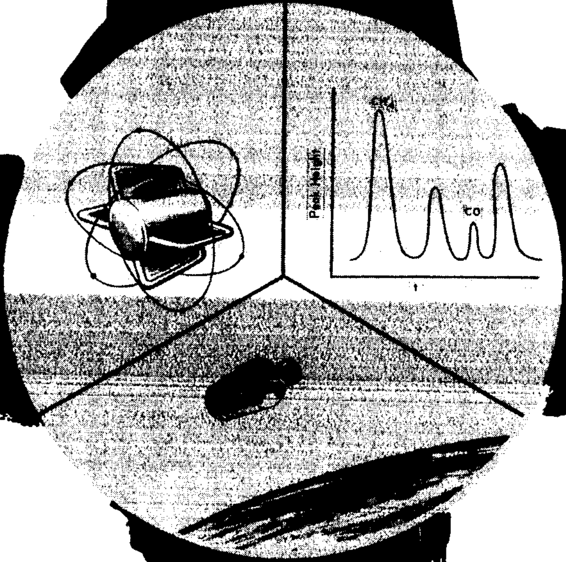
NASA CR-66497

STUDY AND PRELIMINARY DESIGN OF AN ISOTOPE-HEATED CATALYTIC OXIDIZER SYSTEM (U)

ADDENDUM I



PREPARED UNDER CONTRACT NAS 1-6256
by BIOTECHNOLOGY
Lockheed Missiles & Space Company
Sunnyvale, California

GPO PRICE $ ____

CFSTI PRICE(S) $ ____

Hard copy (HC) 3.00

Microfiche (MF) .65

ff 653 July 65

N68-11871 (ACCESSION NUMBER)

(THRU)

57 (PAGES)

1 (CODE)

CR-66497 (NASA CR OR TMX OR AD NUMBER)

05 (CATEGORY)

FF No. 602(C)

[redacted]

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
LANGLEY RESEARCH CENTER, LANGLEY STATION ● HAMPTON, VIRGINIA

ERRATA

For the lenses of the eye, the relative biological effectiveness (or quality factor) for neutrons is twice that for other body organs. Applying this factor, IHCOS contributes less than 5 percent of the total mission allowable continuous eye dose. The total allowable dose rates, based on the current LMSC recommended values for a 180-day continuous exposure are 43 mrem/hr for the lens of the eye, and 139 mrem/hr for skin.

In considering possible maintenance requirements for IHCOS, the recommended maximum acute dosage may become the dominant criterion. An exposure period of 5 days at the surface of IHCOS would result in less than 10 percent of the recommended maximum acute hands-and-feet dose, or less than 25 percent of the maximum acute eye dose.

The closest possible approach to the radioisotope heat source is at the wall of the heat source capsule, and this point can only be reached by disassembling IHCOS. At this location, an exposure time of 50 hours would result in less than 100 percent of the total acute dose to the hands and feet; while an exposure time of 10 hours to the eyes would result in less than 100 percent of the total acute eye dose.

Based on the foregoing data, the radiation field from the unshielded IHCOS constitutes only a minimal perturbation in the operational radiation safety situation. If maintenance operations are approached with the knowledge that the heat source is radioactive, there should be no significant effect on the crew accumulated radiation dose status.

The actual curve for dose level as a function of distance from the unit is classifed. If there is a requirement for this information, refer to NAS CR-66347.

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Prepared Under Contract No. NAS 1-6256
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Biotechnology Organization
Lockheed Missiles & Space Company
Sunnyvale, California

Richard A. Lamparter

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Langley Research Center
Langley Station
Hampton, Virginia

LOCKHEED MISSILES & SPACE COMPANY

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STUDY AND PRELIMINARY DESIGN OF AN ISOTOPE-HEATED CATALYTIC OXIDIZER SYSTEM

ADDENDUM I

By Richard A. Lamparter
Biotechnology
Lockheed Missiles & Space Company

SUMMARY

A study was performed to develop data on an isotope-heated catalytic oxidizer system (IHCOS) including pre and postsorbent beds for 3, 6 and 9-man crew sizes. This work has been used to support a NASA-MSC contract for a Basic Subsystem Module (BSM) Study. The basis for the work was furnished by a NASA-LRC/Lockheed study on the Preliminary Design of a 9-man Isotope-Heated Catalytic Oxidizer System (NASA CR-66346).

The basic study assumed the inlet gas stream to be free of compounds which might poison the catalyst. In an initial task for the BSM Study, the contaminant load was evaluated to define potential catalyst poisons and compounds which might yield toxic products of combustion and sorbents were evaluated which might be used to remove these compounds. Activated charcoal and lithium hydroxide were found to comprise the optimum presorbent bed and lithium hydroxide, the optimum postsorbent bed.

The catalytic oxidizer designed in the previous work was scaled to provide designs for 3- and 6-man units. Results showed little weight and volume savings for the smaller crew sizes due to the geometry requirements of the isotope reentry aids.

The BSM Study considered the use of isotope and electric heat sources for life support systems. Evaluation of the isotope-heated design shows that its configuration is near optimum for an electrically heated version with the exception of the provisions made for intact reentry.

The 9-man pre and postsorbent bed and catalytic oxidizer designs were combined into an integrated system, and potential installations in the BSM life support system investigated. The favored installation for the system is downstream of the main activated charcoal bed in the BSM life support system, primarily to utilize this charcoal as a pre-sorber. The passive nature of the oxidizer requires nothing in the way of active controls. Basic readout information to monitor system operation consists of system temperatures and flow rate.

A reliability assessment showed that the basic goal of 0.99965 could be met with careful design and no spares. The higher goal of 0.9999 could be approached only by sparing the lithium hydroxide pre and postsorbent units. System maintenance requirements were evaluated and procedures defined. The high temperature of the unit and radiation hazard renders maintenance undesireable except in the event of an emergency.

The original development plan for the 9-man oxidizer system with pre and postsorbent beds was modified to include a final phase of flight qualification.

INTRODUCTION

Lockheed Missiles & Space Company (LMSC) has been involved in the development of an isotope heated catalytic oxidizer system (IHCOS) under contract (NAS 1-6256) to the NASA-Langley Research Center. During this program an IHCOS design was developed for a 9-man vehicle. This effort, described in NASA CR-66346 and CR-66347, included a study of all critical aspects of an isotope fuel element with selection of a preferred isotope, catalyst screening tests with selection of a preferred catalyst, and a 180-day test of this catalyst under expected operating conditions to determine if performance degradation occurs. Additional tasks included design of the isotope heating element and an analysis and optimization to determine the system configuration having the minimum weight penalty. The final 9-man IHCOS design was documented with layout drawings. A development plan was also prepared describing the steps leading to flight qualifiable hardware.

Subsequent to the completion of the design of the 9-man IHCOS, documented in NASA CR-66346 and CR-66347, the NASA-Langley Research Center directed LMSC to initiate work to include 3 and 6-man versions of IHCOS and to accomplish the preliminary design of pre and postsorbent canisters for the 3, 6 and 9-man catalytic oxidizers. The results of this effort are reported herein and include the following tasks.

- o Define the contaminant load for the 3 and 6-man catalytic oxidizer and for the pre and postsorbent beds.
- o Develop the design of the 3 and 6-man catalytic oxidizers.
- o Perform a preliminary design of pre and postsorbent beds for the 3, 6 and 9-man systems.
- o Prepare installation drawings and define requirements for expendables and controls and displays.
- o Perform a reliability analysis to establish the required spares.
- o Prepare a development plan to carry the development of an isotope heated catalytic oxidizer system through flight qualification.

The work performed under this design study has shown that use of an isotope heat source in lieu of electrical power can reduce the total equivalent weight of a catalytic oxidizer system considerably. However, the design developed in this study is compatible with resistive heating, and would represent a reasonably efficient design for an electrically heated unit. Provisions have been made in the design to incorporate a resistively heated simulated isotope for evaluation purposes.

CONTAMINANT LOAD DEFINITION

The contaminant types and production rates for the IHCOS design study are based on data obtained from recent manned space flights, ground test data, and space station studies. The allowable concentration data are based on values established by toxicologists working in the field of spaceflight toxicology. These concentrations are considered to be appropriate for continuous exposure up to 180 days. The contaminant load data is presented in Appendix A. The appendix includes (1) the contaminants considered to be appropriate for the mission selected for the IHCOS study; (2) the biological, nonbiological, and total contaminant production rates; (3) the allowable contaminant concentrations; (4) the data source on both production rate and allowable concentration; (5) whether or not the contaminant is primarily removed by oxidation; and (6) the catalytic oxidizer flow rate required for removal of the contaminant.

Selected Contaminants

A study was made to establish what contaminants might be expected to exist in the model spacecraft selected for the IHCOS Program. The contaminants selected are presented in Appendix A, and were obtained from the following sources: (1) outgassing products from materials testing of space cabin qualified materials as measured by Lockheed Missiles & Space Company (ref. 1), North American Aviation (ref. 2), and Minneapolis Honeywell (ref. 3); (2) contaminants detected in Mercury and Gemini (through GT7) charcoal beds (ref. 4); (3) contaminants detected in the AF Biosatellite 30-day test (ref. 5); (4) contaminants reported by Toliver and Morris in the manned 30-day test at the AF Aerospace Medical Research Laboratory (ref. 6); (5) contaminants detected in a 27-day manned test at the AF School of Aerospace Medicine (ref. 7); (6) contaminants detected during Apollo breadboard testing (ref. 8); and, (7) candidates likely to result from experiments onboard space stations such as MORL and AES (ref. 9).

Contaminant Production Rates

The major source of quantitative information on nonbiological (equipment and materials) contaminant production rates was the contaminant identification program conducted by NAA for the Apollo Program. In this effort, the outgassing rate of materials within the Apollo was determined experimentally and indicated that the total quantity of contaminants produced by equipment in Apollo is 2.5 grams/day. This work was accomplished by placing spacecraft materials in a 5 psia oxygen environment for 14 days. The material was kept at its expected operating temperature for the entire period. At the end of the 14 days, the atmosphere within the closed test chamber was analyzed to determine the type and quantity of contaminants evolved. This data was then used, based upon the total quantity of the material tested within the spacecraft, to estimate contaminant production rates. At the present time, approximately 25% of the materials within the Apollo spacecraft have been tested. The 2.5 gram/day estimate is four times the production rate determined for 25% of the materials in the Apollo CM.

As a preliminary design estimate it can be assumed that the mass of internal materials and equipment within a spacecraft is proportional to the total gross weight of the spacecraft. Based on this assumption, an estimate of the equipment contaminant production for the model spacecraft can be made by multiplying the 2.5 grams/day by the ratio of the model spacecraft weight to the Apollo Command Module weight. A space station placed in a 300 mile orbit by a Saturn C5 booster is expected to weigh approximately 220,000 pounds. Since the Apollo Command Module weighs 11,000 pounds, the model spacecraft would be 20 times the weight of an Apollo Command Module. Based on this ratio, a total equipment contaminant production rate of 50 grams per day is estimated for the model spacecraft.

To determine the individual equipment contaminant production rates, the contaminant distribution (i.e., percentage of total) from the NAA Program was utilized with the exception that no primary contaminant was considered to be produced at a rate less than 5 percent of the total and no secondary contaminant was considered to be produced at a rate less than 0.5 percent of the total. Primary contaminants are those where a known large source exists or where the contaminant has been identified in several systems. The remaining contaminants are defined as secondary contaminants.

The majority of production rates for contaminants indicated as metabolic products were based on reported quantitative production rates for humans. Where no quantitative data was available, a minimum removal capability of 0.25 grams/day was assumed.

Allowable Concentration

Contaminant allowable concentration estimates are needed to establish the required performance characteristics of IHCOS. The footnotes listed at the end of Appendix A indicate the basis of estimation for each contaminant. In some instances these are based on gross approximations. The major data sources for allowable concentrations, listed in the order of preference are:

(1) Submarine Habitability Handbook Values. - These concentrations for 90-day exposure in a normal atmosphere are based on long-term exposure studies of animals at 760 mmHg pressure and are believed to be the most applicable data

available as a basis for conversion to extended space station atmosphere purity specifications.

