NASA Conference Publication 3085

Space Station *Freedom* Toxic and Reactive Materials Handling

Edited by
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Proceedings of a workshop implemented by
Teledyne Brown Engineering under contract with
NASA George C. Marshall Space Flight Center
and held in Huntsville, Alabama
November 29–December 1, 1988

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FOREWORD

In the summer of 1988, members of NASA Headquarters, in particular, the Office of Space Science and Applications (Code E), the Office of Aeronautics and Space Technology (Code R), and the Office of Space Station (Code S), along with the George C. Marshall Space Flight Center came to a conclusion that a broad-based review and discussion of Space Station internal contamination issues would be desirable.

Teledyne Brown Engineering (TBE) in Huntsville, Alabama was contracted to organize, conduct, and document a workshop with the theme "Space Station Freedom Toxic and Reactive Materials Handling". TBE mailed over 150 invitations to civilian and military government agencies, research organizations, universities, and industries in the U.S. Also, the Space Station international participants were invited and representatives from ESA and NASDA were in attendance. A number of persons were personally invited to present papers.

The workshop took place at the Hilton Hotel in Huntsville, Alabama on November 29 through December 1. Thirty-two papers were given, supplemented by many lively discussions. Among the 220 persons in attendance were astronauts Dr. Owen K. Garriott, Dr. William Pogue, and Dr. Bonnie J. Dunbar.

Although the workshop had originally been planned to address only questions related to internal contamination issues on the Space Station, presentations, and particularly discussions, covered a larger scope including external contamination issues. Some key workshop results included an increased safety awareness for Space Station Freedom Program participants, clairification of some key safety requirements, and initiation and continuation of dialogue between various program participants.

A panel was formed to moderate the discussion, answer questions, summarize the workshop discussion, and to make recommendations. The panel consisted of Dr. Bonnie J. Dunbar, NASA/JSC, Dr. Martin E. Coleman, NASA/JSC, and Mr. Kenneth L. Mitchell, NASA/MSFC. The panel's summary report and recommendations are included in this proceedings document.

Many attendees expressed the desire that a similar workshop should be convened in the near future.

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ACKNOWLEDGEMENTS

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December 16, 1988

Mr. Paul Galloway
Workshop Coordinator
Teledyne Brown Engineering
Cummings Research Park
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Dear Mr. Galloway,

Thank you again for the opportunity to participate in the Space Station Freedom Toxic and Reactive Materials Handling Workshop. We believe that the workshop was a very successful exchange of information between diverse technical communities and provided useful recommendations for approaching future Space Station designs and operations.

As a panel, we were tasked to "enhance the productivity of the workshop by ensuring that the findings of the workshop did not fall between the cracks". We were asked to summarize the workshop discussions and to provide recommendations related to safety issues, technology development efforts, and other follow-on tasks which might be required. The nature of this workshop and our directive required us to focus on topics of concern; however, this should not diminish the positive contributions which both NASA and its contractors have given to these complex problems. The solutions to technical and operational problems which remain will require a united and cohesive application of our best resources.

Our final panel report is enclosed. While we believe that more workshops in the future will benefit Space Station design and utilization, we also believe that immediate action is required for some identified issues. Should questions arise regarding this report, please contact any member of the panel.

It has been our pleasure to have participated in this workshop.

Sincerely,

Bonnie J. Dunbar

Bonnie J. Dunbar, PhD
NASA/JSC, Astronaut
Panel Chairman

Kenneth L. Mitchell

Mr. Kenneth L Mitchell
NASA/MSFC, ECLSS

Martin E. Coleman

Martin E. Coleman, PhD
NASA/JSC, Toxicologist

SPACE STATION FREEDOM

TOXIC AND REACTIVE MATERIALS HANDLING

WORKSHOP

November 29 - December 1, 1988

PANEL SUMMARY AND RECOMMENDATIONS

December 19, 1988

N91-15931

INTRODUCTION:

Teledyne Brown Engineering (TBE) was tasked by several NASA Organizations to organize, conduct and document a workship devoted to Space Station internal contamination issues. These organizations included the Office of Space Station (Code S), the Office of Space Science and Applications (Code E), and Office of Aeronautics and Space Technology (Code R). Representatives from NASA, NASDA, ESA,Space Station contractors and the private sector were invited to attend. Approximately 200 individuals attended, representing a broad spectrum of industries and organizations.

The official program was divided into several sessions which addressed the following topics:

1. Past Flight Experience (Skylab and Spacelab missions)
2. Present Flight Activities (Spacelabs and Soviet Space Station Mir)
3. Future Activites (Materials Science and Life Science Experiments)
4. Space Station Capabilities (PMMS, FMS, ECLSS, and US Laboratory Overview)
5. Manned Systems/Crew Safety
6. Internal Contamination Detection
7. Contamination Control - Stowage and Handling
8. Contamination Control - Waste Gas Processing

In order to document and summarize the findings of this workshop, TBE appointed a panel consisting of the following members: Dr. Bonnie J. Dunbar (NASA/JSC), Dr. Martin Coleman (NASA/JSC), and Mr. Kenneth Mitchell (NASA/MSFC). The panel facilitated discussion during the sessions and summarized these discussions and resulting recommendations at the completion of each days activites.

This report is a compilation of issues, concerns, and other topics which arose during the workshop. It is divided into three sections. In the first section, Space Station design assumptions are discussed. The second section discusses issues and concerns as they relate to (1) policy and management, (2) subsystem design, (3) experiment design, and (4) internal contamination detection and control. The last section summarizes the recommendations generated during the three day workshop. Most of the concerns and recommendations summarized in this report were not the result of single sessions, but appeared as recurring themes during the workshop.

The panel believes that the workshop was very worthwhile and that serious decisions must now be made. *We believe that, in order to avoid costly redesign in the future, the issues and concerns identified in this report should be receiving maximum attention by the Space Station Project in its early engineering development of subsystems and experiment facilities.*

SPACE STATION DESIGN ASSUMPTIONS:

Space Station *Freedom* design is currently comprised of one habitability module and of three laboratory modules; one each from the United States (USL), Japan (JEM), and the European Space Agency (Columbus). All four of the modules are interconnected by nodes. The experiments which will involve the bulk of the hazardous materials to be handled represent two disciplines: life sciences and materials sciences. While both of the disciplines have flown on prior Skylab and Space Shuttle missions, the Space Station will include many new *in situ* sample preparations. For the materials sciences, this includes a family of liquid etching acids for which we have no prior space flight experience. In the field of life sciences, although we have previously "fixed" samples on orbit, both animal dissection and cell cultures will introduce new experiment materials and operations to the Space Station.

There are several fundamental design and operations concepts which are applied to terrestrial laboratories and which can be considered relevant to a space-based facility. They are the following: (1) the Space Station *Freedom* is an international laboratory which should be governed by well understood and consistent safety policy/guidelines, (2) facility design is the first line of protection against hazardous situations but operations of the design must also be well understood, (3) if the facility design/operations fail, then appropriate detection should be in place to annunciate the hazard to the crew, (4) there must be preplanned on -orbit methods to recover and handle wastes, including accidental in-cabin spills, (5) procedures and hardware must be present to medically treat crewmembers, and (6) the wastes must be transported safely to the ground for further disposal.

The handling of toxic and reactive materials aboard the Space Station will be particularly challenging for the following reasons: (1) The Station is nearly a closed environment-- rapid evacuation is not possible, (2) the laboratory researchers must habitate a volume intimately connected to their laboratory, and (3) materials science and life science experiments wil be conducted in the same laboratory; this does not occur in ground based laboratories.

There are presently three Station subsystems being designed which are involved in the detection and /or control of toxic and reactive materials: the Environmental Control and Life Support System (ECLSS), the Process Materials Management Subsystem (PMMS), and the Fluid Management System (FMS).

The primary U.S Lab subsystem being designed to interact with hazardous/toxic and reactive materials is the PMMS. It consists of the following elements.

- Process Fluids Storage and Distribution
- Chemical Storage
- Materials Transport
- Ultrapure Water Management
- Waste Materials Handling
- Leak Detection
- Crew/hardware decontamination
- Vacuum Venting (high quality source and waste gas vent)

The Space Station ECLSS provides trace contaminant gas removal from the crew's breathable atmosphere as well as monitoring of atmospheric contaminants (gases and particulates). These trace gases are primarily generated from metabolic processes of the crew and electronics equipment off-gassing. The PMMS and/or the payload will provide containment and control for their non-standard substances--not the ECLSS.

The FMS interacts with the PMMS in the vacuum venting of waste gases and the resupply of fluids (water, mitrogen) to the U.S. Lab. The allowable waste gas constituents are being defined to the work packages and the International partners through a Level II FMS working group.

FINDINGS AND CONCERNS

POLICY AND ORGANIZATION

1. THE NEED FOR A SAFETY ATTITUDE

Although engineering solutions are being designed to handle toxic and reactive materials on a routine basis, we found a lack of emphasis on both operations and the exploration of accident scenarios. Clearly, the designers must prepare for the worst in addition to designing to prevent it. Specifically, more emphasis needs to be placed upon approaches to "in cabin spills" resulting in the cleanup of hazardous or toxic materials, and the isolation of contaminated modules,. This was well reinforced by several of the private sector presenters at the workshop. Additionally, the responsiblity for these activities should be assigned to an organization. There appeared to be no one who believed that to be in "their charter". *The safety attitude is germane to any research program. It is a day to day responsibiity for everyone involved.*

2. THE NEED FOR A UNIFORM SAFETY POLICY

This workshop was organized for all Space Station participants. However, ESA sent one representative who was not a professional safety employee and NASDA sent two representatives, but their safety policy was not voiced. From the discussions which occurred, we concluded that the Safety Policies which we believe are in effect for Space Shuttle and which are being developed for Space Station are not being communicated to our international partners. As a matter of information, the ESA representative informed the group that ESA assumed that NASA would dictate safety requirements to them, and had not yet taken a formal look at safety in the Columbus module development. Implementation of safety policies in the US module alone will not protect a crew from catastrophic events.

The Station must be viewed as one resource operating under one standard of Safety, for both experiments and subsystem development. Reference should be made to the NRC series on "Prudent Practices for Handling Hazardous Chemicals in Laboratories". Additionally, the question of who is vested with final responsibility for safety of the Station's internal environment should be clarified

3. THE NEED FOR A MATURE SAFETY ORGANIZATION

During the workshop, both Space Station subsystem designers (ECLSS, FMS, PMMS), and experiment developers stated that their hardware designs were dependent upon clearly articulated safety requirements. Without specific design requirements and access to past flight experiences, hardware is subject to later redesign. However, the Space Station Safety organization is still being developed and not in the position of advising either system designers or experiment developers (particularly material processing furnaces) on such items as fault tolerance, triple containment, etc.

Although the JSC Safety Boards have addressed many of these same questions with respect to the Space Shuttle/Spacelab subsystems and payloads, most of these designers do not have access to these boards. In many cases, the designers, by not being familiar with past flight experiences using similar designs, were "re-inventing

the wheel". For example, the PMMS and FMS are at a point when serious design decisions must be made (these are discussed later). The early involvement of flight safety personnel with facility designers/experimenters should resolve many issues, avoiding serious redesign of equipment.
One suggested solution is to utilize the safety organization at NASA/JSC for an interim period of time, so that timely response is available to the hardware designers. However, with the advent of the Space Station Safety boards, continuity should be maintained. The utilization of different NASA safety organizations should be virtually transparent to a user of either Shuttle or Space Station. Many payloads will fly on both. For example, the furnaces which are being developed by ESA, NASDA, and many US users for Space Station will fly first on Spacelab flights.

Another suggestion is to combine these NASA safety organizations, thereby reducing the number of safety interfaces for a user, and providing consistency and a past flight experience data base to the evaluation of subsystem designs. Consistent safety policy is important for all space flight elements.

Members of the workshop suggested that until more access to the Safety Organization is available, the Space Station program should provide safety related design requirements in a "Users Manual". This manual should provide hardware design options and clearly define such concepts as "two fault tolerance, triple containment and hazard control". Furnace designers wish to understand the concept of "credible failure" and how procedures, functional features (e.g door interlocks, etc) and negative pressure operations contribute to their design. Communication of past and present flightexperience related to safety and facility designs is essential. Designers should also have access to Spacelab Hazard Analyses and Safety Compliance Data. For many users, the need for this documentation is now.

Unless the development of the Safety organization can be expedited, both the station schedule and cost are at risk.

4. THE NEED FOR BETTER COMMUNICATIONS

Better communications are required across the board: Between the international partners, between the NASA Centers, between the contractors and NASA, between NASA and Industry, and between all elements and the flight operations organizations. The Office of Space Flight (Code M) was not an official organizer of this workshop but is responsible for flight crew training and safety. Future discussions regarding operational experiences and approaches to on-board safety may be directed to the Flight Crew Operations Office (FCOD) at NASA/JSC.

FCOD has several internal Astronaut organizations expressly established to develop an early working relationship with flight hardware designers: the Shuttle Mission Development Group, the Space Station Group, and the Science Support Group.

Communications must be open, frequent, and along more clearly defined paths among Centers and other organizations. Our past flight experience with STS-51L and the emphasis that the Rogers Commission placed on communications must not be "lessons learned" which are lost. This workshop was believed by all participants to be an important first step in that direction.

5. COMMONALITY

The question of commonality, which has arisen in other system designs affecting the international modules, is even more important in the arena of safely handling toxic and reactive materials. There is not a common design approach for the handling of these materials and it is not apparent that the international partners are actively addressing the potentional problems. Again, the agency is faced with defining safety design criteria and then implementing these as requirements. An important question is how NASA will task these requirements to the partners and oversee their implementation. The Space Station crews must not be trained to safe three different system designs. The lack of commonality between safety systems is a well known contributer to industrial and aircraft accidents.

STATION SUBSYSTEM DESIGN

6. UTILIZATION OF GROUND BASED LABORATORY SAFETY FEATURES

Procedures and data generated by ground based laborabories is an excellent resource data base for understanding and implementing procedures/hardware for the safe handling of toxic and reactive chemicals. NASA should not re-invent the wheel. One representative from the semiconductor industry stated that we were about 5 years behind industry in our approach to the problem. At the same time, users stated that new safe handling procedures which NASA may develop for this more restrictive environment may have commercial applications on the ground. More interaction with both industry and commercial laboratories should be pursued.

7. NUMBER OF ECLSS STATIONS FOR MONITORING TRACE GASES

The total number of ECLSS locations for monitoring trace gases in the cabin atmosphere needs to be evaluated with respect to the entire monitoring systems in the USL, JEM, and Columbus. Currently 7 locations are baselined in the Space station configuration with the international modules attached. This may not be enough, particularly if early "leak warning" needs to be annunciated to the crew. The PMMS plans to detect at the rack level, but it is not clear if these will be experiment specific or general detectors.

8. PMMS DESIGN LIMITATIONS

As designed, the PMMS proposes to collect a variety of both life science and materials science wastes. In this respect, it has a much broader scope than any existing ground based laboratory or industry. However, it has limited the types of waste it will handle. The limitations to experiment development are not clear. Experiment designers need this information in order to procede. Questions remaining include which wastes are regenerable (besides the water recovery feature) and what waste storage systems will PMMS provide for returning hazardous waste to earth via the logistics elements.

The current PMMS baseline design has a centralized waste material approach. Trades are to be performed on alternate approaches: decentralized storage of waste by PMMS versus user provided waste storage at the rack level. Current Shuttle/Spacelab operations do not use a common waste collection system. Chemicals (e.g. varieties of acids) used in the etching of metrology specimens might be better handled within the glovebox and stored in a separate container for transport back to the ground. The mixing of acids, cell cultures, fixatives, and etc presents an infinite matrix of design requirements for a disposal system. Since Space Station facilities are being designed now, there is a definite need to identify their interfaces and requirements for waste disposal. As an added note, neither the JEM or Columbus have an interface with the PMMS, which may result in at least three methods for storing and transporting experiment wastes. Experiments which may design their interfaces for the US lab may find that although they have access to the ESA or Japanese labs, their experiment interfaces are incompatible.

Finally, NASA should review certain design features of the PMMS using past experience with liquid transport systems (e.g. Shuttle/Spacelab and Skylab). For example, it is not clear how the wastes from a glovebox operated experiment are actually introduced to the PMMS water lines in a micro-g environment; how residue left in containers are handled: how wastes which may have deposited on the interior of the large volume gloveboxes are collected for disposal, and how the task for predicting multi-chemical reactions in a "holding tank" will be accomplished, particularly if the chemicals used in metrology or cell fixation today may not be the same ones we use in 10 years.

9. ISOLATION OF THE ECLSS AVIONICS AIR COOLING LOOP

The isolation of the avionics air loop from the equipment containing toxic chemicals could be a design issue. More investigation of the user requirments for cooling and the hazards associated with the equipment requiring cooling must occur.

10. HUMAN FACTORS ARE AN IMPORTANT ELEMENT IN SAFETY DESIGN

Facilities should consider the mainenance and repair capabilities of the crew on orbit, particularly if a system is critical to continued safe functioning of the station. Hazard detection and adequate alerts to the crew are essential. As illustrated by both the Skylab and Shuttle crewmembers, alerts should identify both the location of the hazard as well as the type.

11. CONTINGENCY PLANNING IS ESSENTIAL

Contingency planning should be an essential element of hardware design. Unexpected events should be expected and planned for. It was recommended that procedures and hardware be developed for in cabin spills (for both subsystem and experiment failure) and that hazardous payloads be manifested far from exits. Participants felt that locating the emergency shower or an alternate decontamination system in the node would provide better isolation of a crewman from a spill and allow more ready access from the ESA and JEM modules.

12. DESIGN OF A CREWMEMBER DECONTAMINATION SYSTEM

Ground based laboratories usually utilize emergency showers and eye wash systems to rapidly remove contaminating materials from the body. Space Station has located a hygiene shower in the U.S. Laboratory which will also be used as an emergency shower. Several aspects of this approach must be evaluated: (1) will a shower work as effectively in a zero G environment as it does in one G? (2) what are the ramifications of detoxifying a crew member in the module which must be isolated? (3) will crewmembers working in other modules having no similar system be able to use the system and won't cross contamination become a problem? and (4) what other neutralizing systems and treatment are also readily accessible?

Ground based showers use a deluge system and rely on a large volume of water to dilute contaminants on the body and deliver them away from the body. In zero G, such a shower would require immediate storage access and a large vacuum to pull water from the body and surrounding shower surfaces.

13. SPACE STATION SMAC VALUES MUST BE EXPEDITED

The spacecraft maximum allowable concentration (SMAC) levels for trace contaminants in the cabin atmosphere have not been defined for space station. Current designs use shuttle data for a 10 day mission. NRC is under contract to JSC to develop design criteria. The ECLSS and the PMMS need this data as soon as possible in order to design control and monitoring systems.

14. DESIGN VERIFICATION ABOARD THE SHUTTLE

Many of the new fluid handling systems represent new technologies and will receive their first flight test once installed on the Space Station. Consideration should be given to flight verification of some of these newer systems prior to implemention on the station. ESA is currently using Spacelab flights for Columbus subsystem and experiment development. Flight test should ideally occur in 1990 to support development schedules (CDR) but the lack of access to the manifest and the estimated costs ($44M/ flight for ECLSS) are presently formidable barriers.

15. DESIGNING AIR FLOWS FOR SAFER OPERATIONS

In microgravity, it may be beneficial to consider designing air flows to give directionality to the movement of fluids in the Space Station modules. In ground based facilities gravity is relied upon to pull hazardous and toxic chemicals down away from the faces of experimenters. On the Space Station, creative solutions may be required to perform a similar function. The greatest personnel hazards are from eye contact, inhalation, and ingestion.

16. DECENTRALIZATION OF HAZARDOUS WASTE

Decentralization rather than centralized handling of waste again became a theme of the "Industry approach". Control the hazard as quickly as possible and isolate it from other locations in the system. This applies even to the laboratory module level. Industries' laboratores are isolated totally from the rest of the facilities. The Space station ECLSS integrates the module atmospheres for control of the total pressure, oxygen pratial pressure, CO2 removal, trace gas contaminant monitoring and control, and some humidity control. If an emergency occurs within a module, there is the capability to isoate it from the rest of the staion configuration but this occurs after the fact. Normally, in the interest of safety and crew rescue, hatches to the experiment modules should remain open during experiment operations and only closed in the event of an emergency.

EXPERIMENT DESIGN

17. IS VACUUM VENTING ALLOWED ?

Many of the experiments in high temperature materials science require an external vent line for two reasons: (1) to rough pump a vacuum on the experiment and (2) to expell inert gases (e.g. He and Ar) which have been used during the experiment process. Although vacuum venting has been used on previous Spacelab flights, there was considerable disagreement regarding its allowance on Space Station. Arguments largely related to the degree of contamination to the external environment. Additionally, although the US users are actively debating this question, it appears that ESA will continue in the Spacelab mode. Therefore, the present station design calls for a US lab which will not allow users to vent inert gases overboard, therefore constraining or eliminating many experiments, while the Columbus will allow it. Resolution of this question must occur as soon as possible. Systems design can not proceed without a decision, and analyses will be required in any case.

18. THE NEED FOR AN EXPERIMENT DESIGN DATA BASE

As stated earlier, there is much confusion among new experiment/facility developers concerning levels of containment, hazards, fault tolerance, etc. There is an early need to establish a data base of criteria and acceptable designs which have previously flown. Many new furnace designers are again re-inventing the wheel and not benefitting from the data generated during Shuttle and Spacelab flights.

19. AVAILABLE CREW TIME FOR EXPERIMENTS

There is still considerable discussion regarding crew availability to perform experiments, experiment reconfiguration, and repair. While crew time may be a factor in equipment design, the science objectives shouldn't be compromised in order to achieve total autonomy. Whether or not an experiment requires extensive crew time depends somewhat on its discipline (e.g. life science experiments may require much crew time) and its objectives. Designers should try to optimize both automation and crew interaction. Where crew operation is required to achieve science objectives, then this should be articulated and coordinated early in the design process. In many cases, automation is less flexible, more costly, and more complicated than use of the crew. Automation lends itself to routine and repetitive tasks and should be used accordingly. Astronauts at NASA/JSC have established a Science Support Group to work with scientists and engineers early in the design process.

20. GLOVEBOX DESIGN AND USER REQUIREMENTS

The Glovebox briefings revealed the need for more user involvment to define user requirements. It wasn't clear whether the potential users of the glovebox (who must interface their experiments with it) were at the workshop. Users must spend more time with the designers and representatives of the astronaut office discussing experiment operation and requirements. Unless this occurs, equipment such as the glovebox, the PMMS, and the general lab support equipment will not be properly developed. More meetings between real lab users and the hardware designers must occur.

INTERNAL CONTAMINATION DETECTION AND CONTROL

19. EXPLORE INSTRUMENTATION TECHNOLOGY MORE THOROUGHLY

Presentations on internal contamination and control showed exciting applications to space station problems. In particular, the government's military programs on chemical and biological warfare has produced instrumentation and removal devices that have significantly more capability than any of the current systems being investigated. NASA needs to explore these developments and determine whether they are first generation systems for the space station or second generation, evolutionary systems that we could place on the station within its 30 year life. The specific items are the MS/MS technology presented by Dr. Marsh and the reactive bed plasma system for contamination control presented by Mr. Joe Birmingham. The particulate detection technology presented by Mr. Robert Caldow appeared to have Space Station applications as well.

RECOMMENDATIONS

POLICY AND ORGANIZATION

1. Establish clear and uniform Safety Policies for all modules: JEM, Columbus and USL. Approaches to safety policy implementation should be similar to those used for ground based national laboratories (consult NRC guidelines).

2. Expedite development of the Space Station Safety Organization and utilize existing NASA safety organizations as required. (Flow chart the different center responsibilities)

3. Develop accident scenarios, such as for "in-cabin spills", and assign responsibility for detection and removal (both hardware and procedures development) to appropriate organizations.

4. Require all modules to develop *common* approaches to the distribution, handling, containment, and use of toxic and reactive materials. Safety dictated designs should immediately be transmitted to JEM and Columbus developers.

5. Improve communications across the board: NASA centers, International partners, contractors, users, industry, flight operations, safety organizations, etc

6. Schedule more user/designer/operator workshops to communicate safety related design requirements.

STATION SUBSYSTEM DESIGN

7. Utilize more ground based laboratory safety features.

8. Reevaluate the total number of ECLSS stations for trace gas monitoring.

9. Conduct a separate review of the PMMS in the following areas: waste storage systems, commonality with JEM and Columbus, 30 year flexibility, waste limitations as they relate to user requirements, introduction of wastes to the system, and quantity of water required for operations.

10. Evaluate potential locations and design requirements for a decontamination center in leiu of an "emergency shower".

11. Reevaluate isolation of the ECLSS avionics air loop from experiments.

12. Review ECLSS, FMS, and PMMS designs with respect to human factors: maintenance and repair, caution and warning, and emergency procedures.

13. Expedite the definition of Space Station SMAC levels.

14. Examine the benefits and limitations for decentralization of hazardous materials handling.

15. Determine if design verification for certain fluid handling systems is required aboard Space Shutlle flights prior to Space Station implementation.

16. Optimize air flows within the modules and the gloveboxes for safer operations.

EXPERIMENT DESIGN

17. Determine the status of potential contamination due to external venting of experiment waste gases by all module elements. This information must be acquired immediately so that design processes for the FMS and experiments can continue. (The External Environments Working Group may be performing this assessment)

18. Generate a Space Station User's manual and an experiment design data base which discusses design requirements as they relate to safety.

19. Re-examine crew operations of experiments both from a safety point of view and for optimizing scientific return. Optimize the automation/crew operation mix.

20. Reevaluate the glovebox design and user requirements (utilize previous flight experience with the ESA glovebox flown on STS-61A)

INTERNAL CONTAMINATION DETECTION AND CONTROL

21. Improve communications with both industry and the military for detection, removal, and control of toxic and reactive materials.

2. WELCOME

Edgar R. Pevey and Kenneth R. Taylor

Edgar R. Pevey*

Good morning ladies and gentlemen. On behalf of Teledyne Brown Engineering, NASA Headquarters, Marshall Space Flight Center, and the MMPF Study Team -- welcome to Huntsville, Alabama, the Huntsville Hilton, and, in particular, to our workshop "Space Station Toxic and Reactive Materials Handling". I am Ed Pevey, Manager, Engineering Studies, Advanced Programs Department, Space Programs Division at Teledyne Brown.