(2) 1965 Threshold Limit Values (TLV) of the American Conference of Governmental Industrial Hygienists. - These values "represent concentrations under which it is believed that nearly all workers may be repeatedly exposed, day after day, without adverse effect," on the basis of an 8-hour work-day for five working days per week. For application to space station atmosphere purity specification, LMSC recommends 0.1 of the TLV as the maximum allowable space cabin atmosphere contaminant concentration (Space - MAC). This reduction is an attempt to account for the added stresses of continuous exposure and other factors, such as zero or low-g, unusual atmosphere, radiation, and mixtures of contaminants that would be encountered onboard a spacecraft. The numerical value of 0.1 is somewhat arbitrary. Others have proposed values from 0.3 to 0.02 for individual contaminants. The average ratio of the submarine limits to the TLVs is about 0.06.

(3) Analogy to Chemical Compounds with Established TLV. - Utilizing homolog analogies, which are valid for chemical reaction studies, is probably a valid approximation method. It has been used where necessary.

(4) Vapor Pressure Limitation. - For substances for which no industrial TLV has been determined, or no other toxicological data exists, it seems desirable to set a limit on the vapor pressure of the compound. For this work, a low vapor pressure of 0.02 Torr was used. This arbitrary limit was used in NAS 9-3415 (ref. 10).

The estimates presented in Appendix A for maximum allowable concentrations have been reviewed by Lockheed Missiles & Space Company toxicologists and are considered appropriate for the design of a trace contaminant removal system for the selected mission.

Contaminants to be Removed by Oxidation

In determining the contaminants to be removed by oxidation, consideration was given to the following factors:

- Ease of oxidation
- Sorbents required for control of potential catalyst poisons or contaminants whose oxidation produces noxious or toxic products.
- Removal of contaminants by other components of the life support systems.

Since the catalytic oxidizer will be operating at a temperature high enough to oxidize methane, it is estimated that it will oxidize all of the remaining contaminants listed in Appendix A. However, many of the contaminants listed will be removed by other processes existing within the life support system, such as water condensation, within the humidity control system, sorption in the CO_2 removal system, vehicle leakage, or by the presorbent provided to remove those contaminants that produce undesirable products or poison the catalyst.

Thus the process used in establishing the contaminants to be removed by oxidation was as follows: The contaminant removal capability of the other life support systems was estimated to determine what contaminants they would control. This removal capability was then compared with the total load indicated in Appendix A, to determine what fraction of the total load can be handled by removal systems other than oxidation. The contaminants not controlled to suitable levels by these methods were then considered to be removed by oxidation.

Catalytic Oxidizer Flow

The IHCOS flow rate required for removal of the contaminants indicated to be removed by oxidation is presented in Appendix A. This flow rate estimate was based on an IHCOS removal efficiency per pass of 80 percent for all contaminants considered except methane.

$$\text{Removal Efficiency (\%)} = \frac{\text{Inlet Concentration-Outlet Concentration}}{\text{Inlet Concentration}} \times 100$$

The 80 percent removal efficiency is based on oxidation efficiency tests performed at LMSC with multiple contaminants (ref. 11). The maximum required IHCOS flow rate, from Appendix A is 3 CFM for a 9-man unit. The removal efficiency required for methane is 30 percent. The flow rate estimates include the effect of the 2.9 pounds per day of vehicle leakage.

CATALYTIC OXIDIZER

Two versions of the IHCOS (conventional insulation and vacuum insulation) have been examined for the 3, 6 and 9-man vehicle configurations. This was done for a dry feed gas stream with a dew point below -40°F, which might occur at the outlet of a Molecular Sieve unit for carbon dioxide removal, and a wet gas feed stream such as cabin air with typical dew points of about 55°F. The following section describes the major design features of each of the insulation concepts and the effect of the feed stream moisture content.

Conventional Insulation Design

The conventionally insulated version of the IHCOS is shown in fig. 1. The overall package dimensions including the weight for 3, 6 and 9-man units are shown in Table 1. The units consist of an outer shield, molded insulation, and an inner body. The inner body is made up of a regenerative heat exchanger, catalyst canister, and radioisotope heat source.

The regenerative heat exchanger is a 5-pass cross-counter flow, stainless steel plate fin heat exchanger. The cold end is bolted to one end of the cylindrical aluminum shield. The hot end of the heat exchanger terminates in a machined flange that mates with the catalyst canister. The gas ports are sealed with Parker metallic face seals.

The catalyst canister is a cylindrical unit that contains the .5% palladium catalyst and the radioisotope heat source. This unit is furnace-brazed and entirely constructed of nickel. The radioisotope is mounted in the center of the catalyst canister where it is supported by posts projecting from either end of the isotope source. One post is tapered and held in place, in a tapered socket, with a pin to prevent rotational movement of the isotope heat source. The other post is cylindrical, and fits into a socket located on the end of the catalyst canister away from the heat exchanger. Axial movement is limited with a Belleville spring placed in this socket. This spring also allows for thermal expansion of the isotope.

The catalyst material is located in 8 compartments located between the fins of the isotope heat source. A perforated steel plate and screen is brazed into one end of the catalyst compartment and a screen is located at the other end to prevent the catalyst material from entering the heat exchanger. A machined flange is located at the end of the catalyst canister away from the heat exchanger to provide access to the isotope heat source and catalyst material. This flange is held in place with bolts and sealed with a Parker metal face seal.

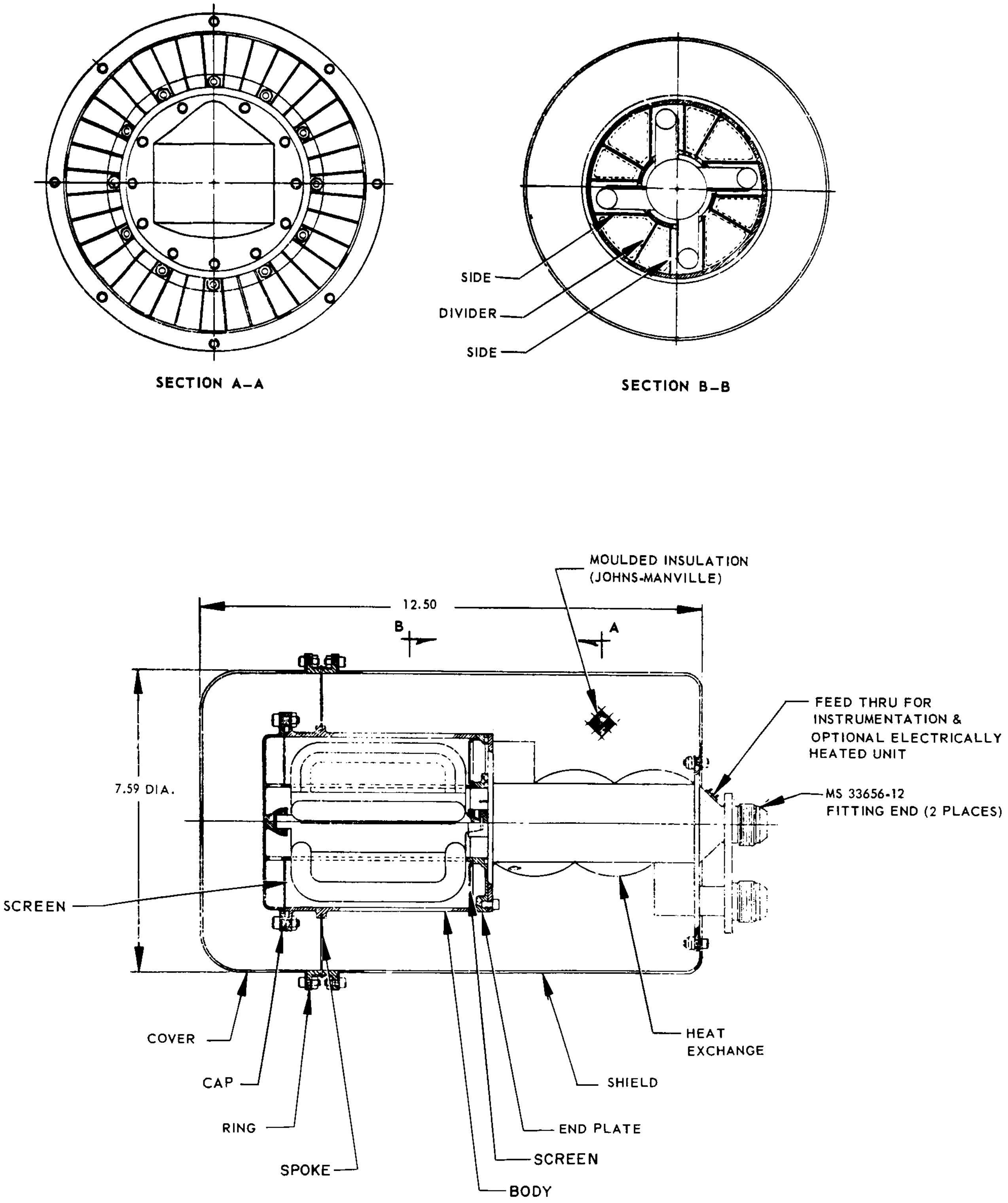

Fig. 1 - IHCOS Conventional Insulation Design

TABLE 1

IHCOS-WEIGHT, VOLUME AND POWER SUMMARY

Moist Gas Units:

	9 Man			6 Man			3 Man	
Insulation	Vac.	X=1.5	X=2.0	Vac.	X=1.5	X=2.0	Vac.	X=1.5
Power (watts)	125	132	122	100	106	97	73	77
Weight (lbs)	27.14	26.05	27.98	24.63	23.49	25.41	21.30	20.02
Length (in)	13.62	13.90	13.93	12.61	12.85	12.94	11.42	11.60
Diameter (in)	6.87	7.6	8.6	6.87	7.59	8.59	6.87	7.59
Volume (in^3)	505	630	810	465	583	750	423	525
$\triangle$ P (in H_2O)	4.24	4.38	4.17	2.31	2.38	2.27	.89	.91

Dry Process Gas Units:

	9 Man			6 Man			3 Man	
Insulation	Vac.	X=1.5	X=2.0	Vac.	X=1.5	X=2.0	Vac.	X=1.5
Power (watts)	100	108	101	82	89	82	51	56
Weight (lbs)	24.77	23.69	25.82	22.73	21.79	23.53	19.08	17.85
Length (in)	12.61	12.86	13.13	11.82	12.11	12.3	10.46	10.66
Diameter (in)	6.87	7.59	8.59	6.87	7.59	8.59	6.87	7.59
Volume (in^3)	467	582	763	437	548	715	387	482
$\triangle$ P (in H_2O)	3.52	3.64	3.54	1.98	2.06	1.98	.84	.86

Vac. - Vacuum Dewar Insulation
X= - Johns-Manville Min K 1301
X= - thickness

The catalyst canister is supported from the aluminum shield assembly by 36 steel wire spokes in tension. One end of the spokes is threaded into the cylindrical wall of the catalyst canister, while the other end is supported in a cylindrical channel section with small threaded disks. The cylindrical channel section is used to support the two portions of the aluminum shield.

The entire area between the inner body and the shield is filled with molded insulation (Johns-Manville Min-K 1301). The insulation is molded in four pieces, mating at the wire spokes and center-line of the unit.

The aluminum outer shield separates at the spoked supports to allow access to the insulation and inner body of the unit. The aluminum outer shield is also attached to the cold end of the regenerative heat exchanger. The shield is painted white to provide a high-emittance, and thus reduce its surface temperature.

Fitting ends on the cold end of the regenerative heat exchanger are per MS33656-12, for flared tube connections. An electrical feed-thru is also located at the cold end of the heat exchanger for instrumentation leads and for the electrical leads of the optional electrically-heated simulated isotope. The instrumentation and electrical leads pass through the inlet gas passage of the regenerative heat exchanger. Instrumentation consists of recording gas temperatures at the inlet and outlet of the catalyst bed.