Prior to the start of the workshop, I wish to recognize some of our key players and those team members responsible for pulling together the participants in this workshop.

First, from Marshall Space Flight Center, our customer Mr. Ken Taylor, Chief, Materials Processing in Space Group; a member of Ken's group and the Contracting Officer's Representative for the MMPF Study - Mr. George McCanless. This workshop is being funded by Codes E, R, and S and to them we are grateful for this opportunity.

Next, from Teledyne Brown Engineering, our Vice President of Space Programs Division - Dr. Owen Garriott. The Manager of Advanced Programs - Mr. Anthony Sharpe. My workshop team: The workshop coordinator - Mr. Paul Galloway and administrative assistants Ms. Becky Dew and Ms. Teresa Strother.

We are indeed pleased to recognize and welcome several former astronauts/mission specialists Dr. Bill Pogue, a former Skylab astronaut, and Dr. Bonnie Dunbar, a mission specialist on the Spacelab D1 mission.

Next, I wish to recognize our Session and Panel Chairpersons.

Session 1 - Mr. Charles Baugher, NASA/MSFC

Session 2 - Ms. Judith Robey, NASA HQ Code S

Session 3 - Mr. Richard Tyson, NASA HQ Code R

Panel Chairperson - Dr. Bonnie Dunbar, NASA/JSC

Panel Members - Dr. Martin Coleman, NASA/JSC
Mr. Kenny Mitchell, NASA/MSFC.

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*Manager, Microgravity Materials Processing Facility (MMPF) Project, Teledyne Brown Engineering

Again, to all of you -- both participants and attendees - a very warm Alabama welcome.

At this time, I present Mr. Ken Taylor for his opening comments.

Mr. Taylor has over 26 years of experience as a Project Engineer, systems engineer, and Program Manager. Mr. Taylor is chief, Materials Processing in Space Group within the Advanced Systems Office of the Program Development Directorate at NASA's George C. Marshall Space Flight Center in Huntsville, AL. The Materials Processing in Space Group is the focal point for planning and managing activities in the new field of materials processing in space.

Mr. Taylor is currently a member of the AIAA Technical Committee for Space Processing. He is a graduate of Mississippi State University with a degree in mechanical engineering.

Please welcome Mr. Ken Taylor.

Prior to our first speaker I have a few administrative announcements.

- The registration desk will be maintained just outside this room. There to assist you with telephone messages, etc. are Becky and Teresa.
- Dinner tickets are on sale - encourage you to invite your spouse.
- We have microphones in the audience - if you have a question please step to the microphone, state your name, and then ask your question or provide comments. If we run out of time for questions, feel free to question the speakers off-line or bring your question up during the panel discussions.
- Our daily schedules are tight - please observe the start time and be seated on time.

Now, I present Mr. Anthony Sharpe who will provide the outline of the Workshop Program.

Mr. Sharpe has over 25 yeas of combined aerospace and space experience as Manager and Project Manager of various systems engineering and Space Station definition studies. Prior to coming to Teledyne Brown Engineering he was with SPAR Aerospace Limited in Canada where he was a Manager in the Shuttle Remote Manipulator System Division. With Teledyne Brown Engineering, he is Manager of the Advanced Programs Department, Space Programs Division. He received his Bachelor of Science degree from the University of Leeds, England. Please welcome Mr. Tony Sharpe.

Kenneth R. Taylor*

From a payload point of view, the advent of Space Station offers us tremendous increases in the capability to operate in space.

- About an order of magnitude increase in power
- Over 5 times the time compared to 10 shuttle flights per year
- Significant increases in volume
- Perhaps an order of magnitude increase in mass of on-orbit payload equipment

In space just as on earth, the amount of R&D that can be done is to a large degree dependent upon the time available to do work, the power available, and the volume and mass of the equipment available. So, the Space Station offers us some great opportunities to expand R&D in space. Moreover, the cost of space R&D, which particularly important to commercial users, is directly affected by the volume of payload activity. The fixed cost of launch and operations can be diluted by increasing payload activity to yield lower cost per experiment run.

Therefore, we believe we need to prepare ourselves to capitalize upon these opportunities by ensuring that we know how to operate R&D payloads on the Space Station.

Essentially we intend to compare what is required with what is available in order to determine what we need to do to captalize on Space Station to the fullest.

Fortunately, we have a lot of background available to us.

- There is our past experience on skylab and we have people that worked on board that vehicle and on the project.
- We have similar expertrise from the Spacelab Module Project.
- We have designers, developers, and investigators on the key items of current and future payloads that will be adapted to or designed for the Space Station.
- We have expertise on the measurement, monitoring, and control of materials.
- And of course, we have key Space Station participants.

Our goal is an interchange between you that will begin to develop the design and operational guidelines that enable us to fully capitalize upon space to advance material science and technology, in particular, and space research and development in general. You

*Chief, Materials Processing in Space Group, NASA/MSFC a:e the key to obtaining this goal. Y‹ u h: ... invited not only for your expertise, but ... cause of your dedication and can-dor a... to your work.

Therefore, we appreciate you... and hope that each of you benefit from this workshop as much as the worksh... efit from you.

3. INTRODUCTION

OUTLINE OF WORKSHOP PROGRAM

Anthony Sharpe*

The advent of the Space Station will mark the beginning of a new and enormously exciting era of space experimentation and operations for NASA and this nation. For the first time since the Skylab days, people will live and work for extended periods of time in a permanent orbiting space facility. Their home will be the habitat module, in which they will eat, sleep, exercise and simply relax. Their workplace will be the laboratory modules, in which they will conduct a wide variety of materials processing and life science experiments, timeshared with many other operations (ranging from routine maintenance and repair, to monitoring and controlling external attached payloads). In the development of these modules the highest possible priority will be given to establishing provisions that will ensure crew comfort and safety at all times. This will be particularly challenging in the case of the laboratory modules, since certain activities within these modules (examples of which are: experiment setup, sample changeout, sample analysis, and experiment hardware cleanup) may require crew interactions with hazardous materials.

NASA Headquarters and the Marshall Space Flight Center recognize that the need to accommodate and handle the wide variety of materials anticipated within the laboratory modules gives rise to major crew safety issues that must be resolved early in the Space Station program. Appreciating that, when complex issues have to be addressed, many heads are better than one (especially if they belong to experts!), NASA Headquarters (Codes E, R and S) - under the auspices of the "Space Station Environmental Steering Group," have given Teledyne Brown Engineering the task of organizing this workshop with the theme: "Space Station Toxic and Reactive Materials Handling.

We would like to extend a very warm welcome to all of you who have accepted our invitation to attend this workshop. Our aim, of course, is to "pick your brains"; but we also hope that these three days at Huntsville Hilton will prove useful and rewarding to you in your own work.

The workshop consists of three one-day sessions, organized in a logical sequence, beginning with a consolidation of hazardous materials handling requirements for Space Station, in Session 1; continuing with a review of current Space Station concepts (both hardware and operational) for handling hazardous materials, in Session 2; and concluding

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with a review of existing and advanced systems for detecting and controlling chemical contaminants, in Session 3.

Specifically, in Session 1, we will review our past experience in handling hazardous materials in space, and will include presentations on previous Skylab and Spacelab missions. Our review of present activities will benefit from presentations on upcoming Spacelab missions and the current work being performed by the Soviets. The future requirements for materials processing on the Space Station will be reflected in presentations on the six Code EN experiment facilities. Also, a presentation on life science payload requirements will identify the unique requirements of the life science community.

In the first half of Session 2, we will have an overview of the Space Station, and those subsystems that are dedicated to the role of handling hazardous materials safely. Two major Space Station subsystems that will be discussed are the Environmental Control and Life Support Subsystem and the Fluid Management Subsystem. Also discussed in the Session 2 will be the capabilities and interfaces of the Process Materials Management Subsystem, which is the primary subsystem of the United States Laboratory charged with the task of handling and disposing of hazardous materials. In addition, the Space Station's logistics capabilities will be addressed.

The second half of Session 2 will come to grips with the subject of manned systems and crew safety, which is the primary purpose of the workshop. NASA should be commended for addressing the crew safety issue early in the Space Station program while modifications to the hardware and operational concepts can be incorporated with little cost and schedule impact.

Our third and final session will address internal contamination detection and contamination control. We will have presentations highlighting existing contamination control devices, such as gloveboxes, and we will examine advanced technology developments and new processes for their potential application to the Space Station program. Various technical approaches to chemical contamination detection will be discussed in this session. Rapid and reliable chemical contamination detection will be one of the greatest technical challenges of the Space Station program.

Many of the speakers in the third session are not involved in the Space Station program, but have extremely relevant knowledge and experience to share with us. We do appreciate their willingness to spend this time with us and we are grateful for their technical contributions to this workshop.

Following each of the three sessions, there will be panel discussions, in which the subjects brought out during the sessions will be discussed by the panel members. We hope for strong audience participation in these panel discussions.

This workshop is intended to address Space Station laboratory module internal contamination issues and to answer some key associated questions. It is quite likely, however, that we will raise as many new questions as we answer!

On Thursday, there will be a summary of the entire workshop, with an outline of the major findings, conclusions, recommendations, and remaining concerns that surfaced during the presentations and discussions of the previous two days. Again, we hope for lively discussions on the part of the attendees and participants of the workshop.

A banquet is planned for tonight. We will have the great pleasure of an after-dinner speech by a former Skylab and Shuttle Astronaut, Dr. Owen Garriott, who is now Vice President of the Space Programs Division of Teledyne Brown Engineering.

It is our sincere wish that the outcome of this workshop will, in terms of value, be greater than the sum of its parts, providing a much-enriched knowledge base from which we can all work.

I would like to extend my own very best wishes to all of you for an enjoyable and profitable time in Huntsville, where the sky is most definitely not the limit!

It is now my pleasure to introduce the Session 1 Chairman, Mr. Charles R. Baugher.

SESSION 1

SUMMARY AND KEY ISSUES IDENTIFICATION

by

Session 1 Chairman: Charles R. Baugher

NASA - MSFC

SESSION 1

SUMMARY

Session 1 consisted of an overview of the United State's past, present, and future requirements for handling hazardous materials in space. The presentations or past experience included America's first Space Station, or "Skylab", and two Spacelab missions (D-1 and SL-3). Present space activities that were highlighted in the workshop were the upcoming Spacelab J and Spacelab USML-1 missions. Also, an overview of the Soviet MPS activities in space was provided as a basis for comparison of the planned U.S. MPS activities for the Space Station Freedom. The future requirements for handling hazardous materials in space were covered in presentation on the six code EN or MSAD Space Station facilities which are the current MPS experiment facilities. In addition, the hazardous materials and operations associated with non-human life science payloads were detailed in an informative presentation by a representative of the life science community.

One former and one current astronaut, Dr. William Pogue and Dr. Bonnie Dunbar, participated in the workshop and made presentations concerning lessons learned on Skylab and Spacelab. The information provided by these astronauts has direct application to the Space Station program. For the reason, it is important to provide in detail the key issues discussed by these representatives of the astronaut community.

Former astronaut Dr. William Pogue, who flew on the last Skylab mission recounted several experiences from his flight and made several points. First, was his concern for the potential of off-gassing from materials. Skylab had over-heated and several hardware items released toxic fumes as a result. Skylab's air was changed out twice before the crew entered it to eliminate most of these gases. Second, was his concern with leakage. The Skylab cooling system used glycol, and this system developed a leak. Dr. Pogue pointed out that the Skylab cooling system was designed to be a leak-proof system. Inadequate equipment was provided for the cleanup and the leaking material spread so much that glycol was detected in the air filters. Metabolic waste and other materials were a frequent source of spills, (for example, sweat thrown from the exercising crew members). Inadequate procedures existed for clean-up. Future missions should provide for these activities. Even with the best designs, accidents will happen. Procedures and tools should be developed to accommodate these contingencies. Thirdly, Pogue was concerned with particulates and their collection and removal. Air filters became packed with contaminants which were very difficult to remove. The vacuum system provided for removing such material was inadequate. A good vacuum system on future missions is highly recommended. Filters should also be large and be placed in locations with easy access, so they can be readily cleaned. Fourth, Skylab suffered from many false alarms. This can lead to desensitization of the crew. Any fire detection or leak detection system should be designed to reduce false alarms. Fifth, fire and leak detection systems should reveal location of problem and hand-held units should be provided for further assistance. Skylab did not have this capability and it took an unnecessarily long time to research false alarms. Plus, in a real emergency the sooner a location is known the better the potential for remedial action. Sixth, any future gas detection system should be capable of detecting all contaminants. Skylab had no leak detection system. Seventh, a tool was used on Skylab which had a numbering system associated with the mechanism. These numbers were glued on and eventually came off. Future labeling systems should not be prone to this problem. Eighth, some combustion tests have indicated that entrained air in a fire extinguishers exhaust may actually feed a fire. More research needs to be done in this area. Ninth, Skylab tests showed that porous materials burn readily in a low-g environment. Lastly, Pogue was concerned by reliance on containment. On Skylab a camera was opened and it was full of broken glass. This glass was supposed to be contained within the camera. The main point is don't depend upon containment. Procedures and tools should be developed to overcome accidental material release.

Dr. Bonnie Dunbar gave an informative presentation on the Spacelab D1 mission. Her presentation was primarily an overview of the mission. She pointed out that a large reason for the missions success was because of extensive preflight training. She also emphasized the importance of crew members having extensive knowledge of the experiments and materials they are expected to handle. One minor point brought out was that the air flow from Spacelab is into the Shuttle middeck and flight deck area. Therefore, debris from Spacelab tended to collect in those areas. It was later pointed out that this would not be a desirable air flow pattern in the case of a hazardous material. One would want the air flow to be away from the crew. In discussing material science experiments, Bonnie pointed out that many materials are toxic only at high temperatures. One sample failed in the gradient heating furnace on this mission. However, a retrieval procedure had been practiced on the ground, this was successfully used on-orbit. The sample that failed was a late mission add-on, which had its composition changed from the sample it replaced. However, the crew was not informed of this change and used an incorrect thermal profile. This anomaly points up the need for tight control between any changes that the experimenter makes to his facility or materials and the need for the crew to be completely familiar with those changes and their consequences. A major failure occurred on D-1, silicone oil leaked from a facility and the oil spread over the rack surfaces and contaminated other adjacent Spacelab equipment. This incident occurred because silicone oil will thoroughly wet almost any surface it comes in contact with.

No procedures or tools had been provided for clean-up. Future missions have to consider these eventualitites. Dunbar encouraged rack developers to provide their own unique tools for equipment repair and operation. Dunbar concluded by saying: 1) Safety is the key to a successful mission, 2) an international policy for safety and these experiments is required, 3) the full safety burden should be shared between SS systems and experiment facilities, and 4) reliable chemical contamination detection units are needed now. She also recommended a new NRC safety document. She also had one comment on automation. You can't automate what you don't know, the crew will be required to make modifications to hardware and procedures.

As the result of Dunbar's presentation several comments were made. One was that in considering triple containment one needed to consider each material on an individual basis. Some materials are safer than others. A discussion of fault tolerance as opposed to triple containment then arose. Another point raised was that the SS does not allow free venting, which the Spacelab does. What operational impacts will this have on the users? Dunbar mentioned here that the glovebox on D-1 worked well except that it had only one glove size, which was too large for her after it was stretched out. Dr. Dunbar recommended various glove sizes for the gloveboxes that will be flown on Space Station.

KEY ISSUES

1. There is a strong conflict between the payload desire to vent waste and the restrictions on external contamination. Sixty-six percent of the existing MPS payloads require venting. The venting requirements do not define a venting allocation for each Space Station Module. All sides appear to be unaware of the rationale on the part of others, and little information is being exchanged. This issue calls for coordination by Level II since it involves many Codes and Work packages.

2. Off-gassing of equipment must be considered a source of potential noxious material. Strict controls should be imposed to reduce or eliminate this hazard.

3. Adequate equipment for lab cleaning must be provided. Filters and other hardware to be cleaned must be easily accessible and must be designed with cleaning requirements in mind.

4. Little consideration was given to ground operations with these hazardous materials. Who is responsible for these areas and what plans have they made for these operations? More attention needs to be given to this area.

5. The potential for various levels of waste treatment exists: at the rack level, at the module level, and for the entire SS. The specifics of these levels of processing need

to be defined as soon as possible as they will impact user hardware design. Many of these designs will be entering Phase A/B development very soon.

6. It is critical that fire and leak detection systems be designed to locate a leak or fire source. General alarms are inadequate. Reduction of false alarms is desirable and hand-held portable units for alarm follow-up are also desired.

7. The current requirement concerning storage of potentially explosive materials is misleading as stated. Strict interpretation of the requirement would indicate that hydrogen gas would have to be stored outside the module.

8. More organized and direct communications are required between Space Station and User technical personnel. In many cases the laboratory users are among the most knowledgeable authorities on handling compounds associated with their experiments and their expertise should be directly focused in a visible fashion. In addition, lack of information to design teams tends to lead to "worst case" over design as engineers attempt to develop systems to accommodate vague generalities.

N91-15932

SPACE STATION FREEDOM

TOXIC AND REACTIVE MATERIALS HANDLING WORKSHOP

PAST EXPERIENCE

"SKYLAB MISSION"

Bill Pogue, Pilot, Skylab 4

The design of the Skylab missions, 1973-74, was intended to exclude any direct handling of hazardous, toxic or reactive materials. The materials processing facility and multipurpose furnace provided a contained environment for conducting metals melting, brazing, sphere forming and crystal growth experiments. At the end of the third mission, following the completion of all other experiments, the materials processing facility was used for a series of flammability experiments. The flammability tests were done last because of the contamination expected from the burning of materials within the facility. The flammability tests demonstrated a number of peculiar effects that have implications for future design(fire detection, location and suppression/control).

Although the results of the flammability tests contain lessons appropriate to planning, a number of events during the flight illustrate situations or conditions that pose considerations beyond the commonly accepted range of concern for safety-related matters. This presentation will include a discussion of:

-Skylab flammmability studies and the implications for fire suppression/control;
-False fire alarms and the Skylab fire detection system;
-Space environmental effects on materials that are normally benign;
-Spills/release of contaminants;
-The detrimental effect that the release of non-hazardous materials have on detection systems;
-The problem of locating sources/originating point of hazards.

HAZARDOUS & TOXIC MATERIALS HANDLING
Skylab Experience Summary

1. Events

MISSION	ACTIVITY/EVENT	HAZARD
SL-2	Polyurethane Heating	Atmosphere Contamination Toxic/Gas: CO, Cyanide Gas, Toluenediisocyanate
SL-2	Brazing/Welding; Sphere Forming	Heat; Gas Products; Electron Beam Energy
SL-2 thru SL-4	Cooling System Leak(Water/Glycol) use of sampling techniques.	Atmosphere Contamination: Glycol No onboard system capability to evaluate samples.
	Collection of Particulates in/on ventilation Duct Filters/Heat Exchangers.	Concentration/retention of potentially hazardous materials: Particulate condensation of toxic agents, micro organisms.
	Spills of metabolic waste and natural sloughing from body & clothing.	Urine, Feces, Vomitus, etc.; Sweat; Skin; Hair; Cloth Fibers.
	False Alarms.	Delay in interpretation and absence of capability to pinpoint the location. Loss of credibility in alarm-system.
SL-4	Discharge of Fire Extinguisher.	Freon
	Puncture of Charcoal Canister (to sample for Glycol).	Particulate charcoal
	CM-RCS (Suspected leak of fuel/oxidizer)	Hydrazine, Nitrogen Tetroxide
	Fragments from photographic plates (S183: Ultraviolet Panoramic Camera).	Glass shards (observation/release during unplanned maintenance).

1. Events (cont.)

MISSION	ACTIVITY/EVENT	HAZARD
SL-4 (cont.)	Bonded Numerals came off the indicator belt drives of the Articulated Mirror System (AMS).	Particulates/Chunks of unknown composition (internal threat to mechanisms).
	Flammability tests.	Gas contaminants; spread of fire.

HAZARDOUS & TOXIC MATERIALS HANDLING
Skylab Experience Summary

2. Conclusions

EXPERIENCE BASIS	CONCLUSION
1. S IV B Insulation Heating (SL-2)	1. Environmental extremes may generate hazards from benign materials.
2. Water/Glycol Leak (SL-2 to SL-4) Freon/Fire Extinguisher Discharge CM-RCS (Hydrazine, Nitrogen Tetroxide)	2. Inadvertent leakage or vent from standard/generic spacecraft systems or the use of contingency/emergency equipment may: 2.1 Constitute a hazard. 2.2 Create confusion in assessing a known/suspected release of hazardous toxic materials. (also see 4., below)
3. Broken glass plates Bonded Numeral Release (AMS) Charcoal Canister puncture	3. Encapsulation protection of potentially hazardous materials may be negated by conducting contingency maintenance/repair operations.
4. S IV B Insulation Heating (SL-2) CM-RCS Leak (SL-4)	4. General detection/assessment techniques were inadequate/unavailable.
5. Particulate accumulation on filters & in the heat exchanger grilles.	5. The ventilation system and cleaning systems of Skylab were inadequate to prevent/correct the flow-blockage/clogging of fine grille heat exchangers.
6. Flammability Tests/Fire Detection	6. Microgravity inhibiting of convective circulation cannot be relied upon to prevent fire/flame propagation. Conditions detrimental to fire suppression and detection include: 6.1 Porosity of materials (O_2 captured within the flammable material)

2. Conclusions (cont.)

EXPERIENCE BASE	CONCLUSIONS
6. Flammability Tests/Fire Detection (cont.)	6.2 Thermo-mechanical response of burning materials that cause local air agitation or displacement out of O_2-depleted zones. 6.3 Local airflow induced by normal cabin ventilation/circulation system. 6.4 Local airflow caused by the use of fire extinguishers (initial blowtorch effect). 6.5 False fire alarms (decreases credibility of detection system). 6.6 Poor detection system design (causing time delays and confusion in interpreting/assessing the indication)
7. Metabolic Wastes & Particulates	7. The accidental spills of metabolic products and unavoidable sloughing of particulates from skin and clothing may cause contamination of the habitable environment and accumulate in quantities sufficient to compromise system performance.

3. RECOMMENDATIONS

1. Develop an approach to identify and evaluate normally benign spacecraft materials, components that may generate hazards when subj ed to environmental extremes that can be encountered in space.

2. Design a hazardous/toxic materials detection/assessment system that will be effective for generic space environment products in addition to sources formally classified as hazardous/toxic.
2.1 The detection/assessment system should be able to locate the source;
2.2 The detection/assessment system should include ancillary manual devices to supplement an automated system.

3. Encapsulation (containment) design should include a careful appraisal of contingency/emergency operations to assure crew safety and equipment protection for maintenance/repair activities that entail violation of containment provisions.

4. Flow restriction zones in cabin atmosphere ventilation systems should be scrutinized during design reviews to:
4.1 Preclude the accumulation of unremovable debris, specifically, the sizes of grille, grid or mesh openings should be optimized to enable easy removal of debris;
4.2 Assure easy access by crew and equipment to effect maintenance/repa . In particular, more powerful vacuum cleaning capability is needed.
4.3 Filters & grilles should be designed with removable sample plugs to support onboard assessment of contaminants.

5. Flammability control & fire suppression design approaches should consider porosity & thermal-mechanical reaction (flammable materials), local circulation velocities and initial effects of fire extinguishers.

6. Fire detection systems should be immune to false alarms and provide unambiguous indications regarding (a) the sensor triggering the alarm and (b) the suspect location of the fire or overheat condition.

3. RECOMMENDATIONS (cont.)

7. Provide a high-volume, high delta P vacuuming device to: clean up spills of metabolic/hazardous-toxic materials and to enable effective cleaning of filters, grilles and grid surfaces.

N91-15933

6. SPACELAB D-1 MISSION

Dr. Bonnie J. Dunbar
NASA/JSC, Astronaut

(Note: This paper has been reproduced from tapes.)

Thank you, and Bill, we did learn from the lessons of Skylab. There were several documents printed after those flights called Lessons Learned from Skylab. I've read them and found them very informational and I think you'll be pleased to know that I think the vacuum cleaner now works better. We did use it for some furnace cleaning and we do clean the filters out and we have improved the access. We have ensured that we don't have to take off all those bolts again.

What I would like to do today is talk about the D1 mission from a couple of perspectives. The first one, of course, is from the point of view of safety, materials handling, toxic materials, but the other is from the point of view of the laboratory and the equipment we used and some of the different philosophies utilized on this flight. My Ph.D. is in Biomedical Engineering but most of my professional life has been in materials and most of my laboratory experience has been with high-temperature furnaces and diagnostic devices and so forth. So I find that this is a very interesting part of the research that's occurring on Spacelab missions, on the middeck, and will occur on Space Station.

(First slide)

I will introduce the crew and background to you. This flight was called 61A in the NASA language. It actually had another name, D1 (Deutchland Eins) which was the first German-sponsored Spacelab flight. Germany, not ESA, but DFVLR in Germany, bought this flight, the launch for about 59M. They invested about 229M of their funds in the experimental hardware that went inside the lab flight. This was a first of a series of flights. D2 will occur in late 1991. Their stated intent is not only science but the development of hardware for Space Station. So, 1991 will see us with a couple of new furnaces that actually won't be heated up but will be tested for advanced technology and will eventually be used on the Station. The crew consisted of five NASA career astronauts. The commander, Hank Hartsfield with NASA, the pilot Steve Nagel from the Air Force with NASA, the Mission Specialists myself - MS1, MS2 Jim Buchli with NASA from the Marine Corps, MS3 Guy Bluford from the Air Force. Guy and I were assigned as the two people on board in charge of the Spacelab subsystems, much as Owen was on his flight and also assigned the task of training for the experiments. There were three Europeans on board. Professor Reinhard Furrer from Berlin, Dr. Wubbo Ockels from the Netherlands, who is an ESA astronaut and flew on this flight because about 30% of the hardware was ESA. It was part of the cooperative agreement ESA had with Germany. And then, Professor Ernst Messerschmid Stuttgart. The five of us then were called the payload crew. We then trained primarily in Europe starting about 19 months prior to the flight. We spent about 6 and 1/2 months in Europe and the rest of the time in Houston. Guy and I trained with the rest of the crew on the Shuttle and the Spacelab systems.