Vacuum Insulation Design

Figure 2 and Table 1 show the configuration and overall package dimensions of the vacuum insulated IHCOS designs. These units are similar in design to the conventionally insulated units with the only differences being the type of thermal insulation.

The insulation technique for this unit consists of a vacuum jacket surrounding the catalyst canister and insulated regenerative heat exchanger. The vacuum jacket is a vacuum furnace-brazed stainless steel vessel. The vessel when assembled is evacuated and sealed to maintain vacuum integrity. The inner and outer walls of the vacuum vessel are joined at a machined ring on the open end of the vessel. Thirty-six radial spokes are brazed under light pre-load, between the inner and outer well, at the closed end of the vacuum vessel. The interior walls of the vacuum vessel have special coatings to achieve the desired thermal characteristics. The inner walls are gold-plated to provide an emittance of 0.07.

The surface of the vacuum vessel facing the catalyst canister, as well as the surface of the catalyst canister, are oxidized to provide an emittance of 0.8.

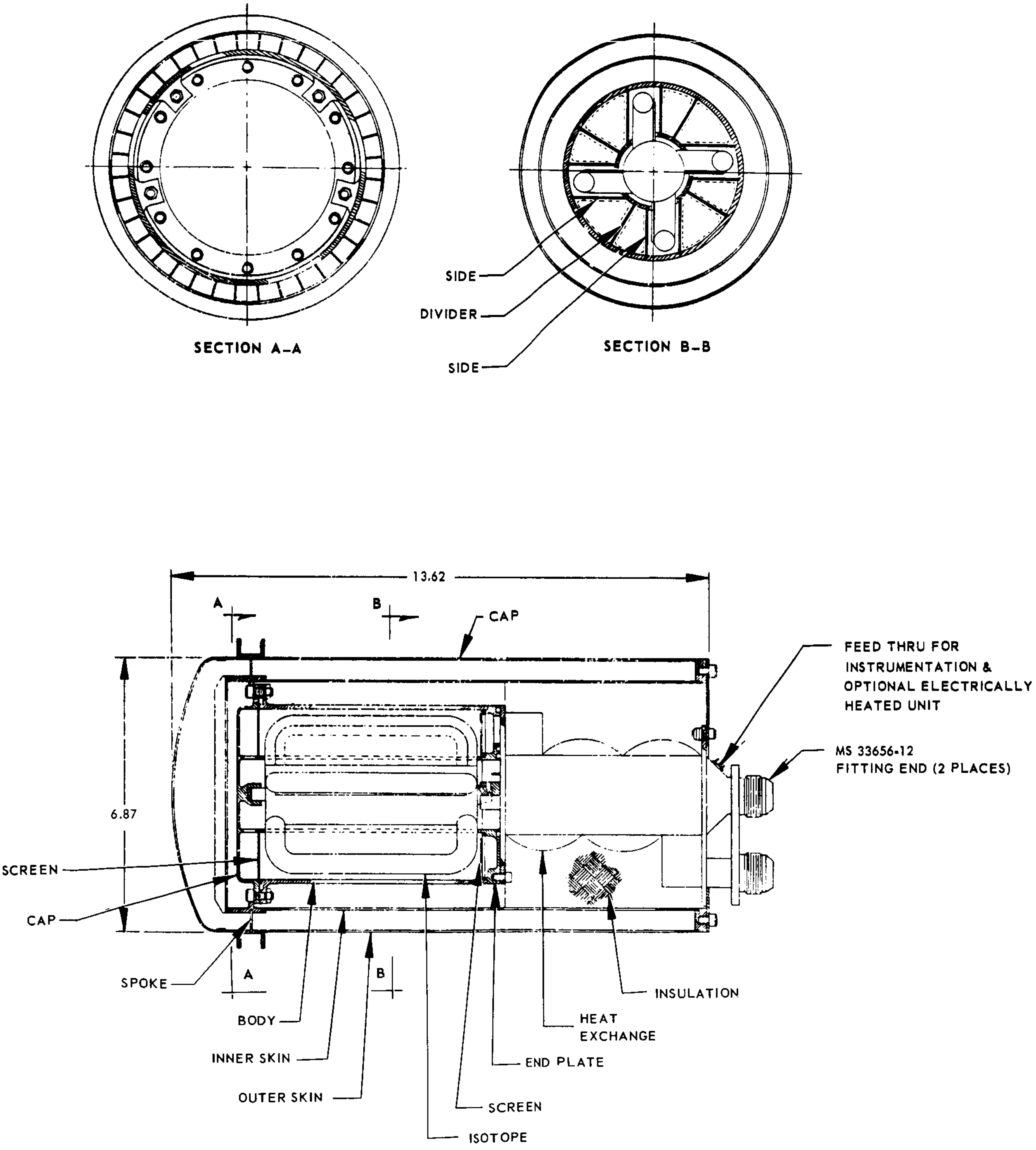

Fig. 2 - IHCOS Vacuum Insulation Design

The catalyst canister containing the catalyst material and isotope heat source is attached to the vacuum vessel at a point adjacent to the wire spokes. The cold end of the regenerative heat exchanger is attached to an aluminum plate, which, in turn, is fastened to the machined ring in the open end of the vacuum vessel. The volume between the regenerative heat exchange and the inner wall of the vacuum vessel is filled with molded insulation (Min K 1301).

Structural analyses were performed on the critical areas of the IHCOS design to investigate the ability of the unit to withstand the static and dynamic loads that are anticipated to be present. The designs indicated in figs. 1 and 2 were found adequate to withstand these loads.

System Operation

The IHCOS unit has two modes of operation, these are normal operation in the vehicle when flow is circulating through the unit and the contaminants are being removed. During all other conditions where there is flow through the unit the internal temperature will rise during the flow shutdown situation.

Normal operation. - During operation, flow from the presorbent beds will enter the IHCOS and pass through the regenerative heat exchanger (See fig. 3) where the air is heated to within a few degrees of the required catalyst operating temperature. The flow leaving the regenerative heat exchanger then passes over the isotope heat source to the far end of the unit. Heat transfer from the isotope source to the gas stream brings the gas up to the required catalyst temperature. After passing over the isotope heat source, the air turns around in a header and returns through the catalyst which is located in channels around the isotope heat source. The gas stream is heated to operating temperature by the isotope surface and catalyst bed providing the necessary temperature difference for operation of the regenerative heat exchanger. During the pass over the catalyst bed, the contaminants entering the bed are oxidized. The gas leaves the catalyst beds and is collected in an annular chamber adjacent to the heat exchanger. The hot gas flows from this chamber into the inlet header of the heat exchanger. The cooled gas leaving the heat exchanger then passes through a post sorbent bed where any toxic products of combustion are removed before being returned to the cabin. The post sorbent bed is not included in the IHCOS unit.

Flow shutdown. - During conditions where there is no flow through the unit, the operating temperature of the IHCOS unit must be maintained within acceptable levels. Heat which is normally lost to the flowing gas stream is dissipated by an increase in unit temperature from the normal operating temperatures to an upper limit of 1000°F. This heat is conducted down the core of the heat exchanger and from the heat source to the surface of the catalyst canister by the heat conducting webs which also contain the catalyst. These webs were sized to meet heat transfer requirements under the no-flow condition.

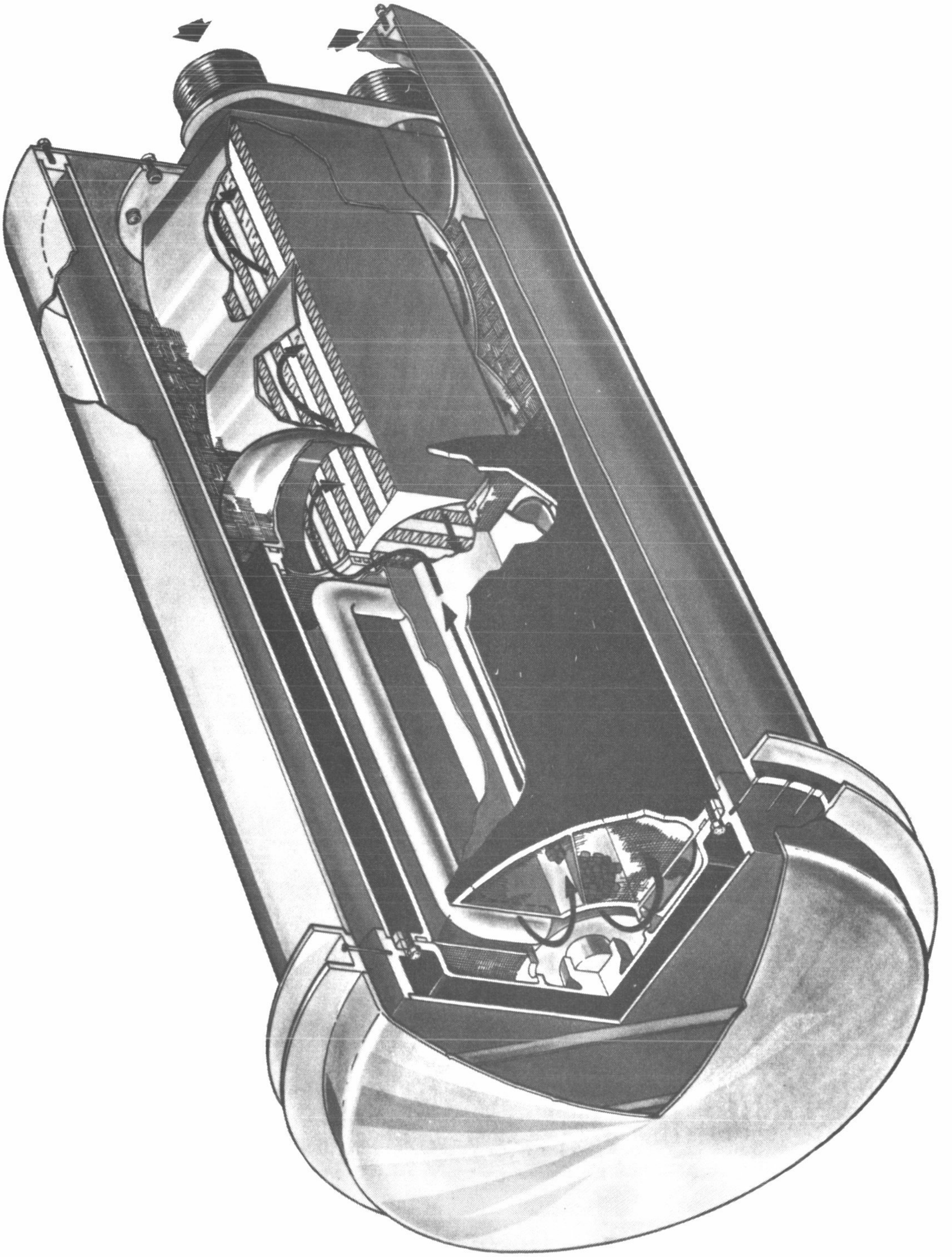

Fig. 3 - Isotope-Heated Catalytic Oxidizer
Vacuum Insulation Version

Operating Characteristics

The IHCOS was optimized for a 9-man unit operating at 10.0 psia and processing 3.0 CFM of flow. This basic optimized design was scaled to provide the data presented in Table 2. The principle scaling procedure was to scale the length of the isotope heat source with power level,and the heat exchanger face area with flow rate. The scaling procedures are valid and will yield new optimum designs for power levels from 80 to 140 watts. However, for the 3-man units, the unit's weight may be reduced somewhat by a total reoptimization. The projected weight savings of the 3-man unit reoptimization is only a few pounds and was not performed in this study.

The IHCOS is designed for operation in a 75°F environment with a 75°F supply temperature. Any increase in these temperatures will yield improved performance of the unit. The gas leaving the IHCOS unit will vary from 105 to 115°F above the feed temperature for the moist gas designs and from 90 to 100°F above feed temperature for the dry process gas designs.

An evaluation of the effect of unit operation at system pressures different than 10.0 psia was made. Changes in unit pressure drop and regenerative heat exchanger performance will result. The isotope heat source for the design unit is off-loaded 20% by the addition of inert material to provide for such contingencies. Operation at 14.7 psi is possible by increasing the power level of the isotope heat source by reducing the off-loading. Pressures lower than 10.0 psia will result in higher than required temperatures and catalyst performance will be improved, or off-loading can be increased thereby maintaining design operating temperatures. Table 2 shows the expected deviation from the design power levels for 14.7 psia and 5.0 psia operation. The 10.0 psia design case is taken as the basis.

TABLE 2

ISOTOPE POWER CHANGES FOR DIFFERENT OPERATING PRESSURES

	14.7 psia	5 psia
9-man moist gas designs	+ 15 watts	- 16 watts
9-man dry process gas designs	+ 13 watts	- 14 watts
6-man moist gas designs	+ 11 watts	- 11 watts
6-man dry process gas designs	+ 10 watts	- 10 watts
3-man moist gas designs	+ 5 watts	- 6 watts
3-man dry process gas designs	+ 4 watts	- 4 watts

If off-loading is used to increase or decrease power level, there will be no changes in the unit weights. Furthermore, because the changes in power level result from changes in heat exchanger performance, the data in Table 2 is independent of the insulation type selected.

The pressure loss of each of the units presented in Table 1 will also vary. These losses will vary as pressure to the 0.5 power. During all considerations of pressure variation, the volume flow through the unit must be held constant to provide constant contaminant removal.

With the unit operating in a 75°F environment, the surface temperature will be 115°F during normal operation. If the cabin is depressurized and there is no flow through the unit, this surface temperature will rise to 215°F. All other operating conditions will fall between these two limits.

Isotope Heat Source

A comparison of several isotope heat sources for use in IHCOS showed a clear advantage for Pu-238. This was the selected isotope used in all of the units. Other sources which were evaluated and rejected for reasons of excessive weight, inappropriate half-life and excessive shield requirements, include Sr-90, Pm-147, Cm-244, Po-210 and Th-141.

Aerospace nuclear safety. - The isotope heat source must meet the following aerospace nuclear safety criteria.

- Complete containment of the isotope during ground handling and launch pad operations.
- Encapsulation materials chemically compatible with potential launch and space abort environments.
- Intact reentry capability.
- Capsule survival in the event of Earth-impact.

The use of radioisotopes requires consideration of safety in all phases of operation, from initial encapsulation of the isotope through mission completion. Concurrent with the heat source design, it is necessary to determine the accidental environments to which the heat source might be subjected and to evaluate the effects of these environments on capsule integrity. Safety criteria are then established and adhered to in order to assure a final design capable of hazard-free operation.

Traditionally, the AEC has required the demonstration of safe containment of all radioisotopes during source fabrication, handling, and use. The development and use of radioisotope heat sources for applications in the national space program have resulted in the evolution of a new series of hostile environments associated with reentry into the Earth's atmosphere, followed by Earth-impact at terminal velocity. Presently, demonstration of complete isotope containment in these environments appears to be the most widely accepted safety criteria.

The potential abort environments associated with each of the following phases of a typical mission were considered.

- Ground transportation
- Launch pad operations
- Suborbital flight
- Orbital flight

The analysis of each of the mission phases resulted in the generation of design requirements for the radioisotope capsule.

Selected heat source. - Consideration of the safety requirements resulted in the heat source design shown in figs. 1 and 2. This heat source is composed of a central cylinder which contains the Pu-238. This cylinder is stressed to assure no release of the isotope material upon impact after reentry. The four fins radiating from this central cylinder with the tube around the edge dissipate the reentry heat and reduce the impact velocities. The entire unit is coated with a material which protects the main structural material from oxidation and has a high emissivity for heat dissipation. The analysis of this heat source showed a minimum fin height of about one inch was required from about 80 watts up to 170 watts. Use of this minimum height was chosen for weight and package considerations of the IHCOS unit.

Radiation dose levels. - The radiation dose level was evaluated for the 9-man moist gas unit. This data can be scaled directly with isotope powered level for each of the other designs using the 125 watt power of the 9-man moist gas unit as the basis. The following is a description of the dose levels for this baseline unit.

At 1.5 meters from all versions of IHCOS, the accumulated dose over the 180-day mission amounts to less than 1 percent of the recommended maximum dosage to the skin. For the blood-forming organs, or abdominal viscera, the allowable dose is lower than the skin dose; however, the radiation from IHCOS (predominantly neutrons) is attenuated in reaching these dose points, and thus IHCOS radiation is responsible for less than 4 percent of the recommended maximum continuous dosage at 1.5 meters.

For the lenses of the eye, the relative biological effectiveness (or quality factor) for neutrons is twice that for other body organs. Applying this factor, IHCOS contributes less than 5 percent of the total mission allowable continuous eye dose. The total allowable dose rates, based on the current LMSC recommended values derived in consultation with C. A. Tobias, University of California, Donnor Laboratory, for a 180-day continuous exposure are 43 mrem/hr for the lens of the eye, and 139 mrem/hr for skin.

In considering possible maintenance requirements for IHCOS, the recommended maximum acute dosage may become the dominant criterion. An exposure period of 5 days at the surface of IHCOS would result in less than 10 percent of the recommended maximum acute hands-and-feet dose, or less than 25 percent of the maximum acute eye dose.

The closest possible approach to the radioisotope heat source is at the wall of the heat source capsule, and this point can only be reached by disassembling IHCOS. At this location, an exposure time of 50 hours would result in less than 100 percent of the total acute dose to the hands and feet; while an exposure time of 10 hours to the eyes would result in less than 100 percent of the total acute eye dose.

Based on the foregoing data, the radiation field from the unshielded IHCOS constitutes only a minimal perturbation in the operational radiation safety situation. If maintenance operations are approached with the knowledge that the heat source is radioactive, there should be no significant effect on the crew accumulated radiation dose status.

The actual curve for dose level as a function of distance from the unit is classified. If there is a requirement for this information, refer to NASA CR-66347.

PRE AND POSTSORBENT BEDS

The design of the pre and postsorbent beds for the IHCOS unit includes an evaluation of the expected spacecraft contaminants. These are evaluated to determine potential catalyst poisons and harmful products. Then, sorbent materials must be evaluated for removing each of the undesirable materials entering the catalytic burner. This information on poisons and harmful products is then combined with sorbent data to yield the final design.

Potential Catalyst Poisons

The IHCOS list of potential contaminants in manned space vehicles was evaluated to determine which specific compounds are potential catalyst poisons, and which compounds produce toxic combustion by-products.

The criteria used in determining what are potential catalyst poisons were based on previous experimental data utilizing 0.5% Pd on alumina pellets and on exhaustive literature search. Studies at LMSC with H_2S show deactivation of the unprotected catalyst after 18 days of exposure at room temperature. Additional tests during this same program at elevated temperature indicated that with Freon-12, vinyl chloride and methyl mercaptan present in the gas stream, the catalyst bed temperature had to be increased 70°F to maintain the desired oxidation efficiency. Experiments at Atlantic Research have also indicated partial catalyst deactivation resulting from exposure to Freon-12. More recently, during the 180-day IHCOS long term catalyst test, it was observed that water vapor in the gas stream caused the catalyst bed temperature to be increased 140°F to maintain the desired oxidation efficiency. Table 3 lists the potential catalyst poisons found in the IHCOS list.

Undesirable Products of Oxidation

Catalytic oxidation of compounds containing nitrogen, sulfur, or the halogens may lead to the formation of new compounds of greater toxicity or of acids that could deteriorate equipment. For example, NRL studies of Hopcalite-catalyzed oxidation of Freon-11, -12, and -114 have indicated halogen and acid products, and the formation of vinylidene chloride and trichloroethylene from methyl chloroform. LMSC tests have detected SO_2 and NO_2 in the outlet stream of an oxidizer fed Freon-114, H_2S, and monomethyl hydraxine; the absence of HCl and HF was attributed to reaction with the monomethyl hydrazine.

TABLE 3

POTENTIAL POISONOUS CONTAMINANTS (IHCOS)

COMPOUND	GENERATION RATE (gm/9-man day)	MAXIMUM ALLOWABLE CONCENTRATION (mg/M^3)
Sulfur-containing compounds -		
Carbon Disulfide	0.25	6.0
Carbonyl Sulfide	0.25	25.0
Dimethyl Sulfide	0.25	15.0
Ethyl Sulfide	0.25	97.0
Ethyl Mercaptan	0.25	2.5
Hydrogen Sulfide	0.0007	1.5
Methyl Mercaptan	0.25	2.0
Propyl Mercaptan	0.25	82.0
Sulfur Dioxide	0.25	0.8
Halogen-containing compounds -		
Carbon tetrachloride	0.25	6.5
Chlorine	0.25	1.5
Chloroacetone	0.25	100.0
Chlorolenzene	0.25	35.0
Chlorofluoromethane	0.25	24.0
Chloroform	2.50	24.0
Chloropropane	0.25	84.0
1, 1 Dichloroethane	2.50	40.0
Ethylene Dichloride	0.25	40.0
Freon-11	2.50	560.0
Freon-12	2.50	500.0
Freon-21	0.25	420.0
Freon-22	0.25	350.0
Freon-23	0.25	12.0
Freon-113	0.25	700.0
Freon-114	2.50	700.0
Freon-114 (usym)	0.25	700.0
Freon-125	0.25	25.0
Hydrogen Chloride	0.25	0.15
Hydrogen Fluoride	0.25	0.08
Methylene Chloride	2.50	21.0
Methyl Chloride	0.25	21.0
Methyl Chloroform	2.50	190.0
iso-Propyl Chloride	0.25	260.0
Tetrachloroethylene	0.25	67.0
Tetrafluoroethylene	0.25	205.0
Trichloroethylene	2.50	52.0
Vinyl Chloride	2.50	130.0
Vinylidene Chloride	0.25	20.0
Others -		
Water	--	--
Hexamethylcyclotrisiloxane	0.25	240.0

Table 4 shows the maximum possible stoichiometric number of inorganic combustion products from sulfur-, halogen-, and nitrogen-containing compounds.

Sorbent Selection

A review of sorbent materials for the pre and postsorbent beds was based on the following criteria: (1) adsorption capacity; (2) selectivity; (3) weight requirements; (4) chemical stability; (5) availability; and (6) regenerability. On this basis, three sorbent materials were selected as potential candidates: acid-impregnated activated charcoal, Molecular Sieve (13x), and lithium hydroxide.

Acid-impregnated activated charcoal has the general capability of adsorbing most organic compounds with good removal efficiency plus the ability to remove ammonia (NH_3) from the gas stream. Activated charcoal meets all of the above requirements for a desirable sorbent, its only short-coming being its limited capacity for inorganic compounds, especially the acid gases.

Molecular Sieve is a good sorbent for all compounds having an effective molecular size greater than methane (CH_4) and hydrogen (H_2). It has good thermal and chemical stability and has a larger adsorption capacity than activated charcoal with a larger range, especially for inorganic compounds such as H_2S, NH_3, SO_2, HCl and HF. The biggest disadvantage of Molecular Sieve, however, is its special affinity for water. In other words, Molecular Sieve will selectively adsorb water over other compounds. The estimated adsorption capacity of Molecular Sieve in a gas stream with a 55°F dew point is 0.5 to 1.0%, as contrasted to its 20 to 30% adsorption capacity in a gas stream with a -55°F dew point.