Just to review a little for you what Spacelab is, it is actually an in-the-bay laboratory connected to the middeck with a tunnel and it's a shirt-sleeve environment. There are two hatches that separate the lab from the middeck at launch, one here in the middeck and one about here at this area. Very often, we carry pallets behind the laboratory when we fly with other experiments and we did so on this flight. This is not our configuration. But we did carry a U.S. pallet in the back which contained the Materials Experiment Assembly which was an automated, high-temperature levitation furnace.

The experiments, as I said before, within the lab were primarily German. We did have a cooperative physiological experiment with MIT which was in here. And then, there were nine middeck lockers devoted to supporting the work in the laboratory. Just a note about air flow. The air flow in this system was such that the cabin air flowed this way through the tunnel into the middeck so that the laboratory environment was really quite clean. It was the cleanest part of the Shuttle. Air debris or environmental debris builds up over time, so by the seventh day all of that those flakes of skin, hair, paper, and food that might be out were really accumulating on the middeck. Filter cleaning was a routine and important part of our mission and every other mission as well. We have improved the access so we don't have to take off the panels with large amounts of screws.

Just a quick look at the lab as it is in MBB/ERNO. You can see the pressure holes on the end and then the experiment racks themselves. Each rack comes with a standard set of facilities. For instance, air handling tubes and electrical cables for data handling and for power.

And as it looked in the payload bay. This was from the middeck back at the lab and you can see the tunnel, the hand rails for the EVA access if we needed to go outside.

This is in German so don't worry about reading the print at the top. It's only one side of the lab but I wanted to briefly explain the disciplines we had to deal with. Thirty percent of this flight was devoted to materials science. Everything from high-temperature processing of metal alloys and semiconductor material such as gallium-antimonide to looking at basic science using laser interferometry to study Marangoni Flow, for instance, and inter-diffusion of melts. The way the flight was organized was that each rack had a discipline so there was not a mix of disciplines within racks and those racks were integrated at a subcontractor before they went to Bremen for a test within the lab floor. The blue rack is a subsystem rack in the Spacelab that had the data or high-data rate recorder, the computer interface here for the subsystems, also the black boxes, for instance, inverters and computers within it. The red racks represented one side of the experiment racks. There was a large materials science double rack. MSDR flew for the first time on Spacelab 1 and this was its second flight. So, those problems that they had encountered on the first flight in 1983 they attempted to fix on this flight in October of 1985. Next to that was a stowage rack. There's also a rack called process commer. This was the rack which contained the small lasers. And, then, next to that a stowage rack with equipment for this vestibular sled. Vestibular science is comprised of about another 30% of the flight. On the other side, not shown, was another large double rack of material science that was called MADEA. There was also a glovebox, a biological glovebox, and you will see that in a moment. In the back you do see the Materials Experiment Assembly here and then three GAS cans, communications experiments flown by the Germans.

Like most Spacelab flights, the scientists on these flights are tied in directly to the crew. We don't have this capability right now for middeck experiments but it is a particularly nice feature of Spacelab flights in that the scientists on the ground can interact with the crew on board and it is something that we do encourage. However, what was unique about this flight is that the scientists were not at Marshall or a U.S. remote POCC. They were all at a POCC, or Payload Operations Control Center, within Germany at Oberfafenhoven. This is what our communications looked like. Here's the Shuttle. We communicated to the TDRSS satellite down to White Sands. This went to a domestic satellite signal relayed to Goddard to JSC. The experimental data, because the Germans are interested in Spacelab subsystem data, they are using their POCC to develop a Space Station capability. They asked that some of that be shipped over as well so we sent that to Intelsat 5, which is a commercial satellite over Germany that went down to northern Germany and then by land line to Oberfafenhoven near Munich. There's a picture out of their control center. It's the same facility that has controlled their satellites. They're using it for their Spacelab missions and they will probably use it to interface with their Space Station operations as well. They do have one feature we don't have and that's color CRTs at their control sites.

On board, you see one of the two shifts working. This is myself and Reinhard and Ernst working in parallel to a flight plan that's been developed over time in 5-minute increments because time is money with a certain amount of time padded in each day for contingencies because there is no perfect world. In-flight maintenance is an important part of every lab whether it be on the ground or on board. In this photo, I have some tools on my leg. You always carry scissors and pencils and other tools around. I'm checking some data in an incubator. Reinhard's at the materials science double rack and Ernst is at the rear probably looking at some vestibular science hardware.

This is glovebox that we carried on board developed by ESA. In this facility, the whole rack contained two incubators, a freezer, a cooler, and the glovebox. This facility was flawless - first flight. It contained over 80 different boxes, which I'll show in this next photo, containing a number of experiments. This is one of the incubators. Each of these little cigarette-shaped boxes contained an experiment. Some were sort of autonomous in that you would rotate the sample from a freezer to a cooler, then maybe to an incubator, and then back into a freezer. Others were actually plugged into little chips at the end of this box and then the data went to the CRT display who would either initiate the experiment, monitor it, or it would let us know when it was finished.

Here's a closer look at the box. This is built by Dornier who built all the boxes and then all the experimenter had to provide was generally the interior. This provided one level of containment. Inside might be something like this. Inside this little box were maize seeds and there were two plungers at the end. One of the plungers provided the water to germinate the seeds and the other one may have been the fixative which we later plunged down and fixed the samples. When we worked with these samples (took them in and out of the box), the glovebox itself was considered one level of containment and that's something to remember when designing experiments. We have a triple containment rule but there are ways of providing that rather than putting everything into three boxes and then not leaving access to them.

On the other side of the lab you see myself and Wubbo working. I'm in front of the MDEA facility which included a gradient heating furnace and a mirror heating furnace. The samples, as you can see here, are all outside the furnace and they are exchanged. This was routine for all five high-temperature furnaces we carried. I think it is important to remember that the materials that we carried, such as gallium-antimonide, are only toxic at temperature, not at ambient conditions, as long as they don't have a high vapor pressure and you are not actually touching the surface. So, in a lot of cases such as this one, that sample has a glass tube around it but you might say that is single level of containment. But once I put it in the furnace and close the door and there is an interlock there that as soon as I start heating it up will prevent me from ever opening that door again until it is back at temperature. We operate in a safe environment. There are a lot of interlocks and safety features built onto this furnace. I consider this the most sophisticated rack facility we have probably ever flown. It has microprocessors which plug under the front which contain the thermal processing curves. There are codes built into the samples themselves that go out and fetch the processing curves. It protects proprietary data and yet it is safe.

This happens to be a drawer full of spare lamps. We were also able to exchange lamps. They are, again, glass lamps or glass bulbs. I don't know if you can see them on the end there, but they are carried up in plastic and foam and then exchanged on orbit.

In the gradient heating furnace we carried very benign metal alloys and the alloy samples themselves are a little over 1 foot. That's the end of the sample which also happens to be a door of the furnace and in that door of the furnace which screws in is a cable that plugs into the front of the panel which then goes to the PROM and fetches all of the necessary information to process or gives the necessary information to process that sample. We did have one problem with the gradient heating furnace sample. One of them, there are thermocouples inside these samples, and, for some unknown reason, one of them broke in the furnace and I pulled it out and recognized that we had less than a full sample down there. We knew it was a non-toxic material. I used a flashlight to look down into the bowl of the furnace and saw the rest of the sample down there. We had long forceps. We retrieved the rest of the sample and there was some debris in there. We put the vacuum cleaner over the front of the furnace and sucked out the debris. We took a bottle brush, cleaned out any powder that might have been in there, and then continued processing the rest of the flight. Now I should add that was not an "on-the-wing" procedure. Preflight, we had tried to provide for all these contingencies and that was a planned operation in case we had any problem with these materials.

A closer look at the materials science double rack. You will see some of this in the short film that I am going to show from the flight. It was called the fluid physics module. We also had a cryostat device for growing protein crystals. We had an isothermal heating furnace, a gradient heating furnace, and then the power boards and so forth.

This is the mirror heating furnace in which we did some of the single crystal silicon and some of the other semiconductors. In this case, the crewman here has it open and is actually cleaning it out. This was one problem we did have on flight and there are probably several reasons this happened. We think that there are two possible things that happened. We know a sample overheated. We think that one plausible reason is that the sample that was provided to us late was not the one that was coded in the computer or documented. In order to start this furnace you have to go up to another minicomputer, you type in a code, and it echos back to you. It is an "arm and fire" situation. You read that code, you press an ENTER, and that puts in the proper thermal profile. In looking back through the data, we think that a slightly different composition sample was provided late by the experimenter and we are trying to tighten up that safety loop to make sure we fly what we think we are flying and that we have the proper procedures to respond to it on board. There are other details to this that I can discuss off-line but that was probably one of the things that caught our attention is that we had something there we didn't know we had.

We can do a lot of things on board now that require small, painstaking actions. Here Ernst is taking small plant roots and cutting them with a razor blade. We are doing more laboratory operations, we are still remaining safe. Everything has a tether on it -- every scissor, every forcep, every razor blade has a tether and velcro because we can't afford to let it loose. We can't afford to let it be a hazard to the rest of the crew. We know it is there but someone else may not.

And the fluid physics module, the question came up about cleaning up fluids. We worry about fluids getting loose that may not be toxic to you and me in a 1-g environment, but in the eye or other membranes can be toxic, and this case is silicon oil. It has a tendency to wet everything once it gets loose. Towels help to some extent but the real action one must take is to prevent it, to contain it, to ensure that the surfaces being used are not wetted by it unless that is part of the experiment and it is contained. On the first flight of this rack some silicon oil inadvertently was let loose. The crew thought they had cleaned it up, the rack was sent back to Germany to DFVLR. It had crawled back behind the rack along every piece of cable back there to the underneath portion of the Spacelab floor and it took them nine months to clean up that hardware.

I mentioned in-flight maintenance. The Space Shuttle has its own IFM tool set, the Spacelab has its own IFM tool set,and sometimes experiments provide their own. We do encourage it. We have a group in the astronaut office called the Science Support Group and we start working with experimenters early trying to pass our lessons learned in experiment operations and how to design them and how to provide access. One of the things we do encourage is it may break. We would all like to think our stuff doesn't break. It may break, it may provide a hazard. So show us how to get in to it, provide us the opportunity for access, and make sure we have the tools on board to do it.

I have just a few concluding remarks. Safety, I think, is the bottom line of any laboratory operations. Not just the Station or the Shuttle but any lab and I've worked in a number of them. I remember some very drastic procedures that were imposed at the University of Washington while I was a graduate student after two very fatal accidents. One where a student walked between two large capacitors and died. Another in which a student froze a fixative in the chemistry department. The refrigerator exploded and he died. So it is not just a Station, it is not just a Shuttle matter, laboratory safety is important to all of us.

Because of that, I was sort of interested in what was happening in laboratory safety and I recently found that the NRC was too. They just put out a new book called Prudent Practices for Handling Hazardous Chemicals in Laboratories. The first thing it says you have to do is develop a philosophy. I would like to encourage us today to talk about what that philosophy is, not just for the U.S. Lab, not just for U.S. hardware, but remember that we are connected to two other national laboratories and that we have to have an international safety policy and words to the effect that we are going to do closed-hatch operations are not acceptable. We cannot leave people alone in an environment in which they may not be safe. We have a common environment. We do not have enclosed life support systems. The air that I breathe is the same air that someone on the other side of the Station may breathe. And so, we would like to pass that on. To recommend a uniform safety policy for the international lab. We don't think the full burden should be on the experimenter, but also on the systems. I think that's happening. In other words, the Spacelab comes with scrubbers and so forth. Not every experiment is expected to do its own scrubbing and provide all the levels of containment. If we did that we'd have no science on board. Nobody could afford it. But we need to have clearly articulated requirements for what the experimenter is supposed to do in proving three levels of containment for instance. We need a reliable contaminant detection, as was mentioned before. I know there are a lot of efforts on mass spectrometers. We don't need them for Station, we need them now. We need to have the various groups working together on it. We need them now because we have a CDSF, Commercially Developed Space Processing Facility, or the Industrial Space Facility that's going to come on board that we are going to revisit. We have to know what the environment is like before we enter. Just for a comparison, when we enter the lab and we know we have scrubbed it before we go up, we look at some parameters on the onboard displays before we ever open the hatch. We look first of all at pressure. We look at pressure over time, the PDT, to make sure we don't have a leak. We look at PPO_2 - partial pressure of oxygen - and CO_2. Then we try to get a look with the cameras. There are cameras hooked up inside to ensure that we don't have anything else rattling around there such as glass shards or other debris that could be a hazard to the crew. So, we do need reliable contaminant detection and we need to have it real time and as soon as possible and we'd like to test it on the Shuttle before we put it on the Station.

Some of the lessons learned in developing experiments. This is maybe not a safety point but something that I would like to pass on. You can't automate what you don't know. If you could automate early on in the process or the experimental development you would not need graduate students. In all the years I spent in the lab before I came to

NASA, I found that when you are trying to develop an experiment or a piece of hardware, you need to tweak it, you need to change process variables, and so forth. We are trying to encourage people to use the human element when it is practical, automate where it is necessary, and come to the best medium of both worlds. Now, some of those experiments will eventually be totally automated, they may even be outside of Space Station. They may be material processing facilities that float out there and we just recover samples ever so often. In the area of life sciences, they may never leave the Station. They may just mature but still remain inside the environment.

Spacelab, Space Station, is a laboratory. It's also unique. It is, in itself, in a hazardous environment and we cannot escape. I am very gratified that this conference is occurring because it will allow us to discuss what we can do to enhance our scientific return at the same time as being safe. The experiences of Skylab, Shuttle, and Spacelab will hopefully lay a foundation for what we have done and how we can build upon it. I think that we need to work very vigorously in this area. My personal opinion was after having flown this flight that Germany had a more aggressive plan in how they were going to utilize their flights to develop Station hardware and I certainly would encourage you, if you are developing hardware, to think about prototypes being flown on Spacelab flights. Maybe not the final version. For instance, on D-2 we will see two new facilities. One is called Rotex. It is an automated furnace facility but it is being flown first inside the lab to ensure that it works because it uses an uplink command capability from Germany. Germany will command across the ocean to JSC and uplink through to JSC and shuttle these commands to operate this furnace. Perhaps something that will go on a free flyer eventually. Also, there is a new furnace on board in the materials science double rack. It is called Isothermal Heating Furnace-T. The T is turbine blade. They have a lot of interest from their power plant companies in Germany on single-crystal turbine blades. I do not know the details of this. It may or may not heat up, but I think it will be a high-temperature furnace and a developmental furnace. And if you read all of their charts they state as a Spacelab goal development for Space Station.

In any case, welcome, and thank you for affording me the opportunity to pass these comments on.

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SPACELAB 3 MISSION

Bonnie P. Dalton

ABSTRACT

Spacelab 3 (SL-3) was the first microgravity mission of extended duration involving crew interaction with animal specimens. This interaction involved sharing the Spacelab environmental system, changing animal food, and changing animal waste trays by the crew. Extensive microbial testing was conducted on the animal specimens and crew and on their ground and flight facilities during all phases of the mission to determine the potential for cross contamination.

Macroparticulate sampling was attempted but was unsuccessful due to the unforseen particulate contamination occurring during the flight. Particulate debris of varying size (250 um to several inches) and composition was recovered post flight from the Spacelab floor, end cones, overhead areas, avionics fan filter, cabin fan filters, tunnel adaptor and from the crew module. These data are discussed along with solutions, which have been implemented, for particulate and microbial containment for future flights' facilities.

INTRODUCTION

SPACELAB 3 (SL-3) was launched on April 29, 1985 and heralded the use of the Spacelab in support of animal facilities for biomedical investigations. Thus the goal on this initial flight of twenty-four rodents and two squirrel monkeys, was verification of the Research Animal Holding Facilities (RAHFs) under microgravity conditions. The main objectives of the Payload were: 1) evaluate the operations and procedures for mission care of animals, 2) provide in-flight biocompatability assessment between animals and the RAHF, 3) gain mission operational experience, 4) study physiological, behavioral and morphological changes occurring as a result of containment in the RAHF during space flight, and 5) verify principal hardware elements to be reflown.[1] Much data was gained from SL-3; all of it was positive in terms of animal maintenance, but particulate contamination as a result of RAHF operations had to be corrected, before RAHFs could be flown again. This paper will address the SL-3 data and changes implemented as a result of SL-3.

ANIMAL MAINTENANCE VERIFICATION

Verification, during SL-3, included the capability of the RAHFs to maintain the animals under conditions comparable to earth based vivarium controls in the laboratory in terms of temperature, humidity, air exchange (carbon dioxide removal and oxygen replenishment), waste management, feeding and watering. The environmental control system of the RAHF utilized circulating fans and thermal electric units (TEUs) for air exchange and temperature control while a condensate separator/collection system maintained humidity control. The RAHF environmental control system is illustrated in Figure 1. Food and water were available on demand through an automated watering system with a self contained water tank and crew replaceable food cartridges. From inflight RAHF environmental data and post flight physiological analysis of the animals it was shown that the flight facilities maintained an environment comparable to that of the ground vivarium. Physiological changes oberved in the animals post flight were readily identified as adaptations to the microgravity environment.[2,3]

CONTAINMENT VERIFICATION

Verification also included operation within the Spacelab without microbiological cross contamination between the human crew and the non-human biospecimens, without odor, and without particulate contamination. These verification requirements were to be met through the use of in-line microbiological filters (0.3 micron HEPA) for incoming and exiting air, through the use of odor absorbing charcoal beds and phosphoric acid treated waste pads to prevent ammonia accumulation and inhibit microbial growth, and through maintenance of the RAHF at a slightly negative pressure with respect to the cabin.

MICROPARTICULATES--The goals of microbiological containment were accomplished during SL-3. Extensive testing was conducted on the animals, crew, facilities housing both animals and crew, and on the Spacelab, orbiter flight deck, and RAHF surfaces during all phases of the mission to thoroughly characterize the microbiological profiles.[4] The success of that testing program was the result of a cooperative effort by the Ames, Johnson, and Kennedy Space Centers which were responsible for the flight biospecimens, crew and flight facilities, and ground facilities' sampling, respectively. Over 1500 samples were collected from the pool of animals intended for flight to insure the Specific Pathogen Free (SPF) microbiological integrity of those animals finally selected. An additional total of 175 preflight, 81 inflight, and 98 postflight samples were obtained from the selected flight animals, crew, and environmental surfaces during the SL-3 mission. This extensive sampling revealed no unusual microbiological accumulations during the course of the mission. In fact it has been reported that "levels of airborne microorganisms in the Spacelab were low compared to values obtained from the Orbiter during previous missions."[5]

Only two instances were reported of isolation of microbiological species of possible animal origin external to the RAHF. These were isolated from a crew member's hand following waste tray changeout and from an air return screen on the Orbiter Flight Deck. Unequivocal determination of origin was not possible. The Spacelab microbiological integrity was maintained even though a slight increase of bacterial growth was observed on RAHF interior samples taken immediately postflight. It must be noted that the organisms of significance, the fecal markers (E. coli, S. faecalis) and a pathogen (Staphyloccus aureus), were only isolated from RAHF interior surfaces.

Particulates were measured through use of air strip adhesion both preflight and at L+O following the opening of the Spacelab module. The postflight particulate strip could not be enumerated as a result of the extensive fine particulate dust (presumably foodbar crumbs) released during flight. Inflight particle counts observed in the Mid Deck, Fight Deck, and Spacelab ranged from <5,000 to 34,000 particulates/m^3. Particulate count during food canister and waste tray changeout ranged from <5,000 to 12,000 particulates/m^3.[6] Particulate levels in the Spacelab were highest during and following waste tray changeout. Aspergillus sp. was the only potentially pathogenic microorganism isolated during the inflight Spacelab sampling. Sample sites were external to the RAHF; no fecal coliforms were isolated.

Table 1 (SL-3 Mid Deck, Flight Deck and Spacelab Particulates) compares particulate levels from the three locations over the duration of the mission. Though measured particulates in the Mid Deck decreased during the flight, Flight Deck values were high. The elevated values were assessed to have been the result of the directional air flow from the Spacelab to the Flight Deck.

In conclusion, though increased particulate levels were observed, the microbiological filters employed in the RAHF along with maintenance of Specific Pathogen Free (SPF) animals ensured no cross contamination between crew and biospecimens. The reader is directed to Reference 4 for complete details of microbiological results.

MACROPARTICULATES--"Macroparticulates" were collected post flight by Kennedy Space Center (KSC) payloads processing personnel. Debris removed from the OV-O99 Crew Module was analyzed by the KSC Microchemical Analysis Branch. Where possible, debris was identified optically. Other methods included scanning electron microscope energy dispersive analysis (SM/EDS) or use of infrared (IR) for organic substances. Table 2 (Crew Module Particulates) indicates sample site, predominant particulates found and predominant chemical characteristics. The conclusion by the KSC analysis team was that debris in the cabin appeared to be of human origin. One bit of debris found in the airlock did provide identical analysis to that observed in the rat food, although the analysis team also stated that, "Most samples were so mixed that exact identification was very difficult."[7]

Avionics and cabin air filter debris were transferred to Marshall Space Flight Center and subsequently to Ames Research Center. The material was identified as retrieved from sever different sites: [8]

Group 1	Floor, end cones, overhead areas
Group 2	STT inlet screen debris
Group 3	Avionics fan filter debri
Group 4	Cabin fan filter debris
Group 5	Avionics fan filter, loose
Group 6	Tunnel debris

Group 7	Cabin fan filter debris, loose
Group 8	Port side rack exterior

A description the materials identified from these specific locations and their weights is indicated in Table 3 (Avionics and Cabin Filter Debri).

RAHF REDESIGN

Though odor was reduced, it was not eliminated. Control of odor and particulate release was the primary goal in the post SL-3 redesign work on the RAHF. Means of obtaining this goal addressed: 1) containment of debri at the source, 2) control of air flow during operations requiring opening the cage or module to the cabin, and 3) control of odor through reduction of module leaks.

Figure 2 illustrates the changes incorporated in the redesigned RAHF, hereafter referred to as the SLS-1 RAHF (Spacelab Life Sciences 1 RAHF). Modifications for particulate containment include the addition of a single pass auxiliary fan (SPAF) to create a high inward air flow during all open-door operations, sealing of the cage/cage module interface, and totally sealing the cages to prevent particles of 150 microns or greater from escaping. The total leak rate for the RAHF is currently less than 10 cfm at 1 in. of water which results in the RAHF operating at a negative pressure to the cabin in flight.

Cage redesign to contain particulates to 150 microns required changing the cage top from the half inch spaced grid to a multi layer 135 mesh screen. In addition, the rodent water lixit has been brought to the interior of the cage via a quick disconnect at each cage compartment and the waste tray has been snugged against the cage bottom. Feeders now sustain a longer lasting, low crumbing food bar necessitating fewer inflight changes of feeders.

The SPAF, incorporated to control air flow during cage operations, is manually activated any time a RAHF cage door is opened, a feeder or waste tray changed, or a cage removed from the RAHF. SPAF activation creates a high inward air flow permitting particulate retention to within two inches from the front of the cage.

Changes initiated in the SLS-1 RAHF were the result of attaining a fundamental undertstanding of the airflow subsystem. Airflow through the RAHF cages during nominal operations is 80 cfm (approximately 6.5 cfm at each cage). Therefore airflow could be treated as an incompressible flow (i.e., oil flow characteristics) with the distributed paths over and through cages being comparable to a "pipeline" system in oil flows. Commercial models are available for such systems. The approach used analysis data correlated with test data to review both the SL-3 and the proposed SLS-1 configuration. This allowed prediction of system performance under all important conditions and a determination of the system configuration required to meet the performance objectives. Predicted models compared within 10% to actual system test results comparing module flow rates, pressure drops, and flow patterns.

Modeling addressed various parameters including: adequate ventilation for oxygen (O_2) supply and carbon dioxide (CO_2) removal, restriction to three cfm design flow required for O_2 and CO_2 control, minimization of thermal losses, various possible leak paths in the cage module including the many wire bundles and tubing lines, and the bleed air rate. The cage configuration, i.e., cage top design, waste tray packing and materials all effected flow paths. As a result, the waste tray packing material has also been changed. Effects of a dirty waste tray were determined to be minimal. Flow models and particle retention models were correlated to cage withdrawal velocities for various expected particle sizes. The rodent RAHF system was analyzed for the velocities corresponding to cage out, feeder out, and waste tray out. Figure 3 is the Rodent System Schematic which was addressed. Figures 4 and 5 illustrate SL-3 particle escape and SPAF reverse flow, respectively.[9]

Further confirmation of predicted models was obtained during the August-September, 1988 SLS-1 RAHF Biocompatability and Systems Sensitivity Tests which were conducted with a full complement of rodents. Odor was evaluated by a panel of ten persons and SLS-1 crew persons, during their visit to the test. The panel represented personnel both within and outside the Project. The group agreed unequivocally that no odor could be detected throughout test operations or at the conclusion of the eight-day test.

In the event of power failure, a leak tight system should also result in less available O_2 over a shorter time. Tests conducted with the SL-3 RAHF in "power off" mode in 1983 showed that four hours were required before rodents exhibited the typical drowsiness associated with O_2 depletion (available O_2 measurements were also taken during the test). The same symptoms were evident in less than 45 minutes in the recent SLS-1 RAHF tests.

Table 4 (Observed Air Flow During SPAF Observations) shows air velocity measurements obtained with the SPAF. Data indicate that full SPAF operation air velocities are sufficient to contain any size particulate potentially escaping the RAHF via cage, feeder, or waste tray removal. Inlet air velocities, indicated under SPAF OFF, Normal Flow Velocity column verify that the RAHF maintains a negative pressure sufficient to contain odors, as designed. Though additional testing is still required at the sides of the cage during cage removal operations, lack of particulate during collections in the Biocompatability Test operations confirmed the conclusions that the SPAF is effective in particulate control.

Incidental confirmation of the improved "leak tightness" of the RAHF was the increased condensate collected. More than twice as much condensate (2.5 liters) was collected in the SLS-1 RAHF compared to operations with the SL-3 RAHF at comparable environmental humidity conditions. An additional opportunity to verify 1-G operation of the RAHF will occur during the SLS-1 Experiment Verification Test (EVT) scheduled for February 1989. This test is the final verification of payload experiment elements prior to release for flight integration at KSC.