Lithium hydroxide, in contrast to activated charcoal and Molecular Sieve, selectively adsorbs compounds by a reaction or chemisorption mechanism. The generally accepted mechanism is the neutralization reaction between a base and an acid, although the complexing and oxidation-reduction reaction of LiOH and other strong bases have been studied. The main advantage of LiOH over the other two sorbents is its greater adsorption capacity; i.e., 50 to 80% by weight, hence a smaller weight requirement. The main disadvantage of LiOH is its limited adsorption range; i.e., approximately 50% of those potential catalyst poisons and 20% of the total contaminants in the IHCOS list. A minor disadvantage is that LiOH is not regenerable, in contrast to charcoal and Molecular Sieve which can be regenerated with the application of heat and vacuum. However, the small weight requirements of LiOH makes it an easy task just to discard the spent LiOH and replace it with a fresh charge.

The final selection of LiOH as the sorbent material for both the pre and postsorbent beds was based on two primary considerations; weight requirements and general adsorption capability. Activated charcoal was eliminated as a

TABLE 4

MAXIMUM POSSIBLE INORGANIC COMBUSTION PRODUCTS

CONTAMINANT	FORMULA	HF	HCl	NO_2	SO_2	SiO_2	HCN	$COCl_2$	Cl_2	COF_2
Ammonia	NH_3			1			1			
Carbon Disulfide	CS_2				2					
Chlorine	Cl_2		2					1	1	
Chloroacetone	C_3H_5ClO		1					0.5	0.5	
Chlorobenzene	C_6H_5Cl		1					0.5	0.5	
Chloropropane	C_3H_7Cl							0.5	0.5	
Cyanamide	CH_2N_2			2			2			
Dimethylhydrazine	$(CH_3)_2N_2H_2$			2			2			
Ethylene Dichloride	$C_2H_2Cl_2$		2					1	1	
Ethyl Sulfide	$(C_2H_5)_2S$				1					
Ethyl Mercaptan	C_2H_6S				1					
Freon-11	$CFCl_3$	1	3					1.5	1.5	0.5
Freon-12	CF_2Cl_2	2	2					1	1	1
Freon-22	CHF_2Cl	2	1					0.5	0.5	1
Freon-23	CHF_3	3								1.5
Freon-114	$C_2F_4Cl_2$	4	2					1	1	2
Freon-114 (unsym)	$C_2F_4Cl_2$	4	2					1	1	2
Freon-125	C_2F_5H	5								2.5
Hydrogen Chloride	HCl		1					0.5	0.5	
Hydrogen Fluoride	HF									
Hexamethylcyclotri-siloxane	$(CH_3)_6(SiO_3)_3$					3				
Hydrogen Sulfide	H_2S				1					
Methylene Chloride	CH_2Cl_2		2					1	1	
Methyl Chloroform	$C_2H_3Cl_3$		3					1.5	1.5	
Monomethyl Hydrazine	CH_6N_2			2			2			
Methyl Mercaptan	CH_3SH				1					
Nitric Oxide	NO			1						
Nitrogen Tetroxide	N_2O_4			2						
Propyl Mercaptan	C_3H_8S				1					
Sulfur Dioxide	SO_2				1					
Trichloroethylene	C_2HCl_3		3					1.5	1.5	
Tetrachloroethylene	C_2Cl_4		4					2	2	
Tetrafluoroethylene	C_2F_4	4								2
Freon-21	$CHCl_2F$	1	2					1	1	0.5
Vinyl Chloride	C_2H_3Cl		1					0.5	0.5	
Vinylidene Chloride	$C_2H_2Cl_2$		2					1	1	

presorbent material as it was calculated that the charcoal in the main sorbent would effectively remove those contaminants adsorpable by charcoal. Moreover, since the toxic and undesirable combustion products are mainly inorganic compounds, activated charcoal is an unsuitable postsorbent. Molecular Sieve is eliminated because of its high weight requirements. A hundred-fold difference in weight between LiOH and Molecular Sieve is calculated on the basis of a moist gas stream passing through the contaminant removal system.

LiOH was chosen both for its low weight requirements and its adsorption capacity for specific catalyst poisons and toxic contaminants not removed by the charcoal main sorbent bed; e.g., SO_2, H_2S, HCl, and HF. As a postsorbent, it will effectively remove those acidic inorganic combustion products.

Sorbent Bed Design

The pre and postsorbent beds are similar in design to the lithium hydroxide carbon dioxide removal canisters which have been designed for a number of space vehicles. They will be packaged in a cartridge of no less than 1.1 pounds per man. The minimum bed size will result in a space velocity which will yield the desired removal efficiency. This minimum bed size will correspond to a 180-day mission. As mission length is measured, this bed will get larger at a rate of 0.003 pounds per man day.

The postsorbent bed has been designed with complete failure of presorbent assumed. This will result in a maximum possible quantities of toxic material generated. If this worst case is assumed a postsorbent bed identical to the presorbent will be required. This will result in a bed which is 1.1 pounds per man for 180 days. This unit will increase in size at a rate of .002 pounds per man day.

SYSTEM INTEGRATION

The integration of IHCOS and pre and postsorbent beds into a space vehicle can be accomplished in three principle ways:

- Completely independent of the ECS.
- Integrated with the main contaminant control unit.
- Integrated with the Molecular Sieve unit.

Independent installation of IHCOS will result in a requirement for large quantities of activated charcoal to prevent catalyst poisoning. These will be in addition to the main charcoal beds. As a result of this excessive weight penalty, it is recommended that IHCOS be integrated with the main sorbent beds in all cases.

Integration of IHCOS with the Molecular Sieve units offers the weight advantage of the dry process gas units, with inlet dew point temperatures below -40°F, and a possible reduction in the lithium hydroxide quantities. At present, little is known about the capability of the regenerable Molecular Sieve beds to remove some of the poisons and taking advantage of its capability is not recommended in view of the low weights of LiOH required. Further, the savings of less than 5 pounds offered by the dry process gas design will most likely not compensate for the weight and design penalties to the Molecular Sieve system.

As a result of these considerations, the recommended approach is for the integration of a moist gas, with inlet dew points near cabin levels, designed with the main contaminant removal system. This unit would be placed in a back flow loop around the contaminant control fans to minimize the pressure loss penalty and utilize the presorbent value of the main activated charcoal beds.

Installation

The elements of the catalytic oxidizer system including the pre and postsorbent canisters may be installed in a package such as shown in fig. 4. This drawing shows an oxidizer and sorbent beds designed for a 9-man vehicle with a 2-year mission life and 10.0 psia cabin atmosphere. The three major subassemblies are shown mounted in a unit with the sorbent beds connected to the oxidizer at one end and with fittings at the other end for connecting to the vehicle contaminant removal system. Provision is made for removal of the inlet face

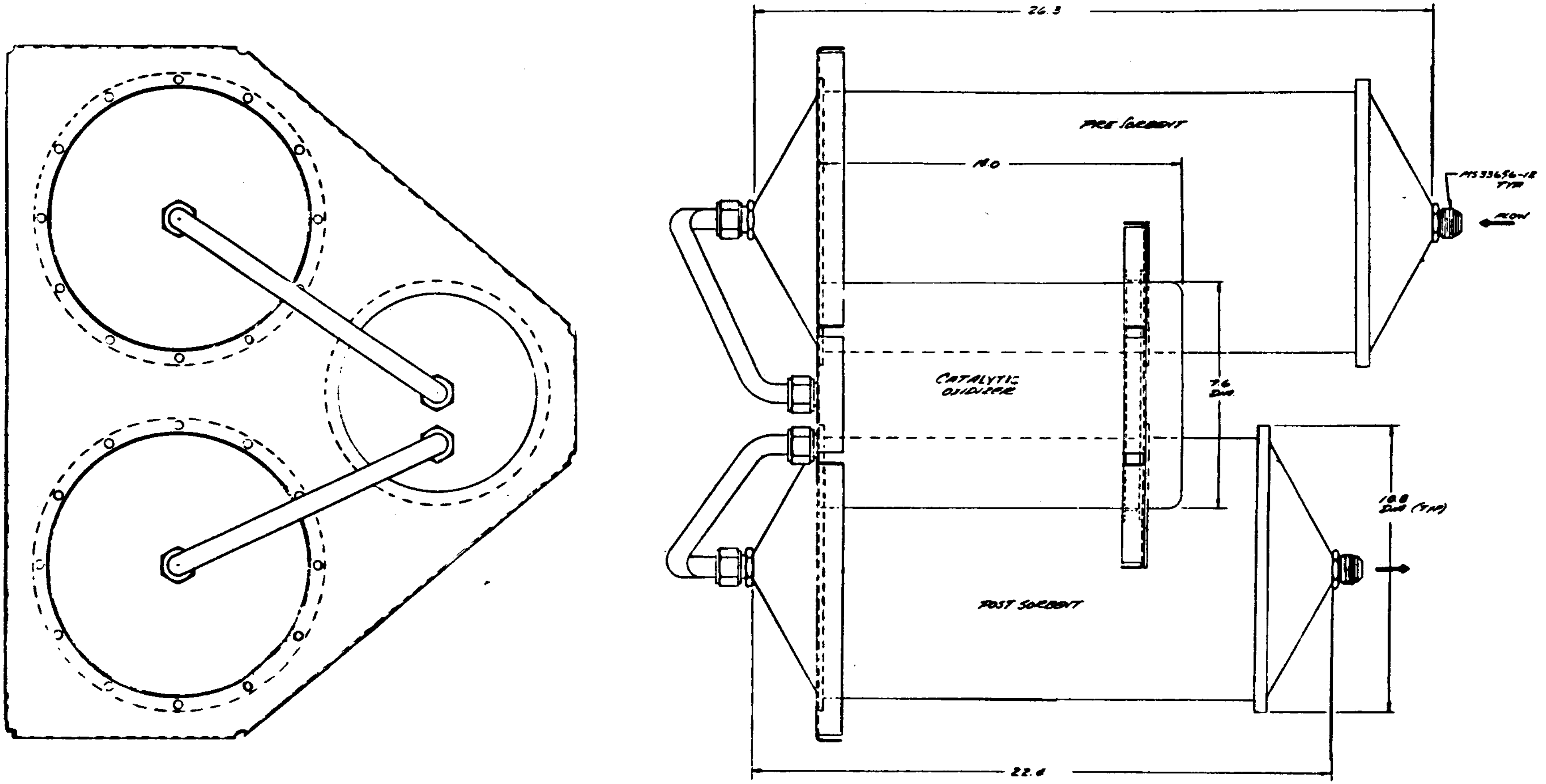

Fig. 4 - Isotope-Heated Catalytic Oxidizer System

of the presorbent bed and outlet face of the postsorbent bed for change of the lithium hydroxide charge. Removal and change of the catalyst will require disconnecting the oxidizer unit for maintenance. In the event that vehicle packaging requirements do not allow such an installation, the components may be mounted remotely as long as the order in the flow stream is maintained.

Modularization Concept

Examination of the weight and isotope power summary presented in Table 1 shows a considerable weight advantage to using a single unit designed for the total crew size rather than a number of smaller units. These advantages also extend to the potential radiation dose as the larger units will require much less isotope power than combining the smaller units. If a single oxidizer unit is chosen for the final configuration, there appears to be no advantage in using multiple pre and postsorbent beds.

The weight penalty of a single 9-man unit over that of a single 3-man unit is small. Thus, the design and fabrication of a 9-man unit will satisfy the requirements of smaller crew sizes with little penalty. The radiation hazard can be minimized by adjusting the flow through the oxidizer to match the crew size. This will result in a reduction in required isotope power level at a given operation temperature. The reduced power and resultant reduced radiation dose can be accomplished by off-loading the isotope source at the time of fabrication immediately before flight.

The pre and postborbent beds, which are the largest components in the trace contaminant control system, will vary in size and weight directly with crew size. As a result, there is a significant advantage in developing units for each crew size. The large backlog of work already done on lithium hydroxide canisters will reduce the cost and development penalties of these components. Consideration of space velocity required to achieve desired bed performance will limit the minimum bed size to one corresponding to a 180-day mission. Extension of missions beyond 180 days can be achieved by resupply of a basic 180-day canister. An alternative approach to variable mission durations for the pre and postsorbent beds is off-loading long duration bed designs to shorter missions. This approach has a minimal weight penalty but a volume penalty nearly proportional to the mission duration.