SLS-1 PARTICULATE CONTROL

The SLS-1 RAHF, Figure 6, along with other ARC developed payload elements will be verified for particulate containment under microgravity operations during the SLS-1 mission which is scheduled for launch June, 1990. One rodent RAHF containing 20 rats will be flown during the mission. Two cages will be reserved for the Particulate Containment Demonstration Test (PCDT) activities, which will verify microgravity particulate containment of the RAHF and accompanying systems. In this series of tests, a particulate sample, equivalent to a 10 day accumulated load of food crumbs, feces, and hair, will be released within a cage. Following the release of the particulate load, air will be sampled around the front of the cage to verify absence of escaped particulates. Particulates will also be measured during a feeder and a waste tray change of the particulate laden cage and during transfer of the cage to the General Purpose Work Station (GPWS). The SPAF will be activated during all demonstrated RAHF operations. Stowage bags will be utilized to further insure no particulate loss during feeder and waste tray changeouts and a General Purpose Transfer Unit (GPTU) will be used during physical removal of the cage from the RAHF.

The GPTU, illustrated in Figure 7 has beon specifically designed for the SLS-1 mission as secondary containment. Particulate release from the cage will be determined post flight through observation of any deposited particulates within the GPTU. The unit is a Tyvek sock connected to a lexan frame. The frame attaches to both the RAHF and the GPWS for entry and removal of the cage. In the event no particulates are observed in the GPTU it is anticipated the unit would not be required in future flights.

Particulates, potentially released as a result of RAHF or PCDT operations, will be measured in flight using a modified RCS air sampler (used for microbiological sampling in Skylab and SL-3). The sampling head of the RCS unit has been modified to incorporate a mesh screen instead of the microbial media agar strips. The mesh screen entraps particulates from 74 to 350 microns. A series of screen heads will be provided to accompany prescribed operations; these will be analyzed post flight.

The General Purpose Work Station (GPWS), Figure 8, is the second major piece of hardware to be flown on SLS-1. The results of SL-3 effected modifications to this unit to insure particulate containment. Modifications have included: specifically designed windows for RAHF cage/GPWS interfaces, incorporation of arm gauntlets similar to those used in microbiological glove boxes, and redesigned front and rear air grilles to ensure entrapment of particulates and liquids in the lower plenum area when the air circulation blower is off.

The GPWS will be utilized for rodent processing on subsequent SLS spacelab flights and for frog egg fixations in SL-J. Available work space (8.5 cu. ft) provided by the GPWS make it a "test piece" for Space Station laboratory equipment. In addition to verifying the GPWS/RAHF cage interfaces for particulate containment, particulate containment within the GPWS will also be verified during SLS-1. Particulates will be released within the unit and their containment measured through sampling outside the GPWS at potential "leak" areas. Ease of cleaning the unit will be evaluated along with particulate and fluid release behavior in the imposed laminar flow atmosphere of the cabinet.

As a piece of laboratory equipment, the GPWS has been designed to support fixative containment, i.e, glutaraldehyde, formaldehyde, isopropanol. No volatiles will be released during SLS-1; the unit has been previously verified by Baker Corporation through the use of spores and dioctyl phthalate (DOP) trace systems. The Trace Contaminant Control System (TCCS), a series of charcoal and lithium hydroxide beds and filters, has been designed to contain components of defined characteristics, i.e., carbon chain length and molecular forces. Two different computer models exist showing the capabilities of the TCCS; chemical removal by the primary cannister has been verified under normal terrestial conditions.[10]

Initial testing of operational concepts for particulate containment in the microgravity atmosphere has been performed through use of KC-135 and Lear jet flights. Though the parabolas are of short duration, they do afford sufficient time to evaluate crew/hardware interfaces and potential design problems. In addition, these flights are readily accessible.

SUMMARY

In summary, methods are available for particulate containment. Those methods can be proven through computer modeling, through ground tests accompanied by appropriate detection methods, and through short term microgravity testing, i.e., parabolic flights. The potential impacts are increased crew operations and hardware constraints. The essential objective is that there be no compromise to the science. The final test is the microgravity Mission.

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TABLE 1
SL-3 MIDDECK, FLIGHT DECK AND SPACELAB PARTICULATES/M^3

MISSION DAY	MIDDECK	FLIGHT DECK	SPACELAB
1	35,000	23,500	3,000
2	-	-	3,750
3	14,000	24,000	4,000
4	-	-	4-12,500*
5	-	-	3,000
6	-	-	-
7		15.000	5,000

NOTES: - No count available
* Hghest count following waste tray changeout

TABLE 2
CREW MODULE PARTICULATES

SAMPLE LOCATION	ANALYSIS	PARTICULATE DESCRIPTION AND COMPOSITION
#1 DEU-1	Observation	Blue/white lint, hair, white and black velcro hooks; yellow, white, green black, orange paint
	SEM/EDS	Aluminum particles (2mm longest), Black-orange low allow steel, Green flake with high Si, K, Cr, and Zn (primer) Red high Si + Fe (RTV), small sand grains, bits of fiberglass Brown/tan organic mixture containing Cl, Si, K, and S
#2 Debris Around DEU 2 & 4 (behind closeout panel)	Observation	Wash and Dri pad holders, straw from food or drink bag, banana chip, orange peel, sugar Hair, plastic packing, photographic film, glossy paper, red snap buttons, white button Fingernail, red RTV, blue-black-white-gray-and yellow paint chips
	IR	Tan organics analyzed as carbohydrate, starch, and soybean oil Brown organics of proteinaceous material containing oil, like soybean oil
	SEM/EDS	Brown organic contained Cl and K Other brown/red glassy organic-high in S, K, Cl 5 mm Al particle + 2 small wires of Stainless (A-286 or 300 series)
#3 Debris Found In Tunnel Adaptor	Observation	Fiberglass, red synthetic fiber, white paint, cellulosic flake
	IR	Plastic film of polyamide, i.e., nylon 6 Brownish clump containing sucrose and starch-carbohydrate Brittle yellow material with spectra like corn syrup
	SEM/EDS	Particles observed were organics: Amber particles contained S, Cl, K, P, Ca, Orange flake contained K, glassy particle contained Cl Red/white particle contained Si, Cl, K, and Ca
#4 Debris Found In Airlock	Observation	3/4" square of black rubber covered with white glossy plastic/paper with felt tip pen number "8" inscribed, plastic film, white nylon thread, green polystyrene, 1 cm fiberglass bundle, cellulosic fiber , black rubbery film, blue-black-white fibers
	IR	Tan crystalline material organic*
	SEM/EDS	Red rubberymater with Si and Ni (IR indicated polyisoprene rubber) Brown spongy material of Si, Al, K, Ca, Fe *Tan crystalline organic with P, K, Ca (thought to be rat food bar) Small aluminum particle and large (6mm dia.) rock high in Si and Al

TABLE 3[1]
AVIONICS AND CABIN AIR FILTER DEBRIS

SAMPLE LOCATION	TOTAL WEIGHT GRAMS	DESCRIPTION OF DEBRIS	ITEMIZED WEIGHT GRAMS
Group #1-Floor, end cones, overhead areas	3.2621	Food, metal filings <500 um	.8354
		Tile wraps	.0265
		Clear silicone like material	.0938
		Hair	.0421
		Lint, string	.5026
		Green primer coating	.0626
		Food particles, metal filings >7500 mm, <1mm	.7787
		Scotch tape	.0469
		Metal filings, wire twists	.1449
Group #2-STT inlet screen debri -SL-FU03-P017	.0252	Hair, food particles	
Group #3-Avionics fan filter OMI L1044	3.5189	Rat feces	.0267
		Fibers, string, plastic	.0045
		Food >1 mm	.4232
		Potting compound, epoxy	.1714
		Lint	7113
		Plastic, epoxy	.1038
		Hair, fingernail	.0123
		Metal shavings, drill twists	.3452
		Food, metal shavings, etc. <500 um	0328
		Palmetto bug legs	.0315
		Plant material (sticks to clothing)	.0548
		White, hard chalk-like pieces	.0062
		Cloth, tie wrap, paper	.0703
		Food, metal filings 250 um	.0527
		Food, metal filings <1mm	.5683

TABLE 3 (CONTINUED)[2]

SAMPLE LOCATION	TOTAL WEIGHT GRAMS	DESCRIPTION OF DEBRIS	ITEMIZED WEIGHT GRAMS
Group #4-Cabin fan filter	7.6173	Lint	2.6052
		Feces	.1120
		Metal filings, lock washer	.1424
		Green epoxy, yellow epoxy chips	.0162
		Small feces piecies, epoxy >1 mm	1.7615
		White, dried bread crumbs	.3003
		Food pieces, metal filings <500 mm	.4815
		Notation (not decipherable)	.0399
		String, tie wrap	.1486
		Food, feces <250 um	.0899
		Hair	.0156
		Plastic, epoxy like pieces	.4156
Group #5-Avionics Filter, loose	C.3237	Food, black specs >500 um	.0273
		Palmetto bug	.2578
		Feces like material (black)	.0203
		Hair -3 strands	no weight
		Lint	.0045
		Cloth	.2708
		Metal shavings, washers, nuts, etc.	1.7715
		Food particles >1mm	.0224
		Pencil lead	.0047
		Food particle composition	.0198
		Plastic amphenol inserts (green and white)	1.7187
		Food bar chunks	.9167
		Rubber band	.7131
		Plastic tubing, plastic pieces	.5740

TABLE 3 (CONTINUED)[3]

SAMPLE LOCATION	TOTAL WEIGHT GRAMS	DESCRIPTION OF DEBRIS	ITEMIZED WEIGHT GRAMS
Group #6-Tunnel	1.0160	Food particles, metal filings <250 um	.2923
		Food particles, metal filings <500 um	.1234
		Food particles, metal filings >500 um	.1008
		White tissue	.0008
		Plastic, silicone pieces, epoxy	.1515
		Lint	.0713
		Food bar chunks	.0315
		Scotch tape	.0115
		Hair	.0120
Group #7-Cabin fan filter, loose	3.3108	Description not decipherable	.0125
		Food, feces, dried bread like	.2605
		Food bar chunks	.5862
		Velcro , cloth tape	.4332
		Scotch tape, plastic tubing	.2089
		M&M chunks	.0115
		Feces	.0327
		Metal washers, drill twists	1.2482
Group #8-Port side rack exterior	3.0292	Scotch tape, white tape, solder bead	

TABLE 4
OBERVED AIR FLOWS DURING SPAF OPERATION

LOCATION	FULL SPAF VELOCITY (FPM)	HALF SPAF VELOCITY (FPM)	SPAF OFF NORMAL FLOW VELOCITY (FPM)
Feeder Door	1500	800	120
Waste Tray Door	3000	1500	150
Around Cage (A,B,C,D)*	410, 0, 120, 70	205, 0, 60, 35	N/A
GPTU Adaptor (A, B, C, D)*	110, 0, 80, 0	55, 0, 40, 0	N/A

NOTES: *Measurements taken at A: Cage Top Opening
B: Cage Right Side
C: Cage Waste Tray Side
D: Cage Feeder Side