The location of all elements of the trace contaminant control system must be such that the chemical and catalyst charges can be changed in case some vehicle failure results in an unexpected contaminant pulse. This location restriction will not have a first priority as an emergency is assumed to cause failure and no routine maintenance will be necessary based on a reliability analysis.

Controls and Displays

The catalytic oxidizer system has a high inherent reliability, making repair or maintenance unlikely. As a result, a minimum of controls and displays will be required to monitor the operation of this unit. As the power of the unit is fixed, the operating temperature will vary with the system flow. This flow must be monitored and maintained at the proper level for the particular crew size. In addition, the operating temperature should be measured and displayed. If temperature drops below the minimum allowable level, a warning light will operate.

In the event that there is a complete on-board gas monitoring system, gas pickup points at the outlets of the major system components can be installed. The selection of the pickup point can be manually operated, as this will serve only as a system diagnostic tool.

In summary, the controls on the unit will include flow and gas monitoring selection. The displays will include flow, temperature, and low temperature warning light. Displays for the gas composition will be the ones for the gas monitoring system.

Expendable Requirements

The lithium hydroxide is the only true expendable in the catalytic oxidizer system. Analysis has shown that the main contaminant control system will contain adequate activated charcoal to protect the oxidizer system if the proper location is chosen. The lithium hydroxide requirements for the assumed vehicle contaminant load are 1.1 pounds per man and .003 pounds per man day in excess of 180 days for the presorbent bed. The postsorbent bed will be 1.1 pounds per man and .002 pounds per man day in excess of 180 days. These beds need not be spared to achieve the reliability goal unless the maximum goal is chosen. In that case, both beds must be spared. In the event of some undefined postulated vehicle failure, it may be necessary to carry backup lithium hydroxide and catalyst.

MAINTAINABILITY AND RELIABILITY

The isotope-heated catalytic oxidizer system, including the pre and post-sorbent beds, has a high inherent reliability as there are no moving parts and key components have a considerable basis of experience in similar configurations. The catalytic oxidizer is composed of several major components. These are:

- Regenerative heat exchange
- Isotope heat source
- Catalyst canister
- Catalyst
- Insulation

The reliability of stainless steel heat exchangers is well known and no problem with this unit is expected. The catalyst canister and main structure are sized primarily for heat dissipation during the no flow condition which results in stress levels far below normal design values. These components will have the highest reliability. The isotope source being designed for an intact re-entry requirement and having an 89 year half-life will require no maintenance or sparing. The only portion of this system that seems prone to failure is the catalyst bed which can be poisoned.

The design of IHCOS is such that insulation on the catalyst canister end of the unit can easily be removed thus exposing the lid of the catalyst canister. Removal of the bolts holding this lid in place will then allow replacement of the catalyst. The catalyst is held in containers contoured in the shape of the channels for ease of handling and particle contaminant. The unit is then re-assembled for reuse.

For some types of poisoning, catalyst regeneration may be possible by increasing the operating temperature. This is done by reducing the unit flow and as a result the heat exchanger losses.

During maintenance operations, a condition of no flow will exist and the temperature of all components will be very high, even with the insulation removed. This will make maintenance an undesireable task except in cases of extreme requirement. However, this task still seems desireable because of the weight and radiation dose penalties incurred in sparing this unit.

Reliability goals have been set for the oxidizer system and sorbent beds. These are:

2 year mission - no resupply	0.999650
2 year mission with resupply	0.999900

As a necessary step in the determination of the reliability of the system in both modes it is essential that all elements have ascribed to them some reliability value. These numerics are all given as figures of merit; i.e., the probability that the device will operate failure free for a period of one year, and are based upon a mixed set of data from both actual space flights or space simulation tests. In each case, the data are identified as to source:

1.	Presorbent Canister (LiOH)	0.99996.	AiResearch. JPL.
2.	Catalyst Canister	0.99990.+	If adequate safety factor is used in design.
3.	Isotope Heat Source	0.99999	Atomics International
3a.	Heat Exchanger (Plate Fin)	0.99990	
4.	Catalyst Al_2O_3 -- 1.0% Pt.	0.99999+	Coors Ceramics, Inc.
5.	Insulation. MIN (K)	0.99999	Johns-Manville Company
6.	Outer Canister	0.9999+	If adequate S/F is used with proof testing.
7.	Postsorbent Canister (LiOH)	0.99996	

The reliability values for the catalyst canister and outer canister are conservative and can possibly be raised to 0.99999 with extensive development if this proves necessary.

From the reliability viewpoint all of the elements are in series, since all must function properly for the device to operate for two years in space with no resupply. The worst case reliability model would thus be:

$$R1.R2.R3.R3a.R4.R5.R6.R7 = R_{subsystem}$$

For the super condition it is assumed that the LiOH canisters are space maintainable in that they can be replaced by a new unit carried, or resupplied as a spare. Under this condition it may be assumed that each canister has a spare in stand-by redundancy, the switching function being affected by the installation of the spare. The model thus becomes:

$$\begin{matrix} R1 \\ \text{switch} \\ R1a \end{matrix} \qquad R2.R3.R3a.R4.R5.R6 \qquad \begin{matrix} R7 \\ \text{switch} \\ R7a \end{matrix} = R_{subsystem}$$

Assessment thus becomes merely a matter of solving the two equations. However, since no hardware of this kind has been space qualified for a period of either one or two years to date, the conditional reliability numerics evolved are predictive in nature; that is to say, that the confidence level associated with them is at best 50%, and the numbers have equally as much chance of being incorrect as valid.

If the reliability values are assumed to be rational, solving for the two year case with no resupply gives:

R1.......R7 as: 0.99959 for one year on orbit.

For the two years on orbit no rational attempt can be made to extrapolate the value. However, it is reasonable to assume that since the life of the heat source is almost infinite, and there are no parts subject to wearout failure in the subsystem, that if the device survives in operable condition for one year, the chances of it surviving for a further consecutive year are almost 100%. It must be noted that the device does not achieve the approximate goal with the conservative canister reliability figures. Increasing the reliability of the catalyst canister and outer canister to the maximum achievable of 0.99999 results in a value of 0.99977 which exceeds the goal.

Solving the equation for the second case gives a better result as the subsystem is re-suppliable, at one year intervals, or better, at any time that failure is encountered. This allows replacement of the LiOH canisters which are a weak link in the reliability chain. For purposes of solution of the equation it must be understood that no expression exists to solve the cases R1 switch R1a, R7 switch R7a, since these devices will not obey the exponential rule for fallibility. However, if it is assumed that the exponential expression for units obeying the rule when in stand-by redundancy is a reasonable approximation, a solution is possible. Assume that the subsystem has two spares or standbys which can be applied in case of failure to either one unit two times, the other unit two times, or one spare to both units the exponential expression for this condition becomes:

$$R = \mathcal{E}^{-\lambda t} \left(1 + \lambda t + \frac{\lambda^2 t^2}{2!} \right)$$

where λ = unit failure rate

and t = time (1 year)

Since no published failure rate exists for the LiOH device, it is necessary to synthesize one from the solution of: $R = \mathcal{E}^{-2t}$ using the R value of 0.99996, t as 1 year in hours, 8760, as the Naperian base and solving for lambda, i.e., 0.045 failures per million hours. Using this value to solve the first equation we have: 0.9999999999.....9 for the first and last terms and the product rule supplied for the rest of the terms. This results in a reliability of 0.99967 which is less than the super goal but can be upgraded to 0.99985 with additional work on the canister units. Achieving the super goal would require upgrading the heat exchanger component which is questionable.

The reliability goal of .99965 can be met by either sparing the LiOH units or expending special effort to upgrade the reliability of the catalyst canister and outer case. Lockheed recommends that this goal be met without spares through increasing component reliability with extra development and testing. The super goal for reliability of .9999 cannot be achieved without sparing of the complete unit. However, .99985 is possible through sparing of the lithium hydroxide beds and extensive component developments. In view of the added radiation hazard of sparing the total unit, Lockheed recommends lowering the super goal for this unit to the achievable .99985 level.

DEVELOPMENT PLAN

This study of the application of an isotope-heated catalytic oxidizer with pre and postsorbent canisters has shown that the most desireable approach is to design the oxidizer unit for the maximum expected crew size and tailor the sorbent beds to the selected mission. This study has resulted in the definition of the mission requirements, selected configuration, catalyst and sorbent requirements and generation of a layout drawing of the system.

The generation of hardware for the BSM based on the requirements and initial layout drawings for the unit will require a development program which is described herein.

The objective of this development plan is to furnish a planning document for implementing the detailed design, fabrication and evaluation of a space flight qualified isotope-heated catalytic oxidizer system. This objective can best be achieved in a five phase program as follows:

I Concept definition and preliminary engineering layout drawings.

II Concept evaluation.

III Isotope heat source fabrication and evaluation.

IV Complete IHCOS design evaluation.

V Flight qualification.

The phase one effort to develop an isotope-heated catalytic oxidizer system resulted in definition of a system and preliminary layout drawings. This phase is described in this report.

The effort required in Phase II includes the finalization of the pre and postsorbent bed designs including model testing. A resistively heated simulated isotope heat source will be built and tested to aid in a detailed design of the final isotope heat source. This program which is presented below will consume about 6875 man hours over a 14-month period.

I Pre and Postsorbent Bed Development

- Final contaminant load definition for the pre and postsorbent beds.
- Design and fabrication of model pre and postsorbent beds.
- Long term sorbent bed evaluations.
- Model sorbent bed design and fabrication.
- Full scale pre and postsorbent bed design.

II Detailed Engineering, Resistive Prototype

- Material specification.
- Joining and fabrication tests.
- Heater fabrication and evaluation.
- Detailed design engineering.

Upon completion of Phase II, the fabrication and evaluation of a resistive prototype heater can be started. This unit will be used in the resistively heated prototype. In addition, a completely integrated system including the simulated isotope heat source will be fabricated, tested, and evaluation. This phase will require 7315 manhours over a 16-month period. The steps in this phase are shown below:

I Fabrication and Evaluation, Resistive Prototype

- Fabrication and evaluation, heat source.
- Fabrication of complete unit.
- Evaluation of complete unit.

II AEC Coordination and Commitment.

Phase III will verify the predicted performance of IHCOS. This data will then be evaluated and an isotopically heated demonstration unit built. This unit will ultimately be flight qualified for the BSM. The steps in this phase of the program are shown below. Completion of this work will require 12,050 manhours over a 20-month period.

I IHCOS Design Evaluation

II Heat Source Design

- o Post demonstration test evaluation.
- o Re-entry aid evaluation.
- o Detailed thermal analysis.
- o Stress analysis.
- o Evaluation and drawings.

III Chemical Compatibility Tests

- o Capsule component compatibility tests.
- o Coating chemical compatibility tests.

IV Fabrication and Assembly Isotope Test Unit

V Isotope Mechanical and Safety Evaluation Tests

- o Shock and vibration loading.
- o Hypersonic Re-entry simulation tests.
- o Impact tests.
- o Post impact creep tests.

VI Final Radioisotope Heat Source Design

VII Fabrication, Assembly, and Qualification Test of Radioisotope Demonstration Units.

- o Isotope component fabrication.
- o Isotope shipping container fabrication.
- o Encapsulation of radioisotope.

VIII Demonstration Testing of Integrated IHCOS

- o System performance test.
- o Post demonstration test evaluation.

The final phase of a program to produce a flight qualified IHCOS for the BSM is the flight qualification program as shown below:

I Flight Qualification

- o Fabricate 6 units for delivery and qualification program.
- o Run environmental tests.
- o Establish and run a reliability and quality control program.

II Coordinate installation of IHCOS in vehicle.

Accomplishment of this task will consume about 18,000 manhours over a one-year period.

In summary, the delivery of a flight qualified IHCOS for the BSM can best be accomplished in a 5 phase program covering a period of 62 months and 44,240 manhours of labor.