RAHF ENVIRONMENTAL CONTROL SYSTEM

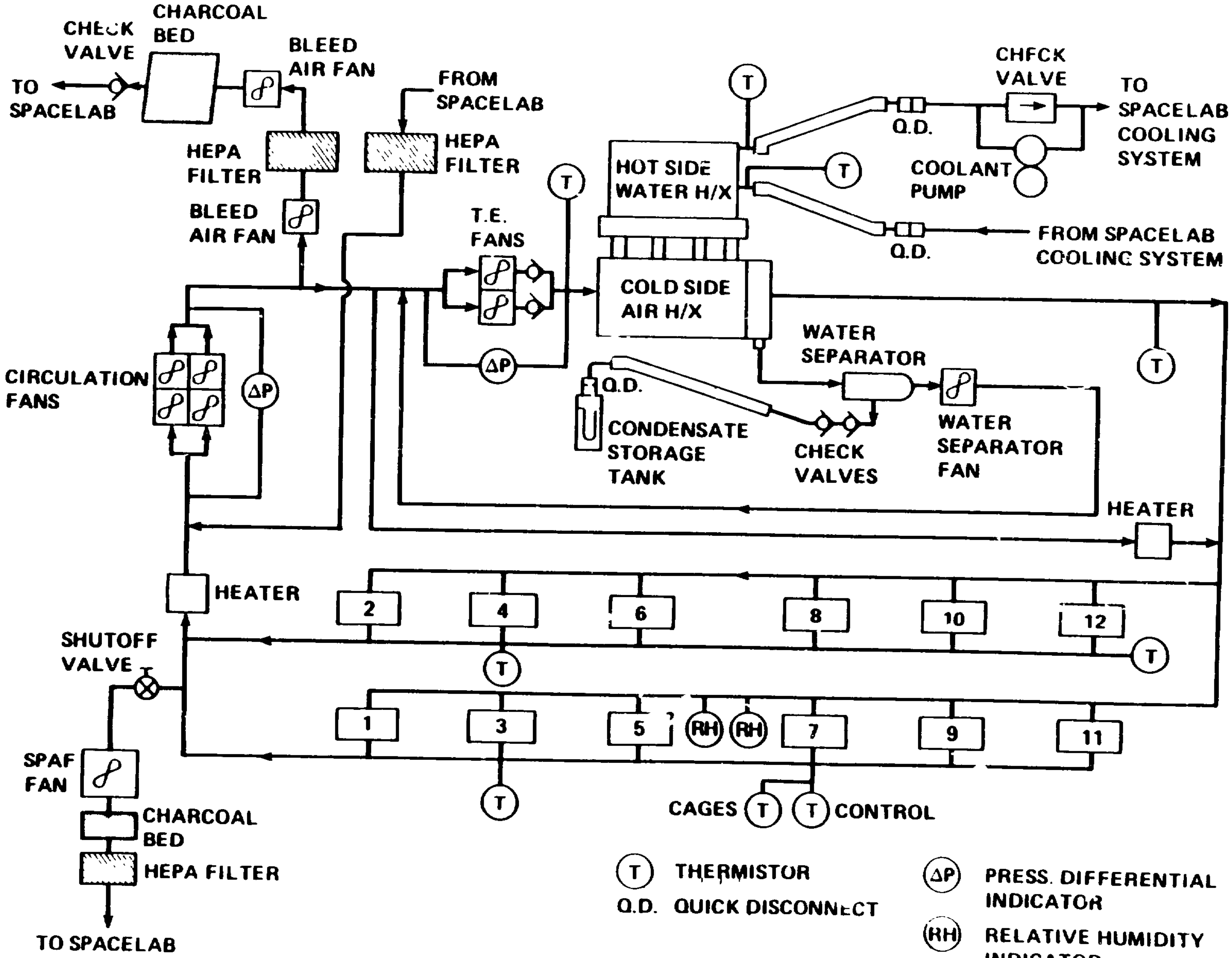

FIGURE 1

RESEARCH ANIMAL HOLDING FACILITY
CHANGES IN RAHF

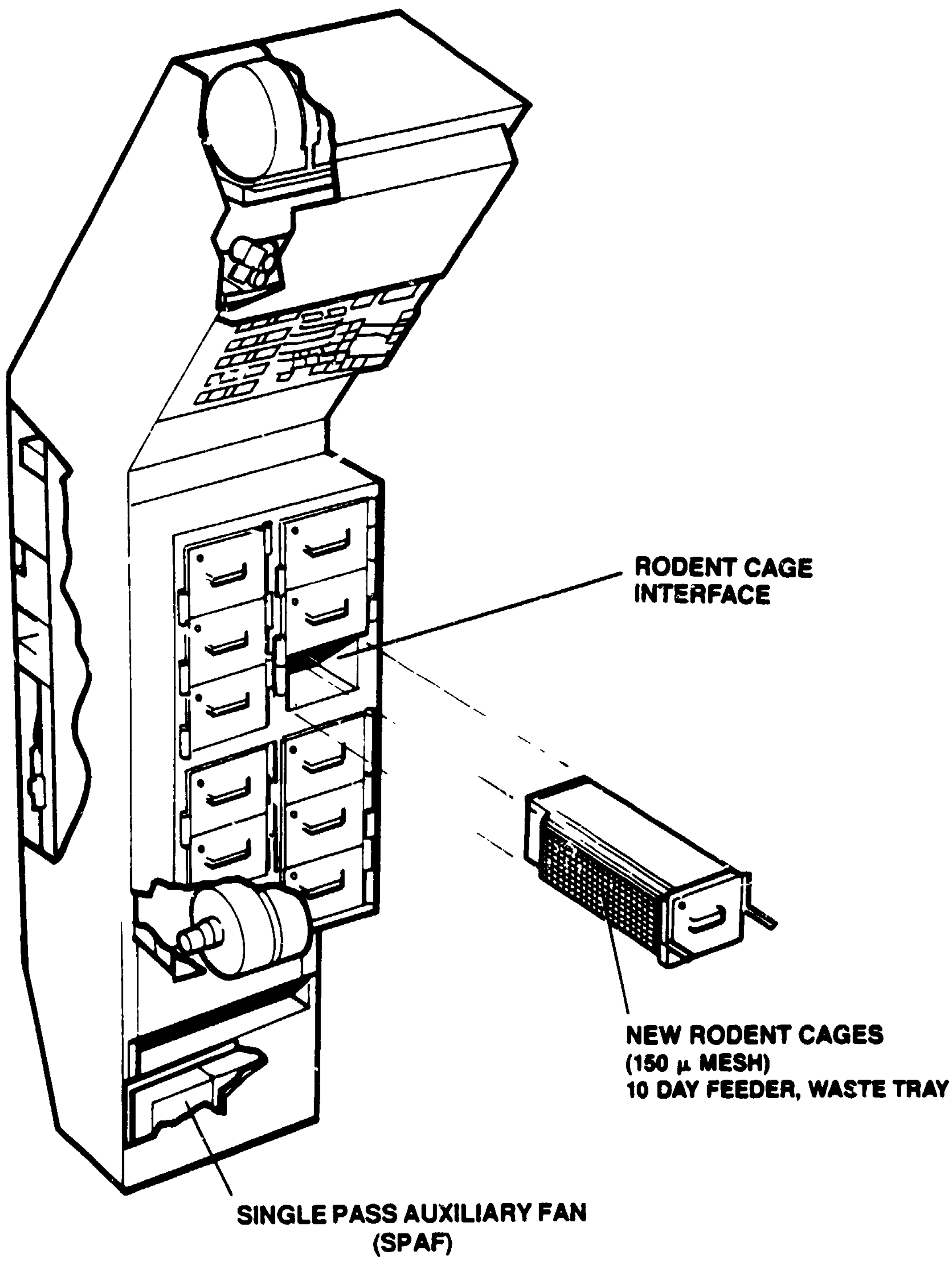

FIGURE 2

RAHF SYSTEM SCHEMATIC – RODENT CONFIGURATION

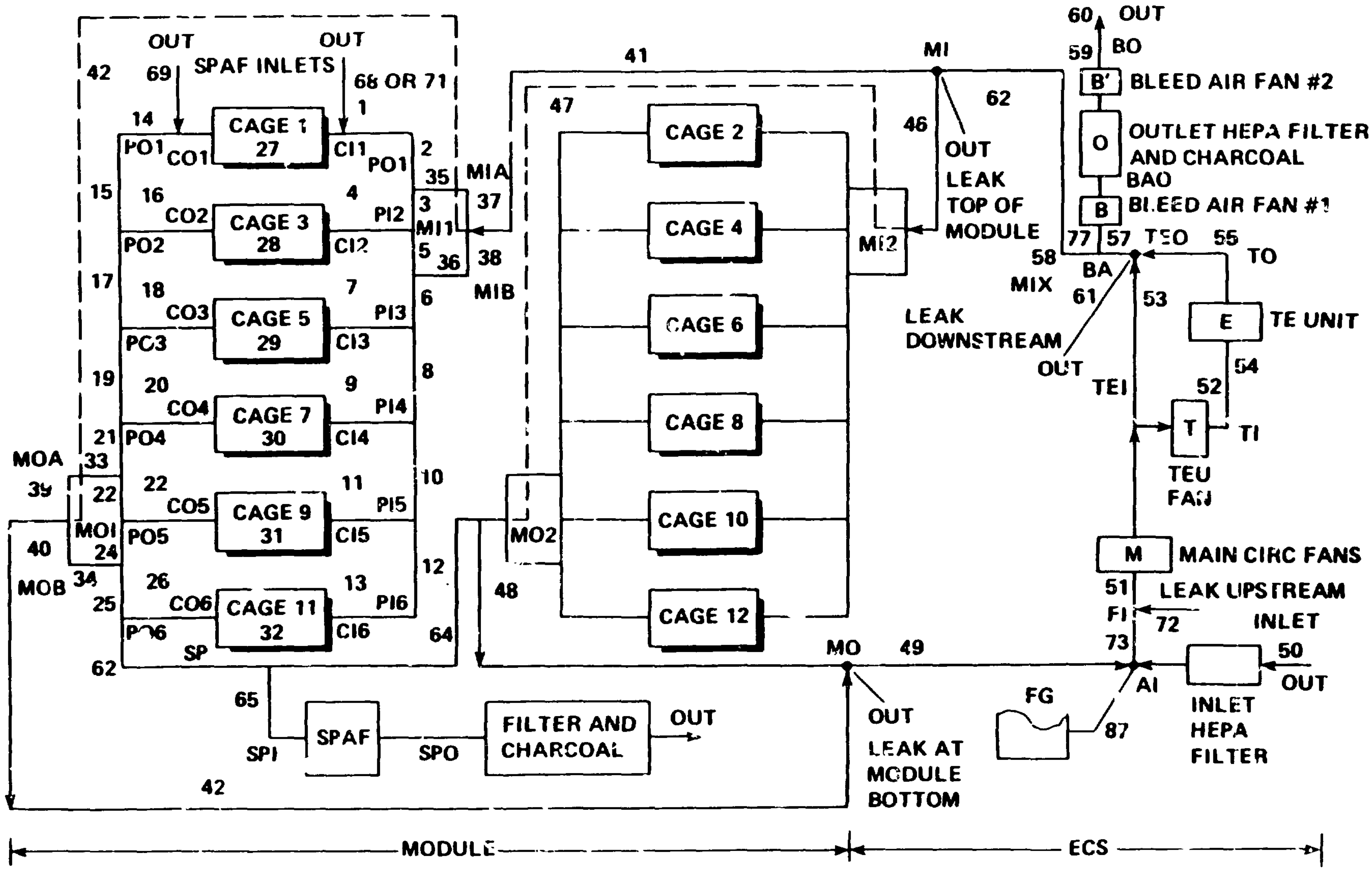

FIGURE 3

SL3 PARTICLE ESCAPE

RAHF SYSTEM SCHEMATIC – RODENT CONFIGURATION

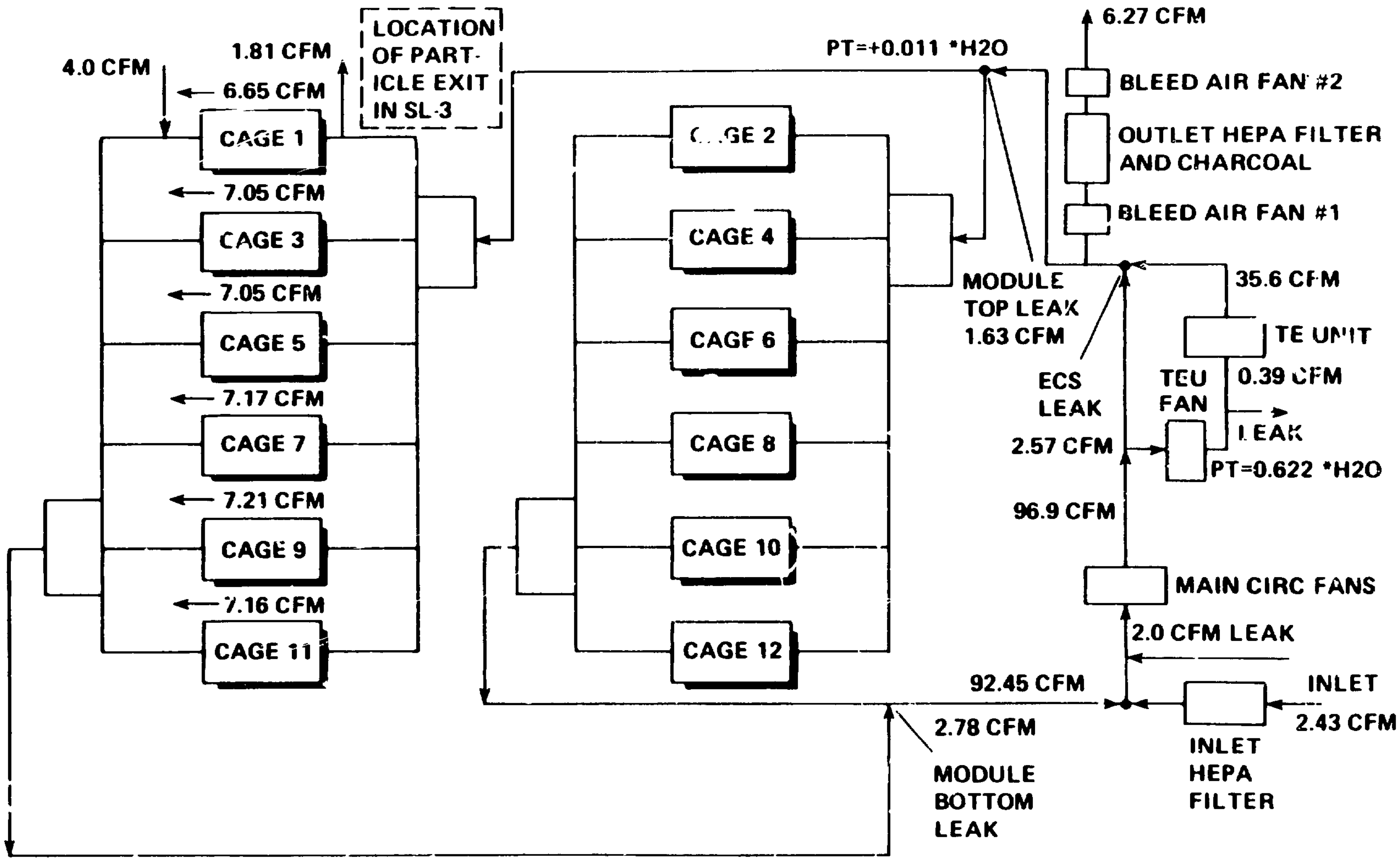

FIGURE 4

RODENT SPAF REVERSE FLOW

RAHF SYSTEM SCHEMATIC – RODENT CONFIGURATION

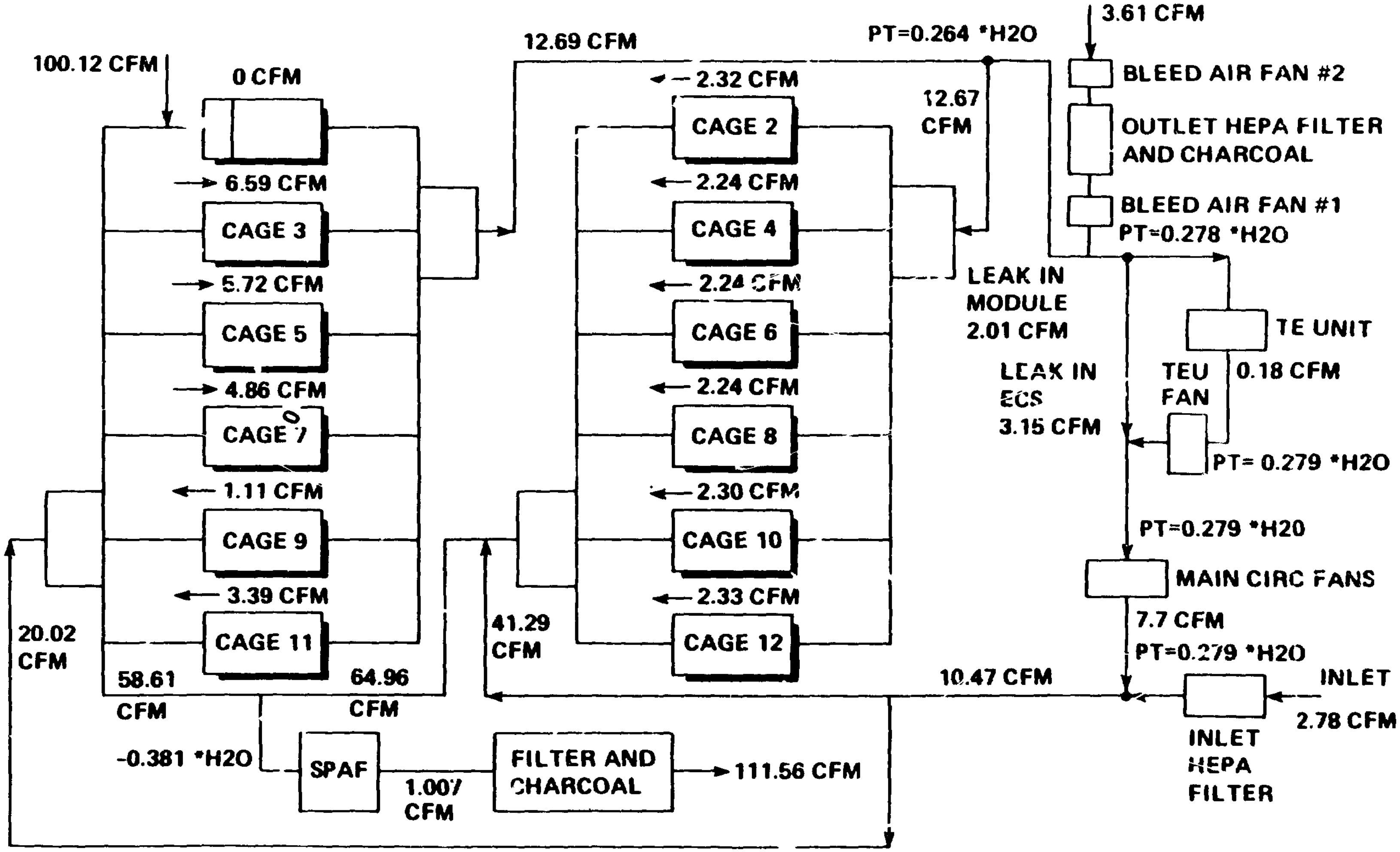

FIGURE 5

SLS-1 RAHF

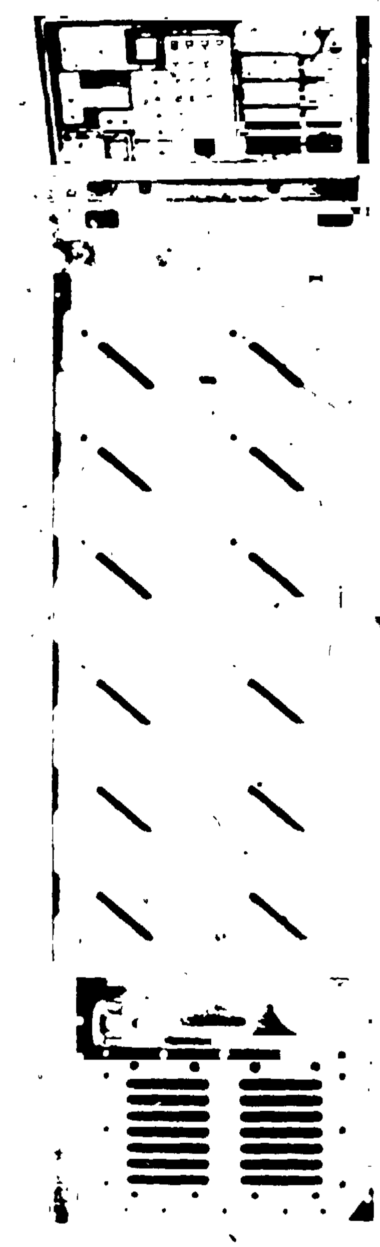

FIGURE 6

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GENERAL PURPOSE TRANSFER UNIT

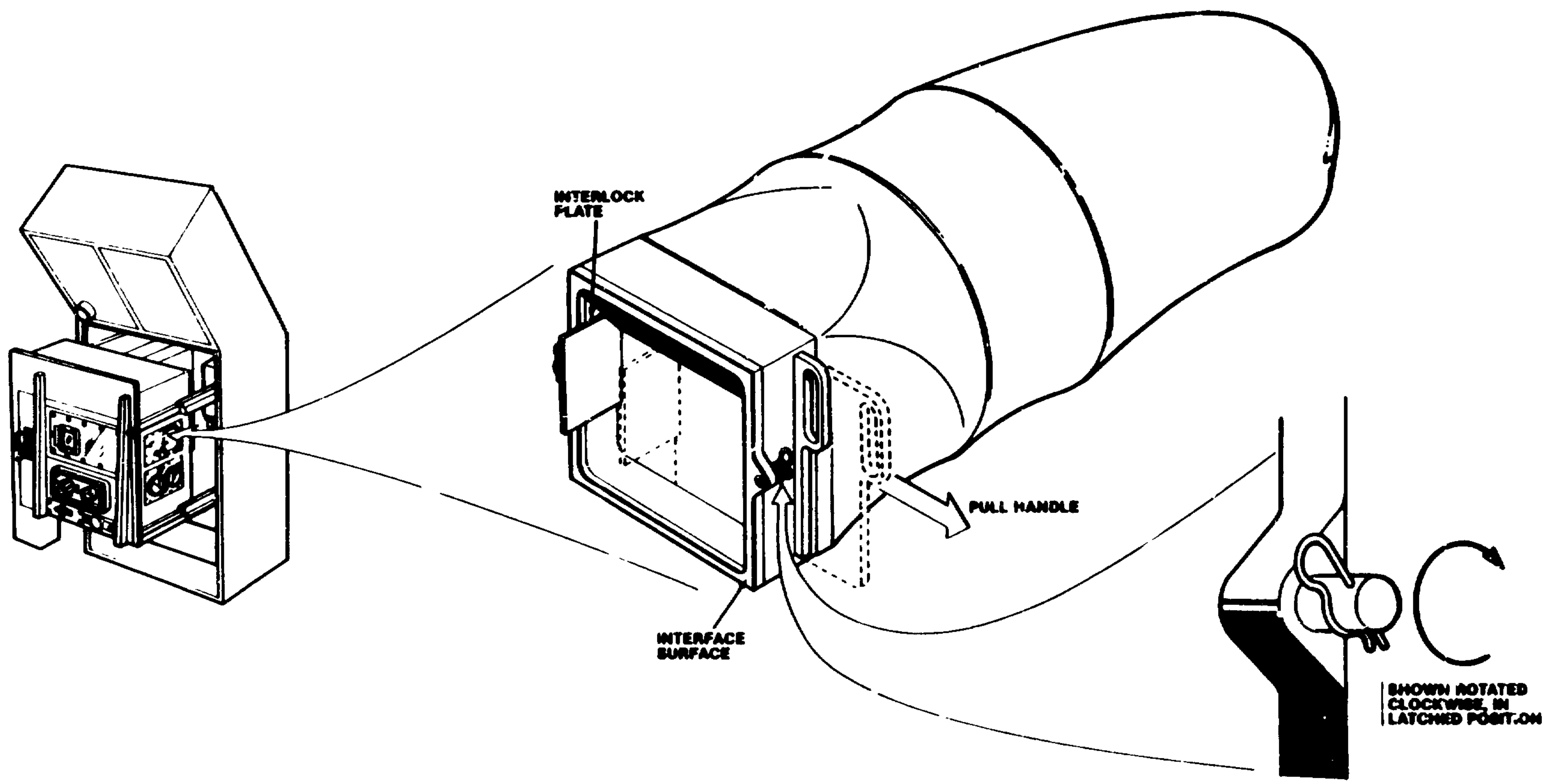

FIGURE 7

GENERAL PURPOSE WORK STATION

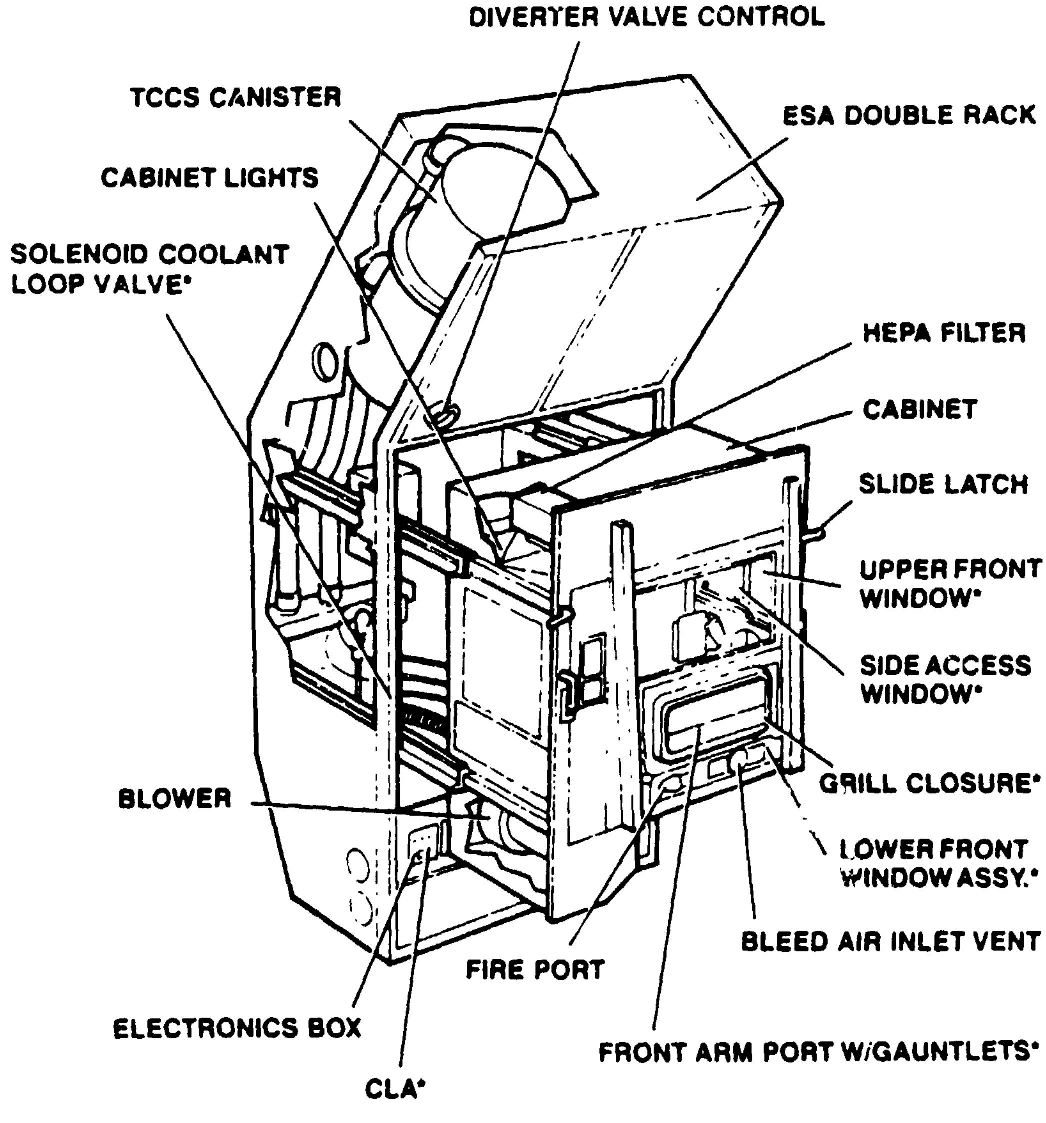

FIGURE 8

SPACE STATION FREEDOM

TOXIC AND REACTIVE MATERIALS

HANDLING WORKSHOP

NOVEMBER 29, 30 & DECEMBER 1, 1988
HUNTSVILLE, ALABAMA

SPACELAB 3 MISSION

BONNIE P. DALTON
AMES RESEARCH CENTER
SPACE LIFE SCIENCES PAYLOADS OFFICE

MISSION BACKGROUND

MISSION PURPOSE:

- CONDUCT MATERIALS SCIENCE EXPERIMENTS IN LOW GRAVITY ENVIRONMENT

MISSION FIRSTS:

- FIRST MICROGRAVITY MISSION OF EXTENDED DURATION INVOLVING CREW INTERACTION WITH ANIMAL SPECIMENS
- HERALDED THE USE OF SPACELAB IN SUPPORT OF ANIMAL FACILITIES FOR BIOMEDICAL INVESTIGATIONS

MISSION SCIENCE:

- FIFTEEN INVESTIGATIONS IN FOUR RESEARCH FIELDS

MISSION SCIENCE

EXPERIMENTS:

- MATERIALS SCIENCE
  - SOLUTION GROWTH OF CRYSTALS IN ZERO-GRAVITY
  - MERCURIC IODIDE GROWTH-VAPOR CRYSTAL
  - MERCURY IODIDE CRYSTAL GROWTH
- FLUID MECHANICS
  - DYNAMICS OF ROTATING & OSCILLATING FREE DROPS
  - GEOPHYSICAL FLUID FLOW CELL
- ATMOSPHERIC AND ASTRONOMICAL OBSERVATIONS
  - ATMOSPHERIC TRACE MOLECULES SPECTROSCOP (ATMOS)
  - IONIZATION OF SOLAR AND GALACTIC COSMIC RAY HEAVY NUCLEI
  - AURORAL IMAGING EXPERIMENT
  - VERY WIDE FIELD CAMERA
- LIFE SCIENCES
  - AMES RESEARCH CENTER LIFE SCIENCES PAYLOAD RESEARCH ANIMAL HOLDING FACILITIES, DYNAMIC ENVIRONMENT MEASURING SYSTEM, BIOTELEMETRY SYSTEM
  - AUTOGENIC FEEDBACK TRAINING
  - URINE MONITORING INVESTIGATION

AMES RESEARCH CENTER LIFE SCIENCES PAYLOAD

- TWO RESEARCH ANIMAL HOLDING FACILITIES (RAHFs)
  - 24 RATS, 2 SQUIRREL MONKEYS

- DYNAMIC ENVIRONMENT MEASURING SYSTEM
  - MEASUREMENT OF FOLLOWING PARAMETERS DURING LIFT OFF, ORBITAL INSERTION, RENTRY, AND LANDING:
    - THREE AXIS ACCELERATION
    - THREE AXIX VIBRATION
    - NOISE

- BIOTELEMTRY SYSTEM
  - MEASUREMENT (via implanted sensors) of
    - DEEP BODY TEMPERATURE
    - HEART BEAT
    - ELECTROCARDIOGARM (ECG)

SPACELAB 3 ARCLSP GOALS AND OBJECTIVES

GOAL:

- VERIFICATION OF THE RAHF UNDER MICROGRAVITY CONDITIONS

OBJECTIVES:

- EVALUATE OPERATIONS AND PROCEDURES FOR MISSION CARE OF ANIMALS
- PROVIDE IN-FLIGHT BIOCOMPATABILITY ASSESSMENT BETWEEN ANIMALS AND THE RAHF
- GAIN MISSION OPERATIONAL EXPERIENCE
- STUDY PHYSIOLOGICAL, BEHAVIORAL, MORPHOLOGICAL CHANGES OCCURRING AS RESULT OF CONTAINMENT IN RAHF
- VERIFY PRINCIPAL HARDWARE ELEMENTS TO BE REFLOWN

ARCLSP VERIFICATION ELEMENTS

ANIMAL MAINTENANCE

- CAPABILITY TO MAINTAIN ANIMALS IN MICROGRAVITY COMPARABLY TO EARTH VIVARIUM CONTROLS
  - ENVIRONMENTAL-TEMPERATURE, HUMIDITY, AIR EXCHANGE, AND LIGHTING
  - PROVISION OF FOOD AND WATER
  - WASTE MANAGEMENT

- TESTED BY POST-FLIGHT ANALYSES
  - DATA INDICATED AN ENVIRONMENT WAS MAINTAINED COMPARABLE TO THAT PROVIDED IN VIVARIUM
  - ANIMAL PHYSIOLOGICAL CHANGES A RESULT OF MICROGRAVITY ADAPTATION

ARC VERIFICATION ELEMENTS

CONTAINMENT VERIFICATION:

- MICORPARTICULATES (MICROBIOLOGICAL CONTAINMENT AND ESM MEASURED PARTICLES)
  - HRPPC GUIDELINES FOR SPECIFIC MICROORGANISMS OF EXCLUSION (SPECIES DEPENDENT)
    - >1500 SAMPLES ON ANIMAL POOL, PERSONNEL, FACILITIES PREFLIGHT BY ARC
    - 354 SAMPLES COLLECTED IMMEDIATELY PREFLIGHT, INFLIGHT, AND POST FLIGHT
      - 175 PREFLIGHT, 81 INFLIGHT, 98 POSTFLIGHT
      - SAMPLED CREW AND QUARTERS, ANIMALS AND HARDWARE, AND MISSION VEHICLE SITES
      - COMBINED EFFORT OF ARC, JSC, KSC, FLIGHT CREW (DSO)

CONTAINMENT VERIFICATION (CONTINUED)

MICROBIOLOGICAL

- *"LEVELS OF AIRBORNE MICROORGANISMS IN THE SPACELAB WERE LOW COMPARED TO VALUES OBTAINED FROM THE ORBITER DURING PREVIOUS MISSIONS"* *(DSPO MICRO REPORT)*

  - ANIMAL ORIGIN MICROBIOLOGICALS EXTERNAL TO RAHF (2 SAMPLES)
  - FECAL MARKERS E. COLI AND S. FAECALIS ONLY ON RAHF INTERIOR SURFACES

CONTAINMENT VERIFICATION (CONTINUED)

<u>PARTICULATES</u> /NON-MICROBIOLOGICAL

- PARTICULATES COLLECTED WITH RCS SAMPLER (ADHESION FOLLOWED BY EMS ANALYSES)
- MEASUREMENTS PREFLIGHT AND L+0
  - INFLIGHT MEASUREMENTS IN MID DECK, FLIGHT DECK, AND SPACELAB
    - RANGE <5,000 TO 34,000 PARTICULATES/M^3
    - FOOD CANISTER AND WASTE TRAY CHANGEOUT (5-12,000/M^3)
    - MID DECK VALUES DECREASED DURING FLIGHT, FLIGHT DECK HIGH (DIRECTIONAL AIR FLOW RESULT)
    - TABLE REFERENCE

CONTAINMENT VERIFICATION
MICROPARTICULATES

CONCLUSION

- *PARTICULATE LEVELS HIGH DURING SL-3*
- *MICROBIOLOGICAL PARTICULATES CONTROLLED BY RAHF HEPA FILTERS*

CONTAINMENT VERIFICATION (CONTINUED)

- <u>MACROPARTICULATES</u>
  - COLLECTED POST FLIGHT BY KSC PAYLOADS PROCESSING
    - IDENTIFIED OPTICALLY, SCANNING ELECTRON MICROSCOPE ENERGY DISPERSIVE ANALYSIS (SM/EDS), INFRARED (IR)
      - TABLE 2 REFERENCE: AIRLOCK SAMPLE = RAT FOOD
    - AVIONICS AND CABIN AIR FILTER DEBRIS TRANSFERRED TO MSFC, SUBSEQUENTLY SENT TO ARC
      - 7 SITES (TABLE 3):

GROUP 1 FLOOR, END CONES, OVERHEAD AREAS
GROUP 3 AVIONICS FAN FILTER DEBRIS
GROUP 4 CABIN FAN FILTER DEBRIS
GROUP 5 AVIONICS FAN FILTER, LOOSE
GROUP 6 TUNNEL DEBRIS
GROUP 7 CABIN FAN FILTER DEBRIS, LOOSE
GROUP 8 PORT SIDE RACK EXTERIOR

- <u>ODOR</u>
  - QUESTIONABLE CONTROL
  - OBVIOUS WHEN RAHF DOORS OPENED

PARTICULATE CONTAINMENT - FUTURE MISSIONS

<u>RAHF REDESIGN</u>

- PRIMARY GOAL
  - MAINTAIN AND ENSURE MICROBIOLOGICAL CONTROL
  - PARTICULATE CONTROL
  - ODOR CONTROL
- MEANS OF OBTAINING GOAL
  - CONTAINMENT OF DEBRIS AT SOURCE
  - CONTROL OF AIR FLOW DURING OPERATIONS REQUIRING OPENING CAGE MODULE TO CABIN
  - CONTROL OF ODOR THROUGH REDUCTION OF MODULE LEAKS
- AREAS AFFECTED
  - CAGE REDESIGN - 150 MICRON CONTAINMENT
    - CHANGE CAGE TOP SCREEN
    - BRING LIXITS INSIDE
    - CHANGE FEEDER DESIGN AND FOODBAR (LOWER CRUMBING)

<u>RAHF REDESIGN</u> (CONTINUED)

- MODULE AIR FLOW CONTROL
  - ADDITION OF SINGLE PASS AUXILIARY FAN (SPAF)-VACUUM
  - COMPUTER MODELING OF SYSTEM FLOWS TO UNDERSTAND AIRFLOW (6.5 CFM/CAGE)
    - PREDICTED MODELS AND TEST DATA AGREED WITHIN 10%
    - ANALYSIS FOR CAGE SYSTEM OUT, FEEDER OR WASTE TRAY OUT
    - WASTE TRAY PACKING EFFECTS (NEW PAD TO ASSURE UNIFORMITY)
    - AIRFLOW CONTROLLED WITHIN 2" OF CAGE FRONT
- MODULE "LEAK" CONTROLLED
  - LESS THAN 10 CFM AT 1 IN. (ACTUAL 2.4 CFM)
    - RODENT CO_2 DROWSINESS EFFECTS (45 MIN. V.S. 4 HRS.)
    - INCREASED CONDENSATE (2 TIMES ORIGINAL RAHF)
    - NO ODOR REPORTED BY PANEL AND CREW
  - MICROBIOLOGICAL CONTAINMENT INTEGRITY MAINTAINED BY HEPA
    - ROOM BIOLOGICAL BIOBURDEN CONSTANT

RAHF REDESIGN (CONTINUED)

- COMPLEMENTARY SYSTEMS TO RAHF
  - GENERAL PURPOSE TRANSFER UNIT (GPTU)
    - TYVEK WINDSOCK WITH I/F DOOR
    - USED TO TRANSPORT RODENT CAGE FROM RAHF TO GENERAL PURPOSE WORK STATION (GPWS)
  - GPWS
    - IN FLIGHT WORK STATION (8.5 CU FT) PROVIDING PARTICULATE AND VOLATILE CONTAINMENT
      - RODENT PROCESSING (SLS-2, 3) - PARTICULATE CONTROL
      - FIXATIONS (SLS-N AND SL-J)-VOLATILE CONTROL THROUGH TRACE CONTAMINANT CONTROL SYSTEM (TCCS)
      - SERIES OF CHARCOAL BEDS AND HEPA FILTERS
      - GLUTARALDEHYDE, FORMALDEHYDE, ISOPROPANOL
    - MODIFIED FOR PARTICULATE CONTAINMENT AS A RESULT OF SL-3
      - GAUNTLETS AKIN TO MICROBIOLOGICAL GLOVE BOX
      - GRILLE CLOSURES TO ENTRAP PARTICULATES AND LIQUIDS IN LOWER PLENUM WHEN BLOWER OFF
      - WINDOWS FOR ENTRY OF CAGES

PARTICULATE CONTAINMENT VERIFICATION

- VERIFICATION OF RAHF DURING BIOCOMPATABILITY TESTING, 8/88
- VERIFICATION OF TOTAL SYSTEM DURING SLS-1 EXPERIMENT VERIFICATION TEST 2/89
  - PARTICULATE CONTAINMENT DEMONSTRATION TEST
    - RELEASE OF 10 DAY PARTICULATE LOAD IN CAGE
    - CHANGE OUT OF FEEDER AND WASTE TRAY
    - TRANSFER OF CAGE (IN GPTU) TO GPWS AND BACK
    - RELEASE OF PARTICULATES IN GPWS
    - PARTICULATE SAMPLING DURING ALL PHASES (70 MICRONS TO 300 MICRONS)

SUMMARY

- PARTICULATE CONTROL IS RESULT OF:
  - COMPUTER MODELING INCORPORATION IN DESIGN
  - ONE-G TESTING AND RETESTING ACCOMPANIED BY PARABOLIC FLIGHTS (KC-135, LEAR JET)
  - CONSTRAINED OPERATIONS (FROM THAT KNOWN IN ONE-G)
- PRIMARY OBJECTIVE:
  - PARTICULATE CONTROL WITHOUT SCIENCE COMPROMISE
- FINAL PROOF WILL ALWAYS REMAIN WITH THE OPERATIONAL MISSION

N91-15935

TOXIC AND REACTIVE MATERIAL HANDLING ON SPACELAB J AND USML-1

By Jack Dashner

Spacelab J and USML-1 provide prime examples of materials which are toxic at ambient conditions or toxic during the processing stages. The materials are used in both life science and material processing experiments.