CONCLUSIONS

This study has shown that a catalytic oxidizer system based upon the design concepted in NASA CR-66346 can effectively control a major portion of the expected contaminant load for advanced vehicles with mission durations in excess of 180 days. The basic oxidizer design configuration is valid over the range of crew sizes of 3 to 9 men.

The oxidizer weight, with a moist feed gas and conventional insulation, will vary from 20 pounds for the 3-man unit to 26 pounds for the 9-man unit. This low weight variation with crew size makes it desireable to produce only the 9-man unit and off-load the isotope for the lower crew sizes rather than using multiple units of the 3-man size.

Evaluation of the expected contaminants has shown that materials which poison the catalyst and produce undesireable products of combustion can be effectively controlled by both activated charcoal and lithium hydroxide. Location of the system downstream of the main activated charcoal contaminant removal bed represents the optimum use of charcoal. The pre and postsorbent beds of lithium hydroxide require a minimum charge of 1.1 pounds per man to achieve the desired removal efficiency. These beds will increase in size for missions in excess of 180 days, at a rate of .003 and .002 pounds per man day respectively.

An investigation of the reliability and maintainability of the unit has shown that .99965 is achievable for a two-year mission and a goal of .9999 can closely be approached if the lithium hydroxide pre and postsorbents are spared. The high operation temperature makes maintenence of this unit undesireable. The highly reliable and passive nature of the system makes instrumentation and controls unnecessary except for minimal readouts to monitor operations.

Evaluation of other catalytic oxidizer designs has shown that the configuration for the isotopically heated unit provides a most effective design for an electrically heated unit with the substitution of an electric heater for the isotope heat source. The major difference will lie in the use of a unit temperature control to conserve on electrical power during some operating conditions.

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Appendix A

CONTAMINANT LOAD FOR IHCOS DESIGN STUDY

Appendix A

CONTAMINANT LOAD FOR IHCOS DESIGN STUDY

Contaminant	Production Rates			Maximum Allowable Concentration (mg/m^3)	Data Source								To Be Removed By Oxidation	Flow Required Through IHCOS (cfm)
	Non-Biological (gm/day)	(1)* Biological (gm/day)	Total (gm/day)		Production Rates (23)							Allowable Concentration		
					A	B	C	D	E	F	G			
Acetone	10.20	0.0045	10.20	240	XX	X	XX	X	XX	X		(2)	X	1.25
Acetaldehyde	2.50	0.0018	2.50	36		X	X	X	X			(2)	X	2.07
Acetic Acid	0.25		0.25	2.5	X			X				(2)		
Acetylene	2.50		2.50	180		X	X	X				(3)	X	0.37
Acetonitrile	0.25		0.25	7			X					(2)		
Acrolein	0.25		0.25	0.25	X							(2)		
Allyl Alcohol	0.25		0.25	0.5	X	X	X		X			(2)	X	1.47
Ammonia	2.50	9.0	11.50	3.5		X	X					(2)		
Amyl Acetate	0.25		0.25	53					X	X		(2)		
Amyl Alcohol	0.25		0.25	36	X							(2)	X	0.16
Benzene	2.50		2.50	8	XX	X	X	X	XX	X		(2)		
n-Butane	2.50		2.50	180		X	X	X	XX			(3)	X	0.37
iso-Butane	0.25		0.25	180	X							(3)		
Butene-1	2.50		2.50	180	XX	X	X	X	XX			(3)	X	0.37
cis-Butene-2	0.25		0.25	180		X						(3)		
trans-Butene-2	2.50		2.50	180		X	X		X			(3)	X	0.37
1, 3 Butadiene	2.50		2.50	220	X				X			(2)		
iso-Butylene	0.25		0.25	180			X	X	X			(3)		
n-Butyl Alcohol	2.50	0.027	2.53	30	X	XX	XX	X	X			(2)	X	2.53
iso Butyl Alcohol	0.25		0.25	30					X			(2)	X	0.20
sec-Butyl Alcohol	0.25		0.25	30	X							(2)	X	0.21
tert -Butyl Alcohol	0.25		0.25	30						X		(2)	X	0.21

*Footnotes defined at end of table.

Contaminant	Production Rates			Maximum Allowable Concentration (mg/m^3)	Data Source								To Be Removed By Oxidation	Flow Required Through IHCOS (cfm)
	Non-Biological (gm/day)	(1) Biological (gm/day)	Total (gm/day)		Production Rates (23)							Allowable Concentration		
					A	B	C	D	E	F	G			
Butyl Acetate	0.25		0.25	71					X	X		(2)		
Butraldehydes	0.25		0.25	70					XX	X		(4)		
Butyric Acid	0.25		0.25	14				X				(5)		
Carbon Disulfide	0.25		0.25	6	X	X	X					(2)		
Carbon Monoxide	2.50	0.30	2.80	29	XX	X	XX		X	X		(6)	X	2.91
Carbon Tetrachloride	0.25		0.25	6.5	X				X	X		(2)		
Carbonyl Sulfide	0.25		0.25	25		X						(4)		
Chlorine	0.25		0.25	1.5							X	(6)		
Chloroacetone	0.25		0.25	100							X	(5)		
Chlorobenzene	0.25		0.25	35					X			(2)		
Chlorofluoromethane	0.25		0.25	24		X						(11)		
Chloroform	2.50		2.50	24	XX	X			X			(2)		
Chloropropane	0.25		0.25	84		X	X					(5)		
Caprylic Acid		X	0.25	155							X	(5)		
Cumene	0.25		0.25	25	X							(2)		
Cyclohexane	2.50		2.50	100	X	X	X		X			(2)	X	0.67
Cyclohexene	0.25		0.25	100		X						(2)	X	0.03
Cyclohexanol	0.25		0.25	20	X							(2)		
Cyclopentane	0.25		0.25	100		X						(12)	X	0.02
Cyclopropane	0.25		0.25	100	X							(7)	X	0.03
Cyanamide	0.25		0.25	45							X	(5)		
Decalin	0.25		0.25	5.0					XX			(13)		

Contaminant	Production Rates			Maximum Allowable Concentration (mg/m^3)	Data Source								To Be Removed By Oxidation	Flow Required Through IHCOS (cfm)
					Production Rates (23)							Allowable Concentration		
	Non-Biological (gm/day)	(1) Biological (gm/day)	Total (gm/day)		A	B	C	D	E	F	G			
1, 1 Dimethyl cyclohexane	0.25		0.25	120					X			(5)		
trans 1, 2, Dimethyl Cyclohexane	0.25		0.25	120		X						(5)		
2, 2 Dimethyl butane	0.25		0.25	93		X			X			(5)	X	0.03
Dimethyl Sulfide	0.25		0.25	15					X			(4)		
1, 1 Dichloroethane	2.50		2.50	40	X	X	X					(2)		
Di iso Butyl Ketone	0.25		0.25	29						X				
1, 4 Dioxane	2.50		2.50	36	XX	X						(2)		
Dimethyl Furan	0.25		0.25	3.0					X			(15)		
Dimethyl Hydrazine	0.25		0.25	0.1							X	(2)		
Ethane	2.50		2.50	180	XX	X				X		(3)	X	0.37
Ethyl Alcohol	2.50	0.09	2.51	190	XX	XX	XX	X	XX	X		(2)	X	0.35
Ethyl Acetate	2.50		2.50	140		X	XX	X	X			(2)		
Ethyl Acetylene	0.25		0.25	180		X						(3)		
Ethyl Benzene	0.25		0.25	44	X				X			(2)		
Ethylene Dichloride	0.25		0.25	40	XX	XX			X			(2)		
Ethyl Ether	2.50		2.50	120					X	X		(2)	X	0.59
Ethyl Butyl Ether	0.25		0.25	200	X							(4)		
Ethyl Formate	2.50		2.50	30				X	X			(2)		
Ethylene	2.50		2.50	180	X	X	X	X	XX			(3)	X	0.37
Ethylene Glycol	0.25		0.25	114							X	(5)		
trans 1, Methyl 3 Ethyl Cyclohexane	0.25		0.25	117		X						(4)		

Contaminant	Production Rates			Maximum Allowable Concentration (mg/m^3)	Data Source								To Be Removed By Oxidation	Flow Required Through IHCOS (cfm)
	Non-Biological (gm/day)	(1) Biological (gm/day)	Total (gm/day)		Production Rates (23)							Allowable Concentration		
					A	B	C	D	E	F	G			
Ethyl Sulfide	0.25		0.25	97							X	(5)		
Ethyl Mercaptan		X	0.25	2.5		X			X			(2)		
Freon 11	2.50		2.50	560		XX		X	XX			(2)		
Freon 12	2.50		2.50	500		X	XX					(2)		
Freon 21	0.25		0.25	420							X	(2)		
Freon 22	0.25		0.25	350		X			XX			(9)		
Freon 23	0.25		0.25	12		X						(11)		
Freon 113	0.25		0.25	700					X	X		(14)		
Freon 114	2.50		2.50	700		XX	XX		X			(2)		
Freon 114 unsym	0.25		0.25	700	X	X						(2)		
Freon 125	0.25		0.25	25		X			X			(4)		
Formaldehyde	0.25		0.25	0.6		X		X				(2)		
Furan	0.25		0.25	3					X			(15)		
Furfural	0.25		0.25	2	X							(2)		
Hydrogen	2.50	0.45	2.99	215	X							(5)		
Hydrogen Chloride	0.25		0.25	0.15							X	(6)		
Hydrogen Fluoride	0.25		0.25	0.08							X	(6)		
Hydrogen Sulfide		0.0007	0.0007	1.5		X						(2)		
Heptane	0.25		0.25	200	X				X			(2)		
Hexene-1	0.25		0.25	180	X	X						(3)		
n-Hexane	2.50		2.50	180	X	X			X	X		(2)		
Hexamethylcyclotrisihexane	0.25		0.25	240	X	X						(5)		

Contaminant	Production Rates			Maximum Allowable Concentration (mg/m^3)	Data Source								To Be Removed By Oxidation	Flow Required Through IHCOS (cfm)
	Non-Biological (gm/day)	(1) Biological (gm/day)	Total (gm/day)		Production Rates (23)							Allowable Concentration		
					A	B	C	D	E	F	G			
Indole	0.25	0.9	1.15	126			X					(5)		
Isoprene	0.25		0.25	140	X			X	X			(4)		
Methylene Chloride	2.50		2.50	21	X	X			X			(2)		
Methyl Acetate	2.50		2.50	61	X				X			(2)		
Methyl Butyrate	0.25		0.25	30					X			(16)		
Methyl Chloride	0.25		0.25	21	X	X						(2)		
2-Methyl – 1 Butene	0.25		0.25	1430	X							(4)		
Methyl Chloroform	2.50		2.50	190		X			X			(2)		
Methyl Furane	0.25		0.25	3					X			(15)		
Methyl Ethyl Ketone	2.50		2.50	59	X	X	XX		XX	X		(2)	X	1.25
Methyl Isobutyl Ketone	0.25		0.25	41					X	X		(2)	X	0.14
Methyl Isopropyl Ketone	2.50		2.50	70	X	X			X			(8)	X	1.03
Methyl Cyclohexane	0.25		0.25	200	X				X			(2)		
Methyl Acetylene	0.25		0.25	165	X							(2)		
Methyl Alcohol	2.50	0.09	2.59	26		X	XX		XX	X		(2)	X	2.90
3-Methyl Pentane	0.25		0.25	295		X			X			(2)		
Methyl Methacrylate	0.25		0.25	41					X			(2)		
Methane	29.5	5.4	34.9	1720	XX	X	XX			X	X	(5)	X	(22)
Mesitylene	0.25		0.25	2.5	X							(4)		
mono Methyl Hydrazine	0.25		0.25	0.035							X	(2)		