SPACELAB J

In addition to the experiments, the mission uses Mission Peculiar Equipment required to integrate the payload including a cooling water loop and a vacuum vent system. The vacuum vent plays an important role in toxicity control on Spacelab J.

While each of the experiments provide interesting and unique requirements for hazard control, the Frog Embryology Experiment (FEE), the General Purpose Work Station (GPWS), the FMPT Life Sciences (FMPT-LS) and FMPT Material Experiment Laboratory (FMPT-MEL) are the elements which contain most of the toxic materials.

The Frog Embryology Experiment is an Ames Research Center experiment developed in conjunction with the University of Michigan to study the effects of weightlessness in the development of amphibian eggs fertilized in space. Female African clawed frogs will be flown, ovulation will be induced and frog eggs will be placed in egg chambers. The eggs will be fertilized using testis and sperm prepared immediately before flight. Some chambers will be subjected to a one g centrifuge, Figure 1, to serve as a control group. Many of the chambers will be fixed with formaldehyde at predetermined periods following fertilization while others will be returned for continued ground studies.

This is a terse explanation of a very interesting experiment which will probably be discussed in a later session. From a toxicity standpoint, the fixative formaldehyde has a low maximum allowable concentration (MAC) and requires triple containment to meet the two failure tolerance required for hazards which could be catastrophic. Containment is provided by a syringe, sealed plastic bag, and a hard side sealed container during storage. Operations are performed inside of the General Purpose Work Station (GPWS), Figure 2. The GPWS provides a sealed container (closed environment) and provides the equivalent of a second containment by virtue of the filtering system which uses specially treated charcoal to remove formaldehyde and other toxic materials during the air circulation process. In the event of loss of power or other failures, the GPWS is placed in a closed loop operation which still provides one level of containment.

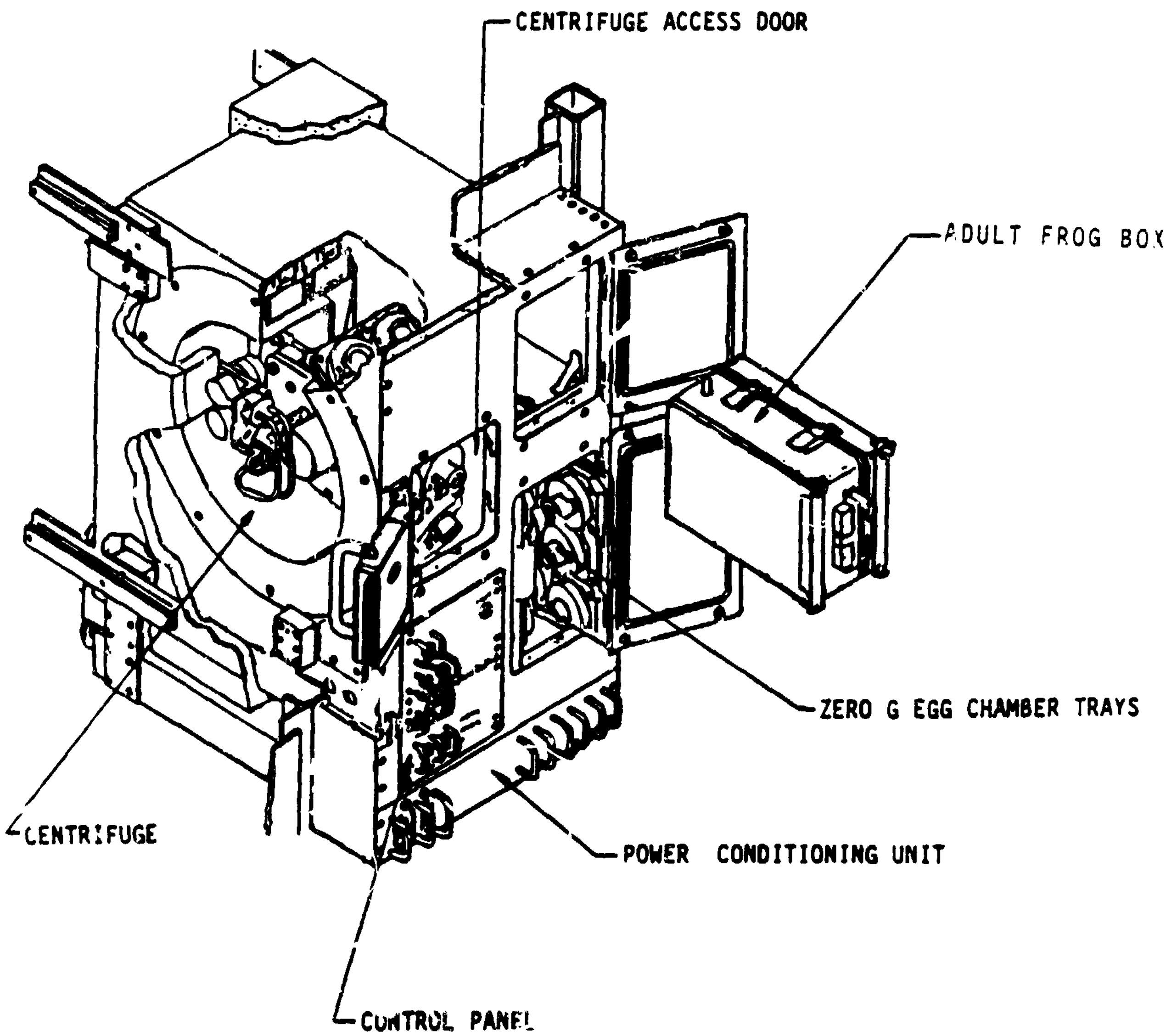

FIGURE 1. FEU EXPERIMENT CHAMBER

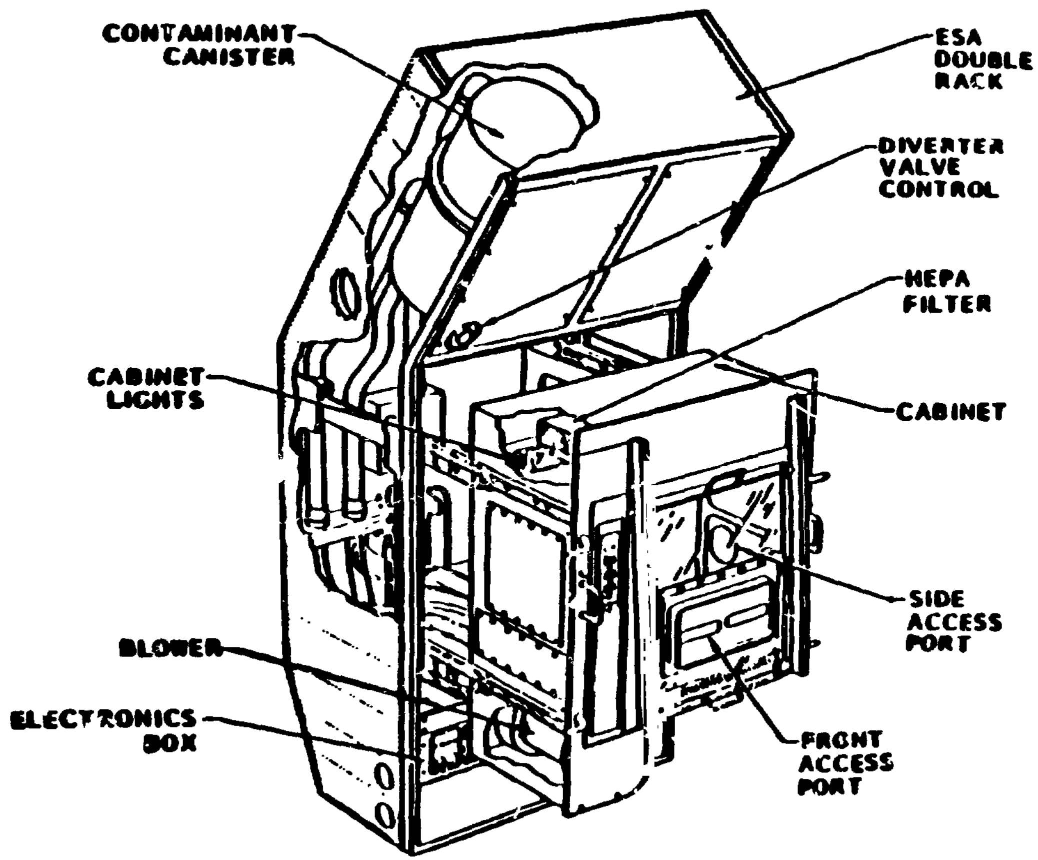

FIGURE 2 GPWS DESIGN OVERVIEW (IN DEPLOYED POSITION)

FMPT Life Sciences

The Japanese experiments use hardware developed by both the Japanese and JSC to conduct 13 experiments including:

- Free Flow Electrophoresis Unit (FFEU)
- Vestibular Function Experiment Unit (VFEU)
- Thermo-Electric Incubator (TEI)
- Light Impulse Stimulator (LIS) Equipment
- Fungi Growth Chamber
- Enzyme Crystallization Kit
- Cell Culture Kit
- Fly Container
- Cosmic Radiation Devices
- Egg Rack
- Physiological Monitoring System
- Urine Monitoring System (UMS) - SL-3

The experiments contain numerous materials including biological materials, fish (2 carp), fungi, enzymes, animal and plant cells, fruit flies, seeds, hen eggs, and urine specimens. While each of the experiments has interesting and unique objectives, the fluids are low or non toxic and use single to dual containment. The cell culture kits present the greatest hazard principally due to the fixative agent glutaraldehyde which fixes samples at various stages of growth. This example has been selected principally to display a rather innovative syringe used to provide dual containment (Figure 3).

The life science experiments have been slighted in order to discuss the material processing facilities.

FMPT - Materials Experiment Laboratory (MEL)

The FMPT-MEL will occupy two double Spacelab racks to house the experiments and support equipment. Figure 4 depicts the configuration and Table 1 identifies the equipment.

The FMPT-MEL consists of 22 experiments performed in 11 different facilities which include 6 different types of furnaces. The experiments and facilities are listed in Table 2.

In addition to the experiment facilities a dedicated vacuum vent facility is required in conjunction with a turbomolecular pump to provide a high quality vacuum. Additionally, high pressure gasses (3000 psi helium, 3000 psi synthetic air, 3000 psi argon, and 1000 psi krypton) are provided for processing, quenching, purging and pneumatic valve operation.

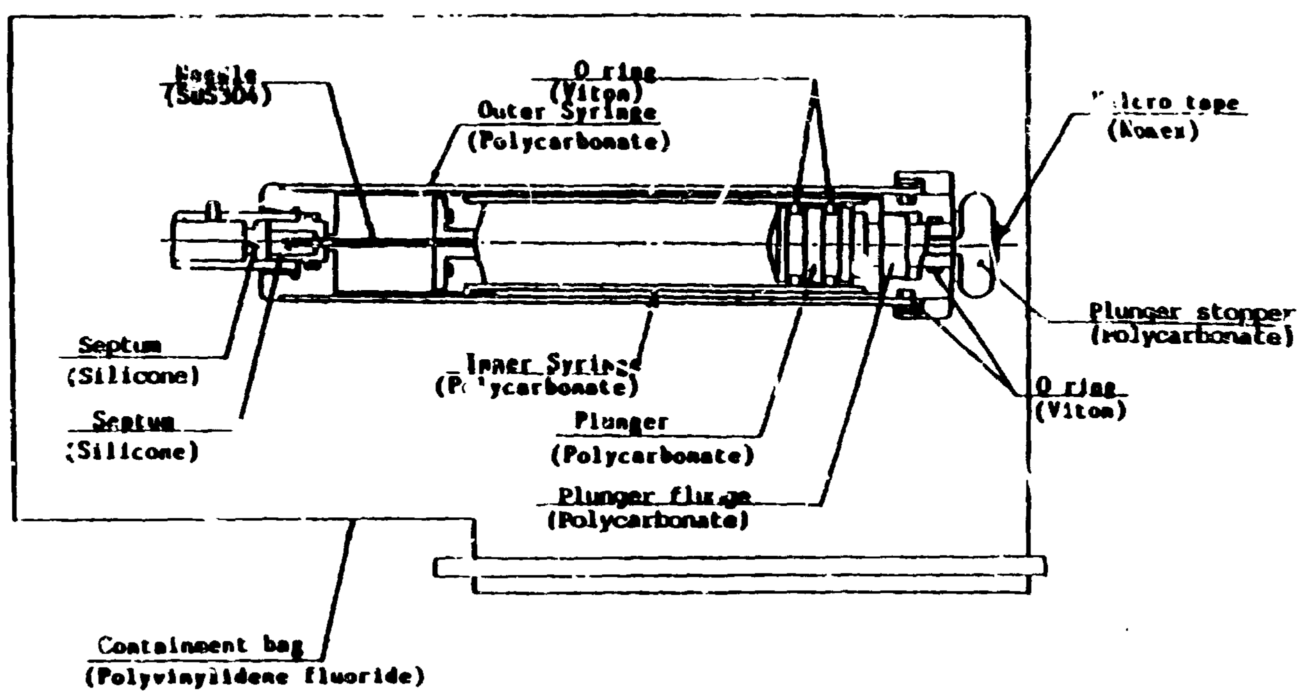

FIGURE 3 GLUTARALDEHYDE CONTAINER (DOUBLE SYRINGE TYPE)

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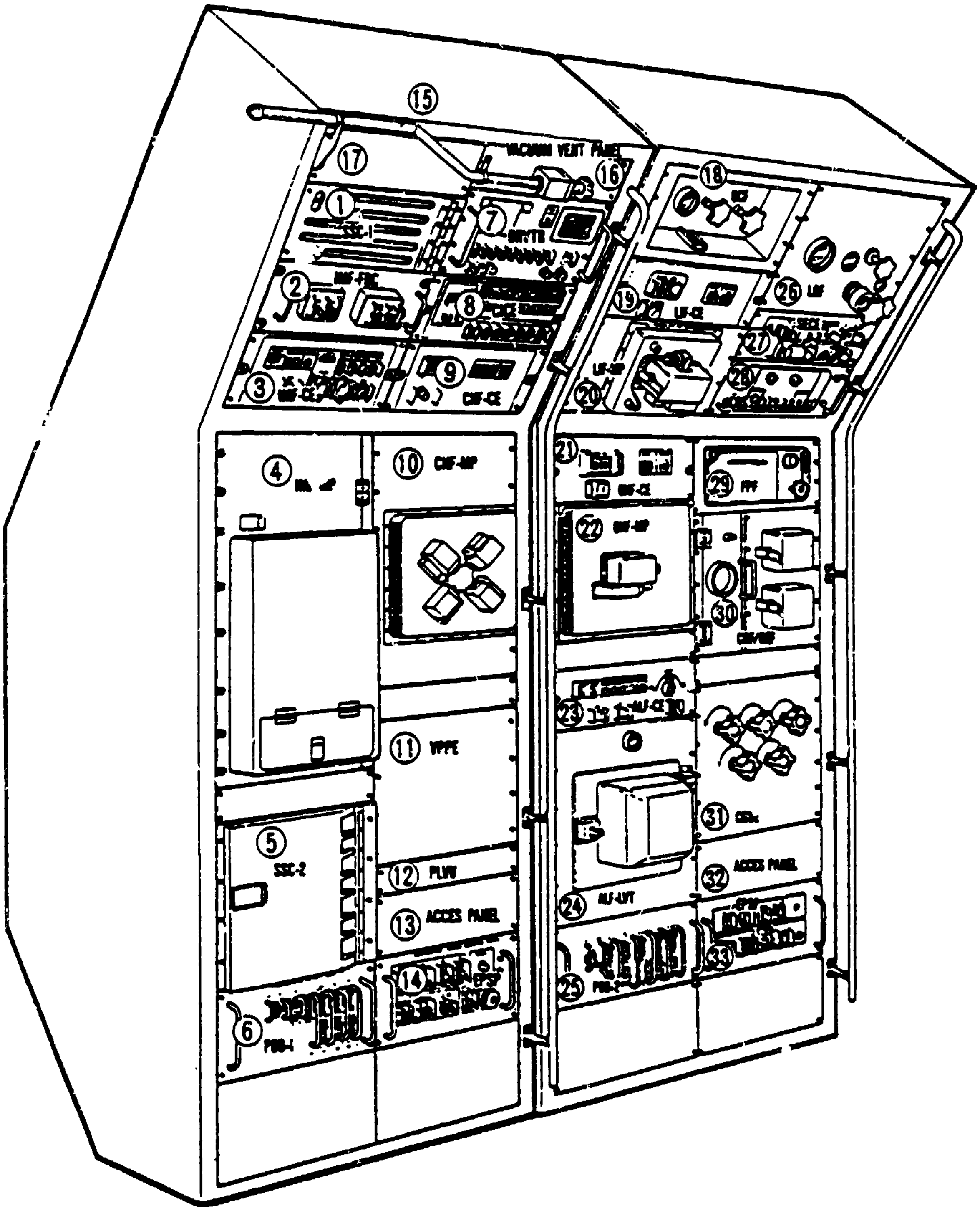
OF POOR QUALITY



NOTE: The equipment numbers on this page correspond to the numbers and titles in Table 8-1.

FIGURE 4 FMPT-MEL EXPERIMENT

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TABLE 1. FMPT-MEL EXPERIMENT EQUIPMENT
IN SPACELAB RACKS 8 AND 10

1 Sample Stowage Container (SSC-1)
2 Image Furnace - Furnace Drive Controller (IMF-FDC)
3 Image Furnace - Control Equipment (IMF-CE)
4 Image Furnace - Material Processing Unit (IMF-MP)
5 Sample Stowage Container (SSC-2)
6 Power Distribution Box-1 (PDB-1)
7 Data Recording Video Tape Recorder (DRVTR)
8 Central Interface and Control Equipment (CICE)
9 Continuous Heating Furnace - Control Equipment (CHF-CE)
10 Continuous Heating Furnace - Material Processing Unit (CHF-MP)
11 Vacuum Pump Package Equipment (VPPE)
12 Pilot Valve Unit (PLVU)
13 Access Panel
14 Experiment Power Switching Panel (Rack 8)
15 Vent Line
16 Vacuum Vent Panel
17 Blank Panel
18 Organic Crystal Growth Experiment Facility (OCF)
19 Large Isothermal Furnace - Control Equipment (LIF-CE)
20 Large Isothermal Furnace - Material Processing Unit (LIF-MP)
21 Gradient Heating Furnace - Control Equipment (GHF-CE)
22 Gradient Heating Furnace - Material Processing Unit (GHF-MP)
23 Acoustic Levitation Furnace - Control Equipment (ALF-CE)
24 Acoustic Levitation Furnace - Material Processing Unit (ALF-LVT)
25 Power Distribution Box-2 (PDB-2)
26 Liquid Drop Experiment Facility (LDF)
27 Specific Experiment Control Equipment (SECE)
28 Intercom Remote Station (ICRS)
29 Fluid Physics Experiment Facility (FPF)
30 Crystal Growth Experiment Facility and Gas Evaporation
Experiment Facility (CGF/GEF)
31 Compressed Gas Supply Equipment (CGSE)
32 Access Panel
33 Experiment Power Switching Panel (Rack 10)

TABLE 2. EXPERIMENT PLANNED FOR FMPT-MEL MISSION

Exp	Title	Facility	Remarks
M1	Crystallization of Pb-Sn-Te	GHF	Compound type semiconductor single crystal growth
M2	Zone Melting of Pb-Sn-Te	IMF	Compound type semiconductor single crystal growth
M3	Floating Zone of In-Sb	IMF	Compound type semiconductor single crystal growth
M4	Solidification of Superconducting Materials	CHF	Solidification process of immiscible alloys (Al-Pb-Bi)
M5	Deoxidation of Steels	LIF	Removal of solved oxygen from molten steel
M6	Dispersion - Strengthened Superalloys	LIF	Superalloy matrix reinforced by dispersed fine particles
M7	Mutual Diffusion in Liquid Metals	CHF	Study of diffusion process
M8	Density of Glasses	IMF	Measurement of glass density as function of temperature
M9	Spherical Si Crystals	CGF	Production of spherical Si crystals
M10	Solidification of Immiscible Alloys	GHF	Solidification process of immiscible alloys (Al-In, Cu-Pb)
M11	Composites (Al-Carbon Fibers)	CHF	Al Matrix with 3-dimensional carbon fiber reinforcement
M12	Liquid Phase Sintering	LIF	Production of metal powder by liquid phase sintering
M13	Amorphous Semiconductors	CHF	Production of amorphous semiconductors
M14	Ultra-Fine Powders	GEF	Metallic powders produced by evaporation process
M15	Fluid Dynamics in 3-D Acoustic Field	LDF	Behaviour of liquid drop levitated in acoustic field
M16	Behaviour of Bubbles in Liquid	BBU	Bubble behaviour at liquid-to-crystal interface
M17	Firing of Glasses	ALF	Contactless meeting of very pure glasses
M18	Marangoni Convection and Heat Transfer	MCU	Effects of Marangoni convection on Brigeman process
M19	Solidification of Eutectic Alloys	CHF	Study of solidification process
M20	Floating Zone of Minerals	IMF	Growth of single crystals from Samarskite minerals
M21	Organo-Metallic Crystals	OCF	Growth of crystals from organo-metallic compounds
M22	Crystallization of In-Ga-As	GHF	Compound type semiconductor single crystal growth

Furnace operations generally require installation of experiment samples by hand and automatic processing by computer although manual controls are available for hazardous function control. For all furnaces interlocks and doors are provided to prevent sample removal prior to cooling to touch temperatures of 45°C.

Gradient Heating Furnace (GHF)

The GHF, Figure 5, has been developed for several types of experiments such as crystal growth, melting/solidification, and eutectics. The facility functions by positioning the sample, and after heatup, the furnace translates to provide a moving gradient across the sample. The furnace uses two heating coils at one end and a single coil at the other end. Between the coils is a water cooling chamber. The furnace, which operates at temperatures up to 1100°C, processes the sample in a vacuum. Two samples, M 01 and M 22 of Table 3 provide three levels of containment by the use of two quartz ampoules and a tantalum cartridge. Sample M 10, Figure 6, is encased in an unsealed tantalum cartridge. The metals in this sample will offgas toxic gases during processing. Containment is provided by the furnace (one level) and by use of the vacuum vent line. During processing, the toxic residue is pulled in to the vent line for release to space. Based on partial pressures, the offgas rates are low. In order to use the concept that vacuum venting provides the equivalent of containment there are safeguards required. The furnace pressure is continuously monitored and must remain negative in relation to spacelab ambient pressure. In the event that the furnace pressure approaches module pressure, the furnace automatically shuts down. The sample materials are nontoxic in the solid state and sample M 10 remains in the furnace after processing.

Imaging Furnace (IMF)

The Imaging Furnace, Figure 7 and 8, is designed to accommodate several samples, including crystal growth, by pulling the crystallization zone among the sample Axis. The IMF contains twin ellipsoidal mirrors with one common focus where the sample is located. Two halogen lamps, each located at the focal point of the ellipsoid, provides the heat source. Movement of the melting zone is accomplished by moving the twin mirror furnace along the sample axis. A quartz tube is installed over the samples during processing and an inert gas, argon, flows past the sample. All pressure inside of the furnace, including the argon is at a negative pressure in relation to the module. The pressure is continuously monitored and the furnace automatically shuts down for positive pressure. As in the GHF, the vacuum vent serves as a containment level equivalent. The IMF will process four types of samples. Samples M 02 and M 08 of Table 4 use a quartz ampoule for processing. Figure 9 shows one of the quartz ampoules. Samples M 20 and M 03 (Figure 10) both are naked samples. The naked samples use the sealed IMF and vacuum vent to achieve containment. The IMF is equipped with two view ports to allow visual inspection of the samples to assure that toxic ash or residue has not coated the interior of the furnace. Handling of processed samples requires the use of disposable gloves and samples are placed in sealable bags for storage.

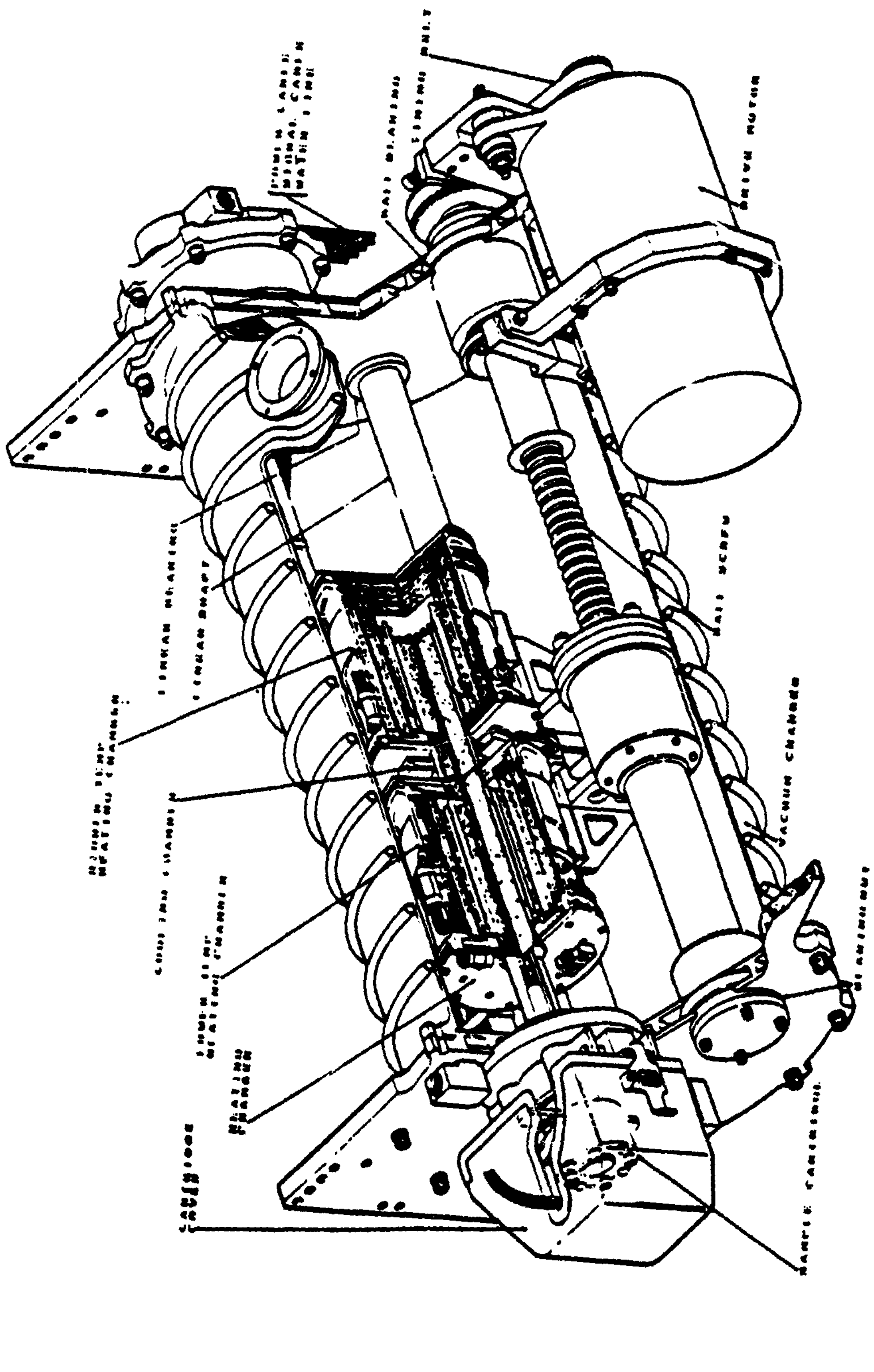

FIGURE 5 GHF-MP FURNACE

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Table 3 FMPT · MEL SAMPLE DATA

Experiment /Equipment	Ingredients	Quantity	Process Temperature °C	SMAC (mg/m^3)	Containment
M01 GHF	Pb Sn Te	91	1000	0.04 0.04 0.02	3 Containments 2 qtz & Ta
M22 GHF	In Ca As	18	1070	0.02 0.5 0.002	3 Containments 2 qtz Amp Ta Cart
M10 GHF	Al In Cu Pb	26.5	1050	2 0.02 0.04 0.04	Unsealed Ta Cart Remains in Furnace

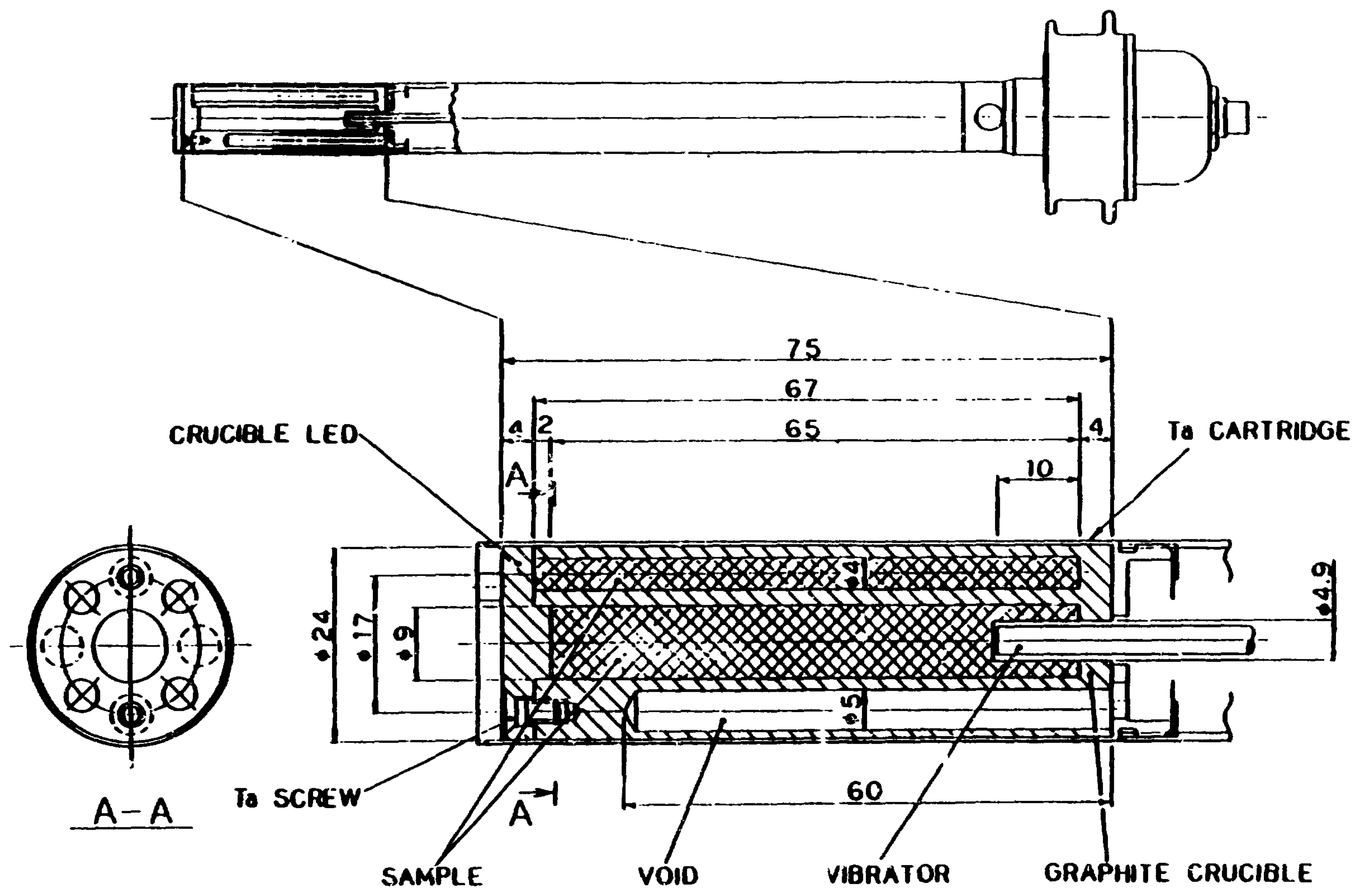

FIGURE 6 FO'MIO SAMPLE

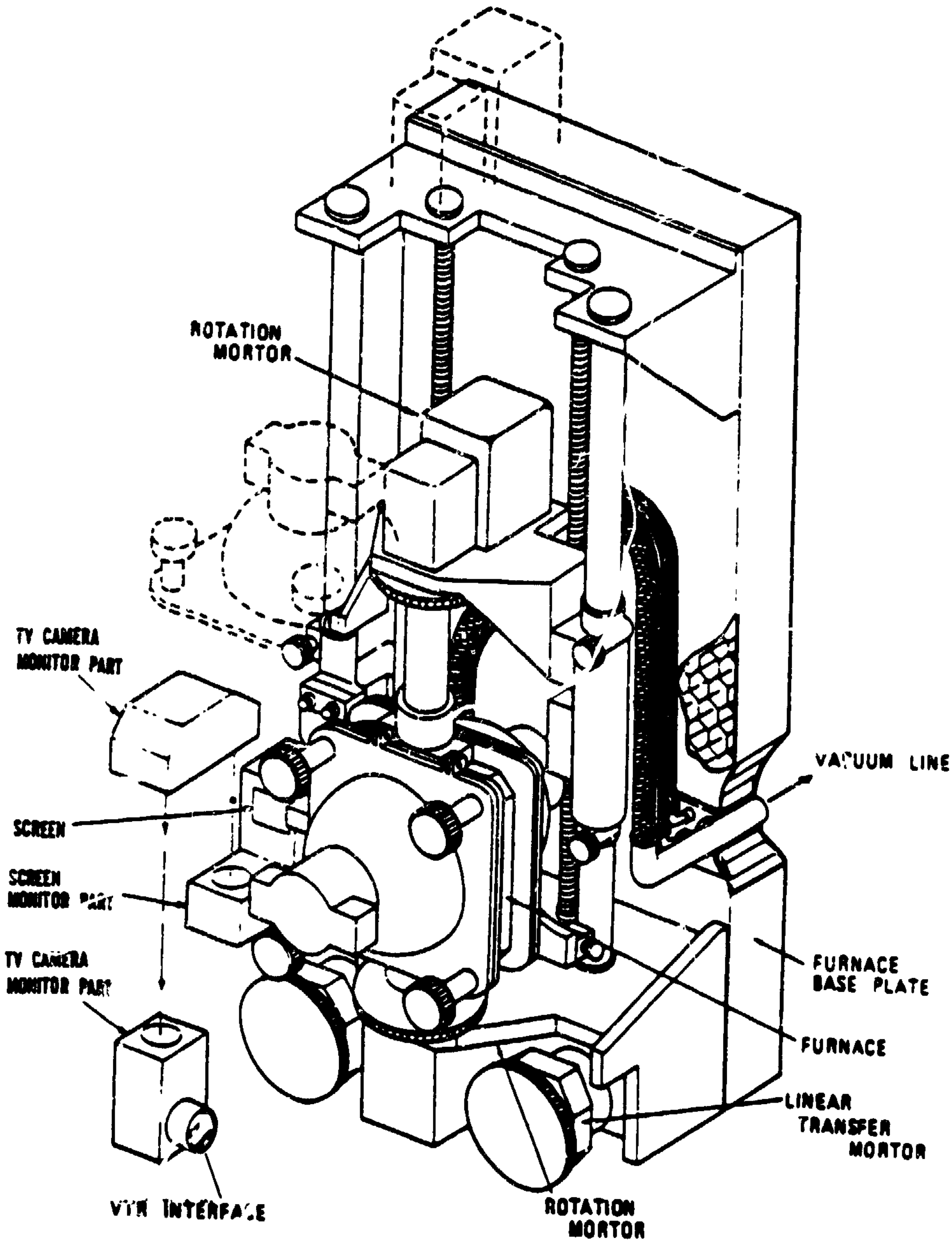

FIGURE 7 IMF-MP FURNACE

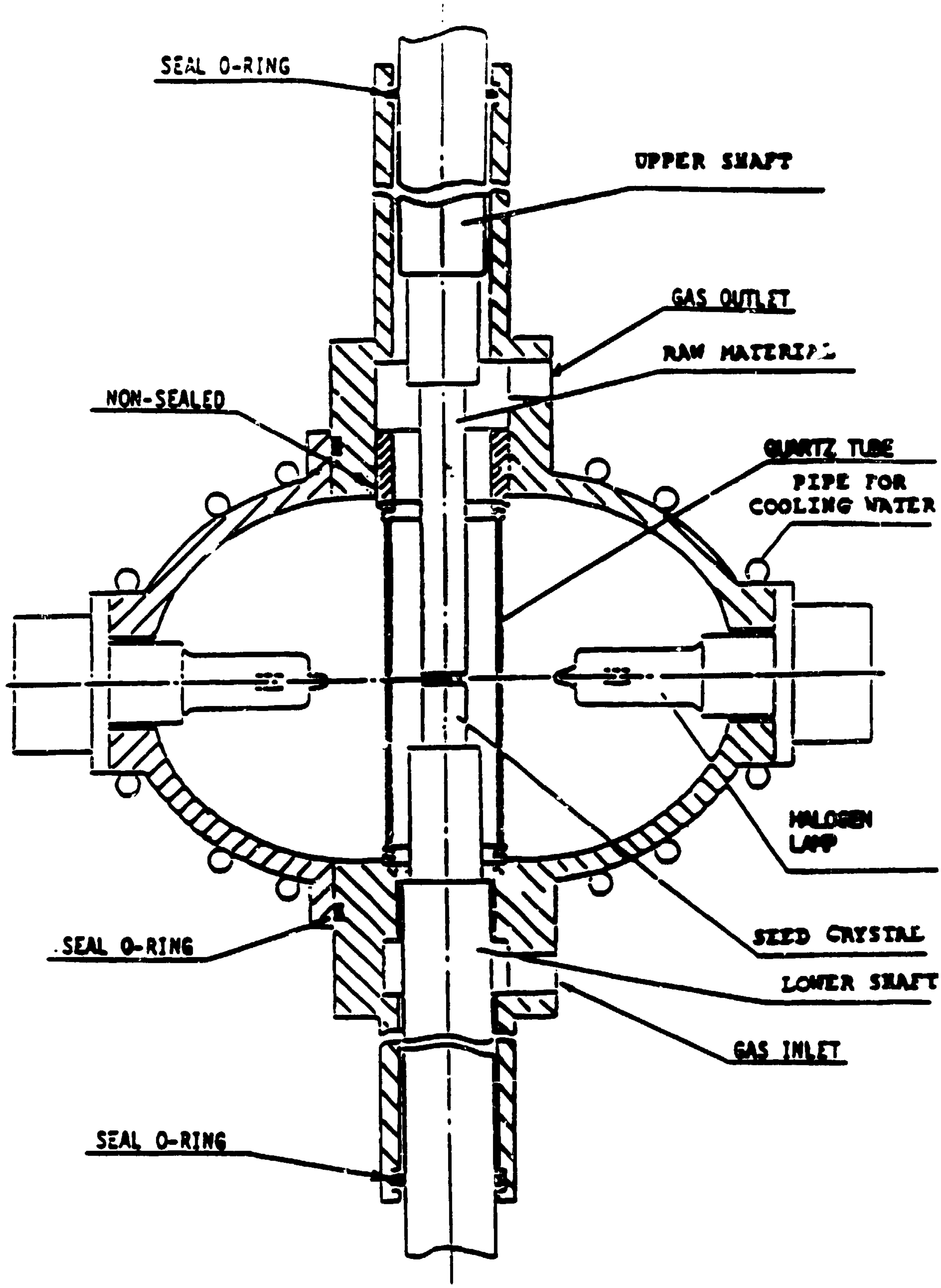

FIGURE 8 INSIDE OF IMF FURNACE

Table 4 FMPT - MEL SAMPLE DATA

Experiment /Equipment	Ingredients	Quantity (g)	Process Temperature °C	SMAC (mg/m^3)	Containment
M02	Pb		850	0.04	1 QUARTZ
IMF	Sn			0.04	
	Te			0.02	
M08	Na_2O		1200	0.4	1 QTZ AMP
	B_2O_3			2.0	
IMF	CaO			0 4	
	Co0			0.0254	
	Au			1.0	
		1.162			

Table 4 (cont'd) **FMPT-MEL SAMPLE DATA**

Experiment /Equipment	Ingredients	Quantity	Process Temperature °C	SMAC (mg/m^3)	Containment
M20	CaO		1400	0.4	Naked
IMF	UO_2			?	*
	$YO_{1.5}$			0.25	
	FeO			1.0 (Fe_2O_3)	
	$NbO_{2.5}$			0.5	
		1.33			
M03	In		550	0.02	Naked-Furnace 1-Remains In Furnace
IMF	Sb			0.1	
		374.1 (Max.)			

**Does Not Exceed SMAC

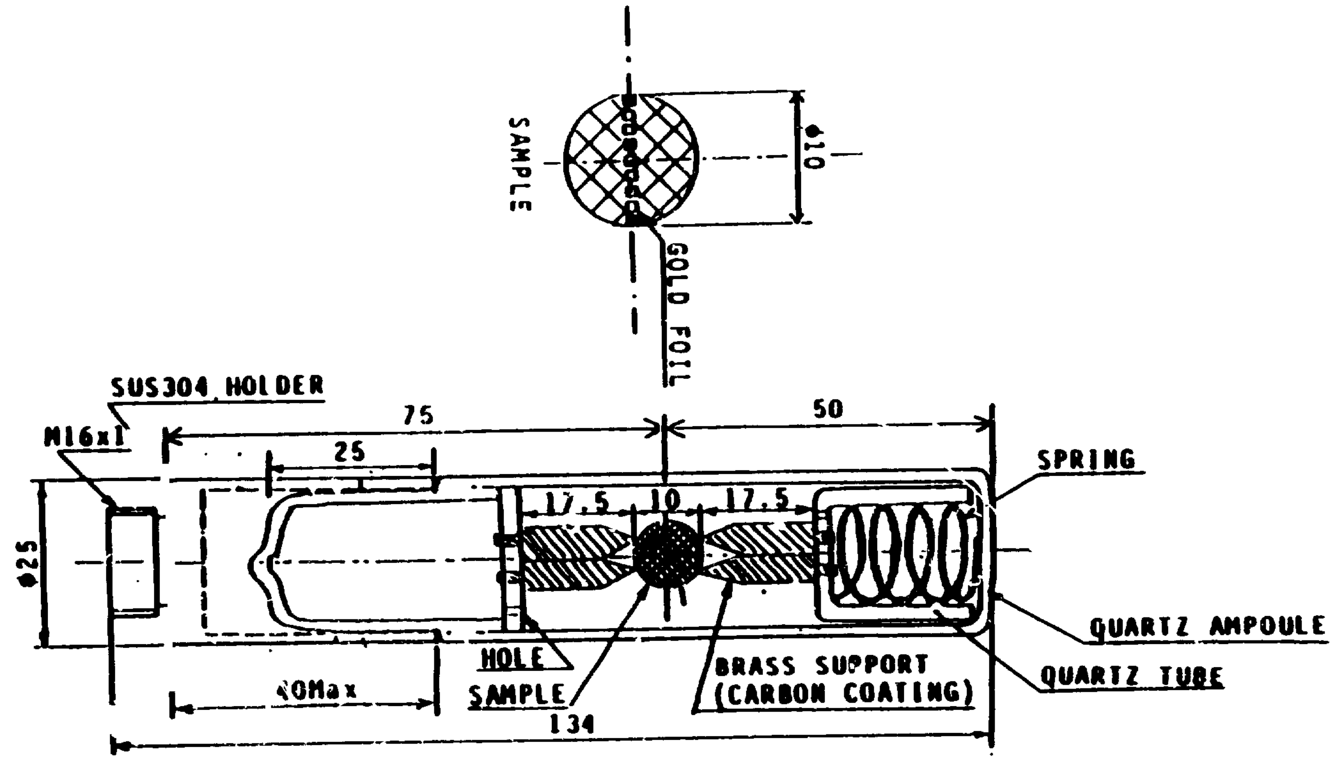

FIGURE 9 FO 408 SAMPLE

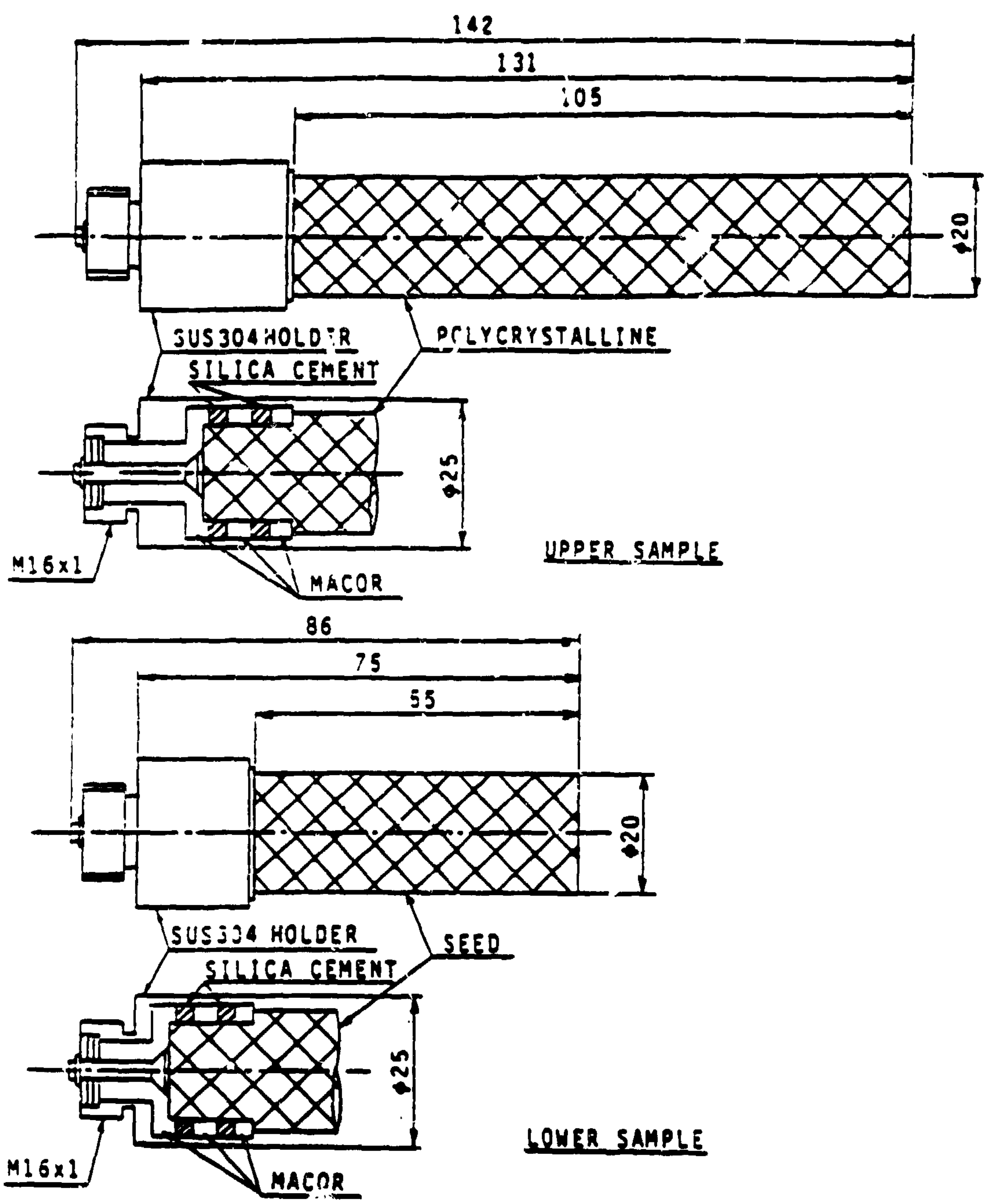

FIGURE 10 FO MO3 SAMPLE

Continuous Heating Furnace (CHF)

The CHF, Figure 11, is a unique vacuum furnace designed to process samples continuously. The CHF combines two heating chambers and two water cooled chambers to achieve continuous heating of two samples and rapid cooling of two samples. The furnace operates at a maximum of 1300°C and can cool two samples from 1200°C to room temperature in approximately 10 minutes. Heating and cooling chambers are alternately arranged. The furnace translates fore and aft to position the chambers over the samples. After heat up and sample processing, the furnace translates aft, rotates 90°, and then translates forward such that samples which were being heated, are then cooled. At the completion of the cooling cycle (touch temperature of 45°C) the cooled samples are replaced with new samples for the next phase. The CHF will process five sample types - M 04, (Figure 12) M 07, M 13, M 19, and M 11 of Table 5. All of the samples provide triple containment except M 11, Figure 13, which provides dual containment. In this case the furnace and vacuum provide the extra levels of containment. All of the containments are somewhat different, however the examples, Figures 12 and 13 are representative.

Large Isothermal Furnace (LIF)

The LIF, Figure 14, is a vacuum heating furnace which operates at temperatures up to 1600°C. Provisions are made to allow pressurization of some sample cartridges at 6 bar (Figure 15). Furnace heat up and processing are accomplished in a vacuum and cooling uses helium gas at pressures which are negative in relation to the module. In the event of positive pressure, the furnace automatically shuts down. Three sample types will be processed - M 05, M 12, and M 06 of Table 6. Both M 05 and M 12 cartridges provide dual containment while M 06 is a naked sample which remains in the furnace after processing. Figure 16 depicts one of the sample cartridges while Figure 17 shows the naked sample.

Crystal Growth Facility (CGF)

The CGF, Figures 18 and 19, consists of two furnace chambers, one for a spherical sample and one for a bar sample. The furnaces operate at temperatures in excess of 1400°C and samples are processed in gaseous argon which is at a negative pressure in relation to the spacelab module. In the event the furnace pressure approaches module pressure, the furnaces automatically shut down. Each furnace chamber will process one naked sample of silicon (Sample M 09 of Table 7) which will remain in the furnace after processing until removal on the ground. Silicon is a low toxic material and the furnace plus the vacuum vent provide adequate containment.