Contaminant	Production Rates			Maximum Allowable Concentration (mg/m^3)	Data Source								To Be Removed By Oxidation	Flow Required Through IHCOS (cfm)
					Production Rates (23)							Allowable Concentration		
	Non-Biological (gm/day)	(1) Biological (gm/day)	Total (gm/day)		A	B	C	D	E	F	G			
Methyl Mercaptan		X	0.25	2			X		X			(2)		
Naphthalene	0.25		0.25	5.0					X			(2)		
Nitric Oxide	0.25		0.25	32		X						(5)		
Nitrogen Tetroxide	0.25		0.25	1.8							X	(5)		
Nitrogen Dioxide	0.25		0.25	0.9			X					(6)		
Nitrous Oxide	0.25		0.25	47							X	(5)		
Octane	0.25		0.25	235					X			(2)		
Propylene	2.50		2.50	180	XX	X	XX	X	XX			(3)	X	0.37
iso-Pentane	2.50		2.50	295		X			X			(2)	X	0.21
n-Pentane	2.50		2.50	295	X	X			X			(2)	X	0.21
Pentene -1	0.25		0.25	180	X							(2)	X	
Pentent -2	0.25		0.25	180	X							(2)		
Propane	2.50		2.50	180	X	X						(2)	X	0.37
n-Propyl Acetate	0.25		0.25	84					X			(2)		
n-Propyl Alcohol	2.50		2.50	75	XX	X			XX	X		(9)	X	0.97
iso-Propyl Alcohol	2.50		2.50	98	X	X	XX		XX	X	X	(2)	X	0.73
n-Propyl Benzene	0.25		0.25	44						X		(17)		
iso-Propyl Chloride	0.25		0.25	260					X			(20)		
iso-Propyl Ether	0.25		0.25	120					X			(19)		
Proprionaldehyde	0.25		0.25	30	X							(4)		
Propionic Acid	0.25		0.25	15				X				(4)		

Contaminant	Production Rates			Maximum Allowable Concentration (mg/m^3)	Data Source								To Be Removed By Oxidation	Flow Required Through IHCOS (cfm)
	Non-Biological (gm/day)	(1) Biological (gm/day)	Total (gm/day)		Production Rates (23)							Allowable Concentration		
					A	B	C	D	E	F	G			
Propyl Mercaptan		X	0.25	82					X			(5)		
Propylene Aldehyde	0.25		0.25	10						X		(18)		
Pyruvic Acid		3.4	3.4	0.9								(21)		
Phenol	0.25	3.4	3.65	1.9							X	(2)		
Skatol		X	0.25	141			X					(5)		
Sulfur Dioxide	0.25		0.25	0.8							X	(10)		
Styrene	0.25		0.25	42	X							(2)		
Tetrachloroethylene	0.25		0.25	67		X		X	X			(2)		
Tetrafluoroethylene	0.25		0.25	205		X						(4)		
Tetrahydrofurane	0.25		0.25	59					X			(2)		
Toluene	2.50		2.50	75	X	XX		X	XX	X		(2)		
Trichloroethylene	2.50		2.50	52	XX	X	XX	X	X			(2)		
1,2,4 Trimethyl Benzene	0.25		0.25	49	X							(4)		
1,1,3 Trimethyl cyclohexane	0.25		0.25	140							X	(5)		
Valeraldehyde		X	0.25	70							X	(4)		
Valeric Acid		X	0.25	110			X					(5)		
Vinyl Chloride	2.50		2.50	130	X	XX	X		X			(2)		
Vinyl Methyl Ether	0.25		0.25	60						X		(19)		
Vinyldene Chloride	0.25		0.25	20		X						(6)		
O-Xylene	2.50		2.50	44		X			XX		X	(2)		
m-Xylene	2.50		2.50	44	X	XX					X	(2)		
p-Xylene	2.50		2.50	44	X						X	(2)		

NOTES FOR APPENDIX A

1. Metabolic production rate based on 9 men, production per man from Bioastronautics Data Book, NASA SP-3006. Contaminants noted by check mark have been reported, but without rate estimate.

2. Limit taken as 0.1 of the Threshold Limit Value (TLV) for 1965, American Conference of Governmental Industrial Hygienists, May 1965.

3. Limit derived by analogy to 1965 TLV for propane, butadiene, and LPG (liquefied petroleum gas).

4. Limit taken as that estimated by R. H. Edgerly, North American Aviation, October 7, 1964.

5. Limit taken as concentration that results in a vapor pressure of 0.02 torr, except for hydrogen and methane for which vapor pressure of 2.0 torr is used.

6. Limit taken as the allowable 90-day continuous exposure limit for submarines as published in Submarine Habitability Handbook, Navships 250-649-1, and from personal communication, Capt. J. Siegel, Naval Toxicology Unit.

7. Limit derived by analogy to 1965 TLV for cyclohexane.

8. Limit derived by analogy to 1965 TLV for methyl propyl ketone (pentanane-2).

9. Limit taken as 0.1 of TLV suggested by H. B. Elkins, Chemistry of Industrial Toxicology, 1959.

10. Limit taken as adverse level limit set by State of California.

11. Limit derived by analogy to 1965 TLV for chloroform.

12. Limit derived by analogy to 1965 TLV for ethyl butyl ketone.

13. Limit derived by analogy to 1965 TLV for naphthalene.

14. Limit derived by analogy to 1965 TLV for Freon-114.

15. Limit taken as 0.1 of Sax's suggested value for furan.

16. Limit derived by analogy to 1965 TLV for lower esters.

17. Limit derived by analogy to 1965 TLV for ethyl benzene.

18. Limit derived by analogy to 1965 TLV for acetaldehyde.

19. Limit derived by analogy to 1965 TLV for ethyl ether, plus divinyl ether data.

20. Limit derived by analogy to 1965 TLV for ethyl chloride.

21. Limit derived by analogy to 1965 TLV for formic acid.

22. The removal efficiency required for methane with a flow of 3 CFM is 27%.

23. Listed contaminants have been reported in connection with materials screening or atmospheric analysis as follows: (an "X" indicates reported, a double "X" means found in large amounts).

    A. = Outgassing products of space cabin qualified materials as determined by LMSC studies, as reported by Apollo C/M contaminant control studies, and as cited in Honeywell report A63 777A 22(2).

    B. = Detected as contaminants in charcoal desorption tests of samples from Mercury and Gemini (up to GT-7) ECS. (R. Saunders, Naval Research Lab.).

    C. = Detected by LMSC as contaminants in Air Force Biosatellite 30-day ground test (chimpanzee subject) (AMD TR-66-1, April, 1966).

    D. = Reported in 30-day manned experiment conducted by Aerospace Medical Research Lab. (W. H. Toliver and M. L. Morris, Aerospace Medicine, 37, 3, 233, March 1966).

    E. = Reported in 56-day manned experiment conducted by School of Aerospace Medicine (J. D. Adams, et.al., Aerospace Medicine, 37, 6, 555, June 1966).

    F. = Reported as present in Apollo C/M ECS breadboard testing.

    G. = Contaminants likely to result from experiments conducted onboard space stations.

PERTINENT CHEMICAL SYNONYMS FOR APPENDIX A

2-Butanone = Methyl ethyl ketone

Chlorodifluoromethane = Freon 22

Crotonaldehyde = Propylene aldehyde

Decahydronaphthalene = Decalin

1, 2 Dichloroethane = Ethylene chloride = Ethylene dichloride

Dichlorodifluoromethane = Freon 12

Dichlorofluoromethane = Freon 21

Dichlorotetrafluoromethane = Freon 114

p-Dioxane = 1, 4 Dioxane

2-Methyl butanone-3 = 3-Methyl 2-Butanone = Methyl isopropyl ketone

Methoxyethane = Vinyl methyl ether

Propene = Propylene

Propyne = Propine + Methyl acetylene

Pentafluoroethane = Freon 125

Perchloroethylene = Tetrachloroethylene

Trichlorofluoromethane = Freon 11

Trichlorotrifluoroethane = Freon 113

Trifluoromethane = Fluoroform = Freon 23

1, 3 5 Trimethyl benzene = mesitylene

Appendix B

COMPONENT SPECIFICATIONS

Appendix B-1

CATALYTIC OXIDIZER ASSEMBLY

Purpose

The catalytic oxidizer must maintain oxidizable trace contaminants which are not removed in the contaminant removal sorbent beds below the spacecraft maximum allowable concentration.

Description

The catalytic oxidizer assembly consists of a regenerative heat exchanger catalyst bed and either an electrical or isotope heater. These components are enclosed in a blanket of insulation to minimize the power consumption of the unit. The assembly is installed between the pre and postsorbent beds in the trace contaminant removal system. Cabin air enters the unit from the presorbent bed and passes through the regenerative heat exchanger where it is heated to near the operating temperature. This air then passes over the heater and then over the catalyst bed. The air then passes back through the regenerative heat exchanger and to the postsorbent bed. At the elevated temperature in the catalyst bed, trace contaminants are oxidized into harmless products. Figure 1 is a drawing of this unit.

Performance and Design Data

Operating pressure	10.0 psia
Temperature (with flow)	680°F
Temperature (no flow)	1000°F
Methane Removal efficiency	.30
Inlet Gas temperature	75°F
Outlet Gas temperature	185°F
Pressure loss	4.5 in. H_2O
Weight	27 lbs.
Envelope	7.6 in. Dia. x 14 in.

Appendix B-2

PRESORBENT CANISTER

Purpose

The chemical in the presorbent canister removes those contaminants in the inlet stream to the catalytic oxidizer which might poison the catalyst. This allows the continual high performance of the catalyst material.

Description

The presorbent canister is located downstream of the main contaminant removal activated charcoal adsorbent bed. Air with catalyst poisons passes through the bed which is charged with lithium hydroxide. The concentration of the poisons are reduced by an order of magnitude when passed over the bed. The outline of this unit is shown in fig. 4.

Performance and Design Data

Operating pressure	10.0 psia
Operating temperature	75°F
Contaminant removal	less than .10 inlet
Pressure loss	.22 in. H_2O
Weight	31 lbs. total
Weight - Lithium Hydroxide	25 lbs.
Volume	10.8 in. Dia. x 26.3 in.

Appendix B-3

POSTSORBENT CANISTER

Purpose

The undesireable gases generated by combustion of contaminants in the catalytic oxidizer must be removed in the postsorbent canister. These gases will include materials such as HF, HCl, Cl_2, etc. The contaminant level of the gases leaving the unit must be held below the spacecraft maximum allowable level.

Description

The postsorbent canister is located downstream of the catalytic oxidizer. Air from the catalytic oxidizer containing undesireable products of combustion passes into the unit from the oxidizer and through a bed of lithium hydroxide. The lithium hydroxide, combined with the poisonous gases, prevents their return to the cabin.

Performance and Design Data

Operating pressure	10.0 psia
Operating temperature	185°F
Contaminant removal	outlet less than SMAC
Pressure loss	.18 in. H_2O
Weight	25 lbs.
Weight - Lithium Hydroxide	20 lbs.
Volume	10.8 in. Dia. x 22.4 in.

LIBRARY CARD ABSTRACT

A study was performed to develop data on an Isotope-Heated Catalytic Oxidizer System (IHCOS) including pre and postsorbent beds for 3, 6 and 9-man crew sizes for a Basic Subsystem Module Study being carried out by Convair for the MSC. This was an extension of a "Study and Preliminary Design of an Isotope-Heated Catalytic Oxidizer System" conducted for Langley Research Center by Lockheed.

Potential catalyst poisons and substances which might yield dangerous products of combustion were identified. Sorbents were evaluated for the purpose of protecting the catalyst and to control undesireable substances in the catalytic oxidizer system. Activated charcoal and lithium hydroxide were selected for the presorbent bed, and lithium hydroxide was selected for the postsorbent bed.

The oxidizer unit was originally conceived for a 9-man crew and space station mission application. The 9-man oxidizer unit was scaled to provide data for 3- and 6-man crew sizes. Only slight weight and volume savings were shown for the smaller crew sizes.

A reliability evaluation of the system was made and it revealed that a basic goal of .99965 could be met with careful design and no spares. The goal of .9999 could be approached only by providing spare lithium hydroxide units.