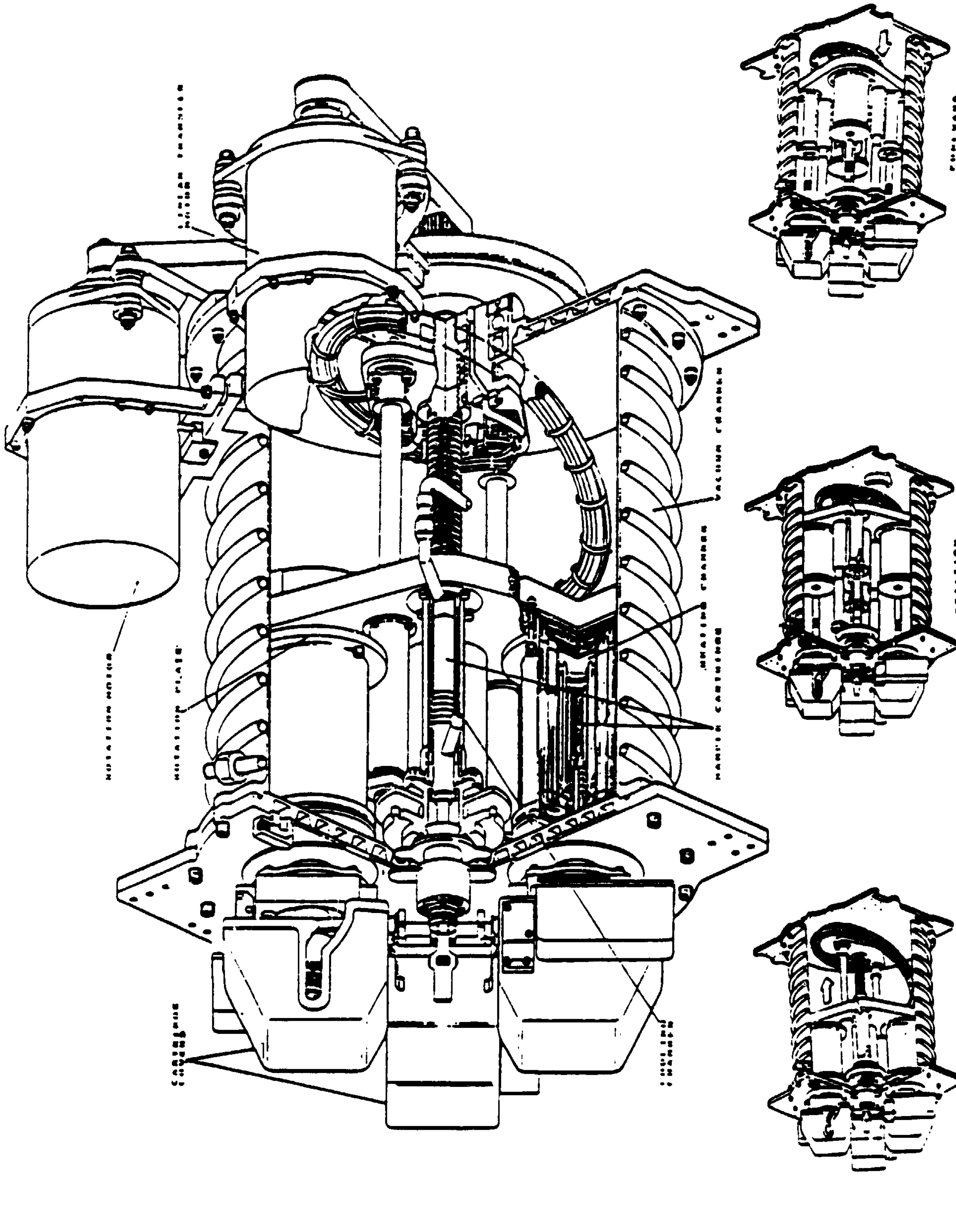

FIGURE 11 CIIF-MP FURNACE

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Table 5 **FMPT - MEL SAMPLE DATA**

Experiment /Equipment	Ingredients	Quantity (g)	Process Temperature °C	SMAC (mg/m^3)	Containment
M04	Al	a.		2	3 Containments 2 Ta Cap 1 Ta Cart
		b.	1300		
CHF		c.			
	Pb	a.		0.04	
		b.	1300		
		c.			
	Bi	a.		0.5	
		b.	1300		
		c.			
	(total)	a. 6.69 b. 6.69 c. 6.69			

Table 5 (cont'd) **FMPT - MEL SAMPLE DATA**

Experiment /Equipment	Ingredients	Quantity (g)	Process Temperature °C	SMAC (mg/m^3)	Containment
M07 CHF	Au Ag	6.9	1300	1 0.02	3 Containments 2 QTZ AMP 1 TA CART
M13 CHF	Si As Te Mn	6 in total	1300	2 0.002 0.02 0.2	3 Containments 2 QTZ AMP TA CART

Table 5 (cont'd) FMPT - MEL SAMPLE DATA

Experiment/ Equipment	Ingredients	Quantity	Process Temperature °C	SMAC (mg/m^3)	Containment
M-13 CHF	Si	a. b. c. d. e. f.		2	3 Containments 2 QTZ AMP 1 Ta CART
	--------	--------	1300		
	As	a. b. c. d. e. f.		0.002	
	--------	--------	1300		
	Te	a. b. c. d. e. f.		0.02	
	--------	--------	1300		
	Mn	a. b. c. d. e. f.		0.2	
	(total)	a. 1.00000 b. 1.00000 c. 1.00000 d. 1.00000 e. 1.00000 f. 1.00000			

Table 5 (cont'd) FMPT - MEL SAMPLE DATA

Experiment /Equipment	Ingredients	Quantity (g)	Process Temperature ^{0}C	SMAC (mg/m^3)	Containment
M19 CHF		2 ea. X			3 Containments 2 QTZ AMP Ta CART
	Al		700	2	
	Cu			0.04	
	(total)	a. 1.40 b. 1.40 c. 1.40			
M11 CHF	Al In C	6 ea. X 4.51	1550	2 0.02	2 Containments QTZ AMP Ta CART

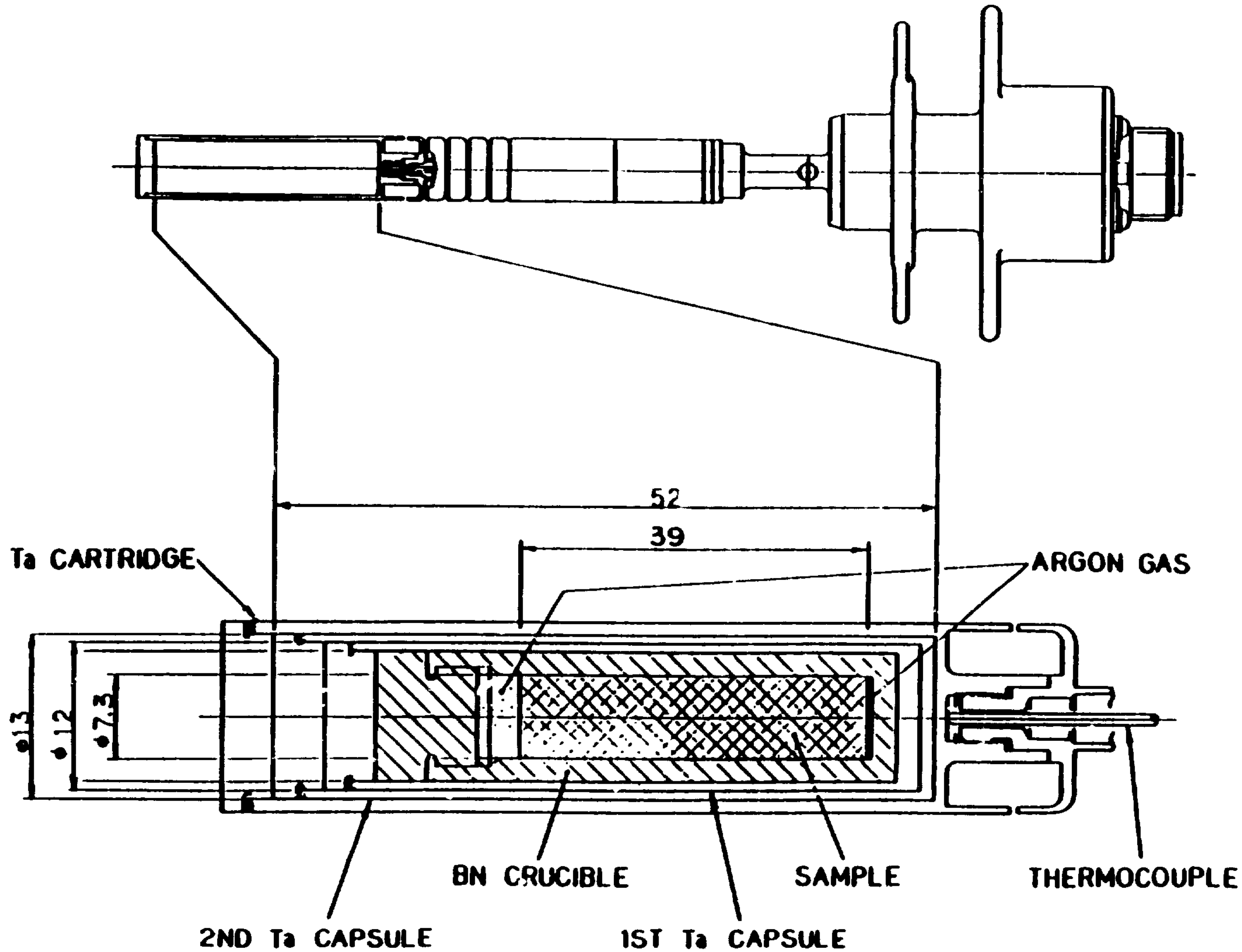

FIGURE 12 FO M04 SAMPLE

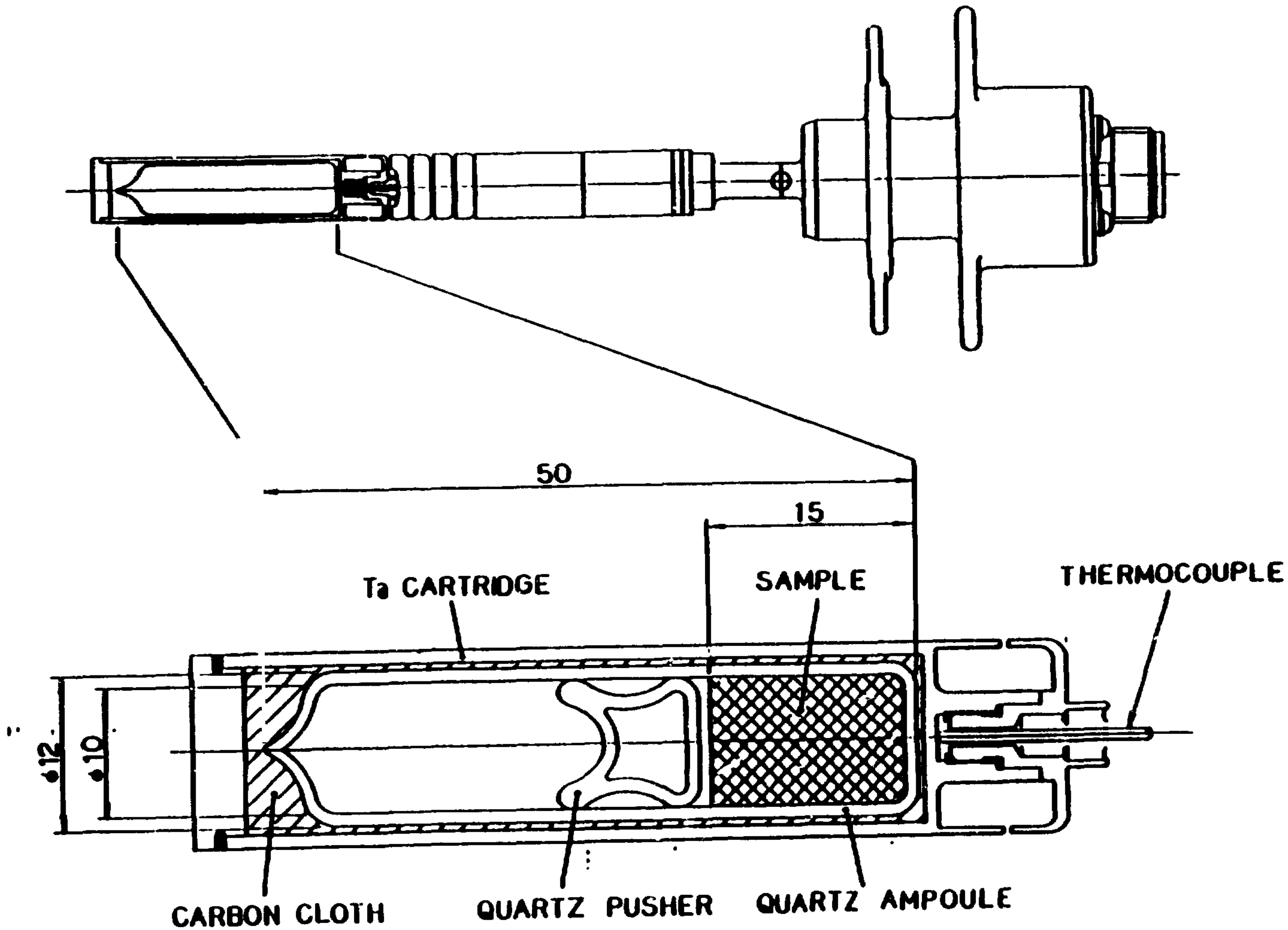

FIGURE 13 FO M11 SAMPLE

Table 6 FMPT - MEL SAMPLE DATA

Experiment /Equipment	Ingredients	Quantity (g)	Process Temperature °C	SMAC (mg/m^3)	Containment
M05 LIF	Fe Ni Al Mn Si O	57.6	1600	1 0.08 2 .0 0.2 2 - -	2 Containments MOLY CONT. Ta CART
M12 LIF	W Ni	43	1550	1 0.08	2 Containments *Ta CAPSULE Ta CART
M06 LIF	Ni Mo Cr Co TiC	168.98	1380	0.08 3 0.1 0.009 3	Unsealed- Left in Furnace

Table 6 (cont'd) FMPT - MEL SAMPLE DATA

Experiment/ Equipment	Ingredients	Quantity	Process Temperature °C	SMAC (mg/m^3)	Containment
M06 (CONTINUED)	(Glass Sealant)				
	SiO_2			?	
	B_2O_3			2	
LIF	Na_2O			0.4	
	Al_2O_3			?	
	K_2O			?	
	Fe_2O_3			?	
		0.7			

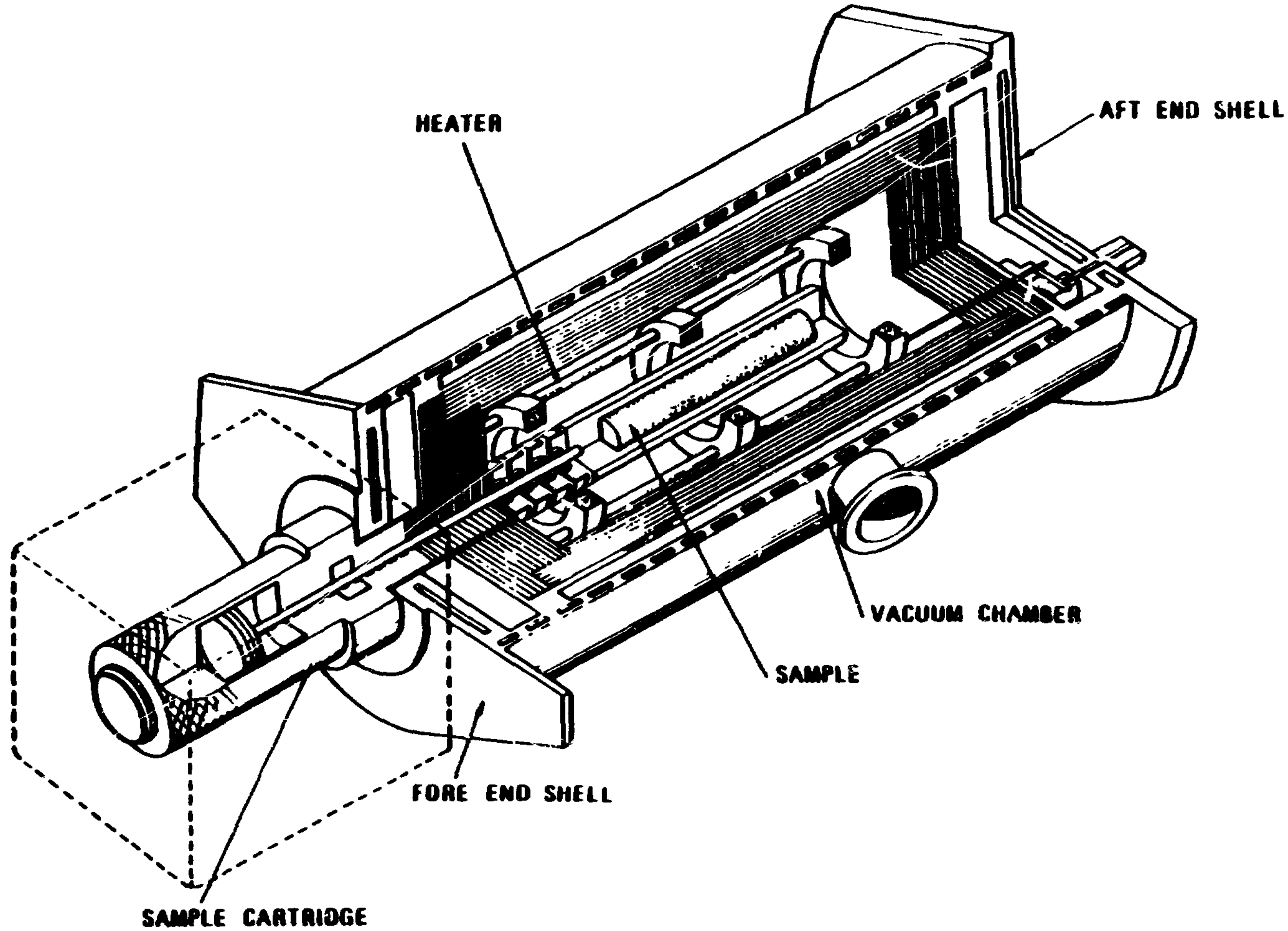

FIGURE 14 LIF-MP FURNACE

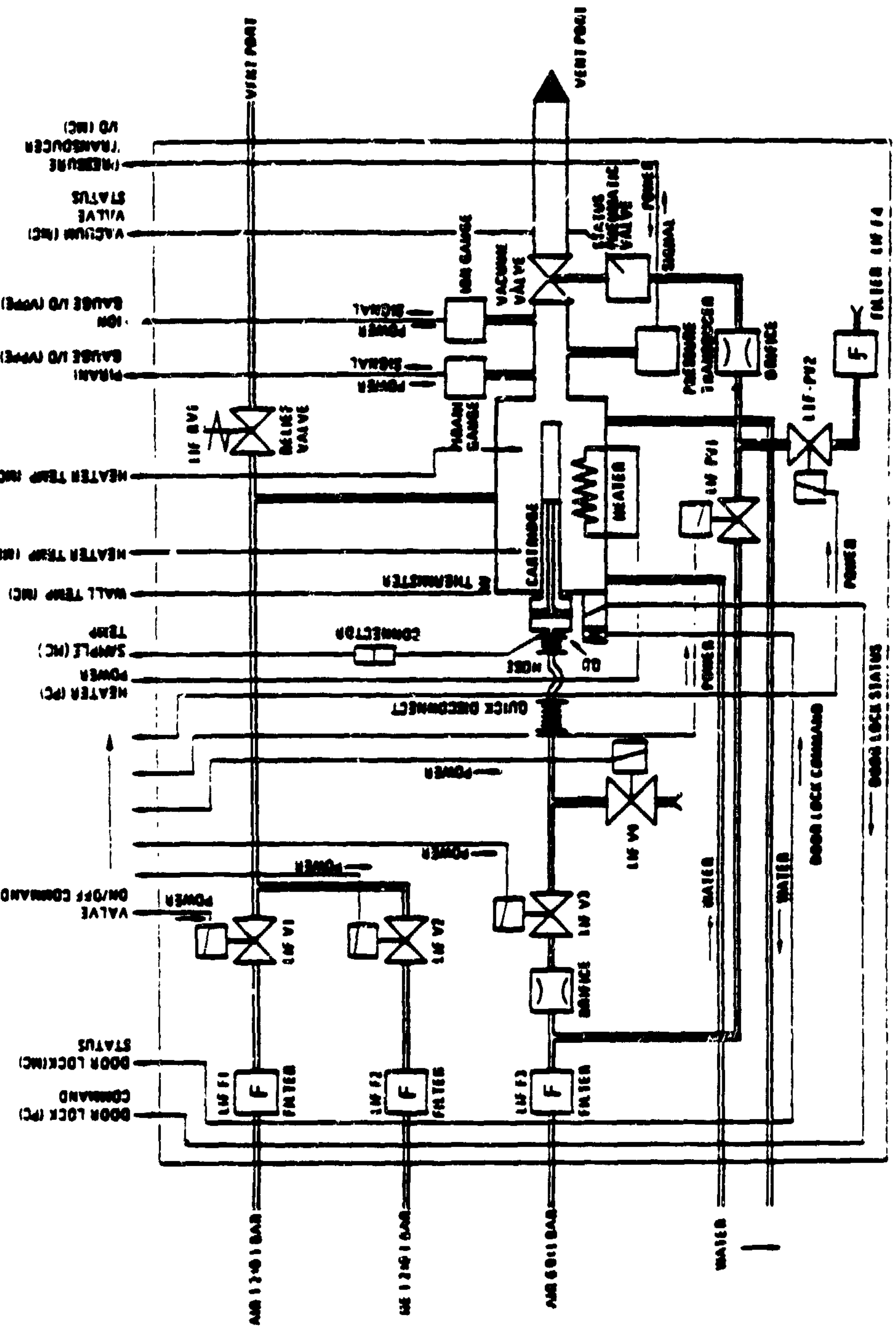

FIGURE 15 LIF-MP FUNCTIONAL DIAGRAM

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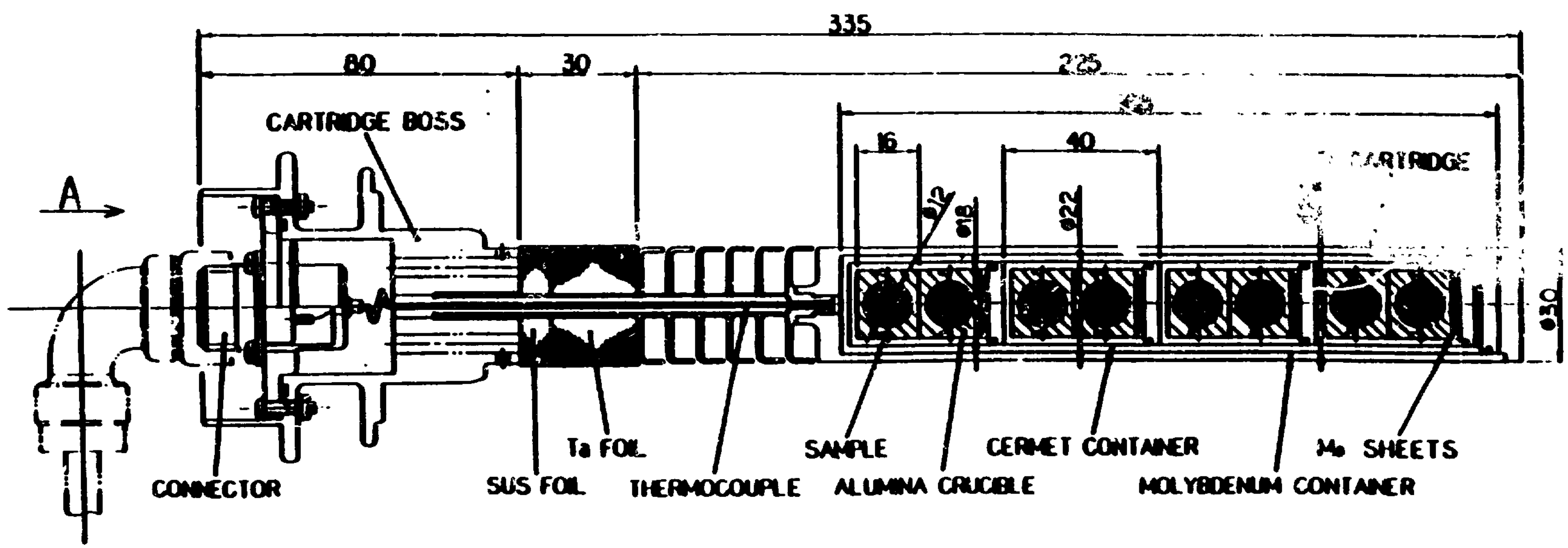

Figure 16 FO M05 Sample

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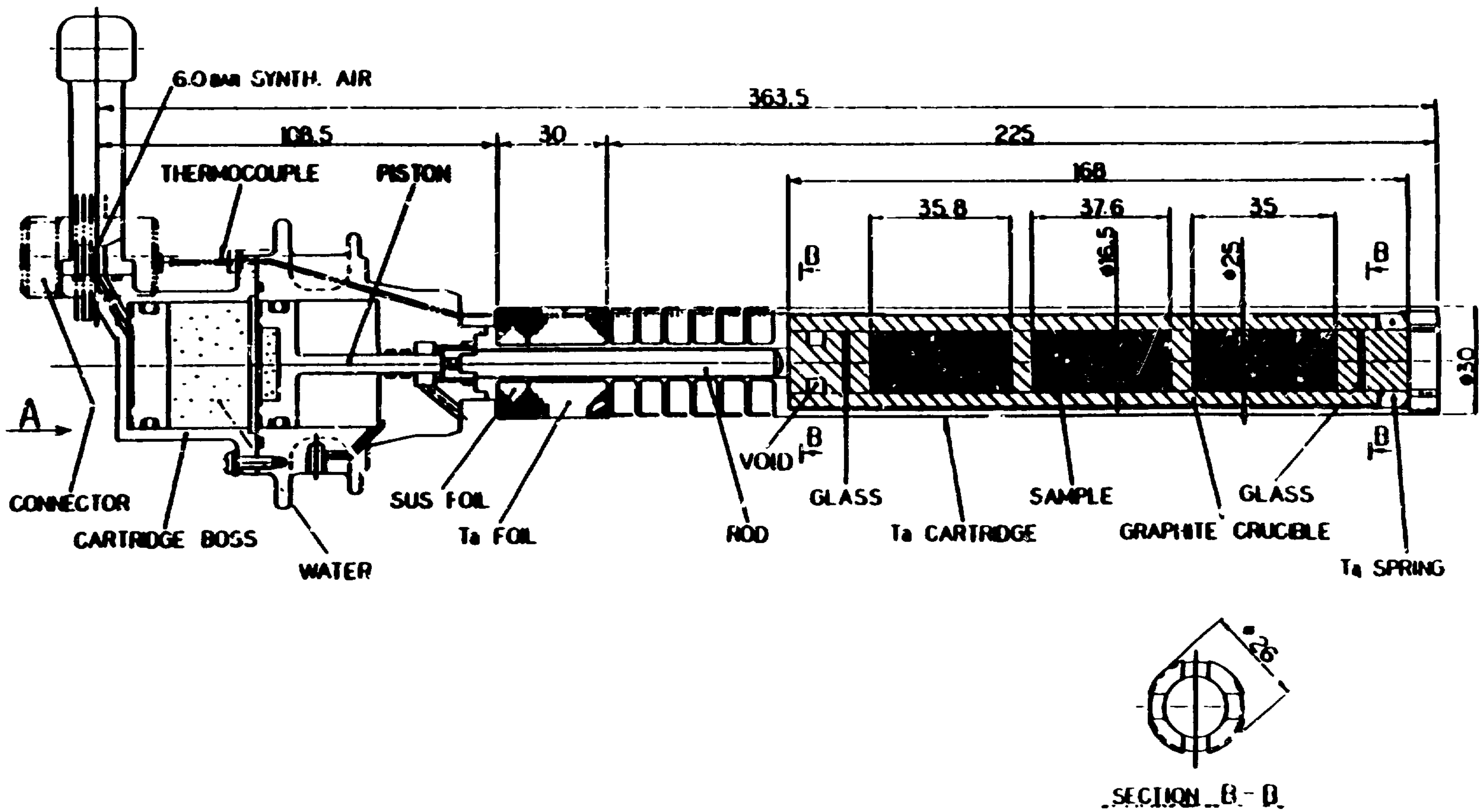

Figure 17 FO M06 Sample

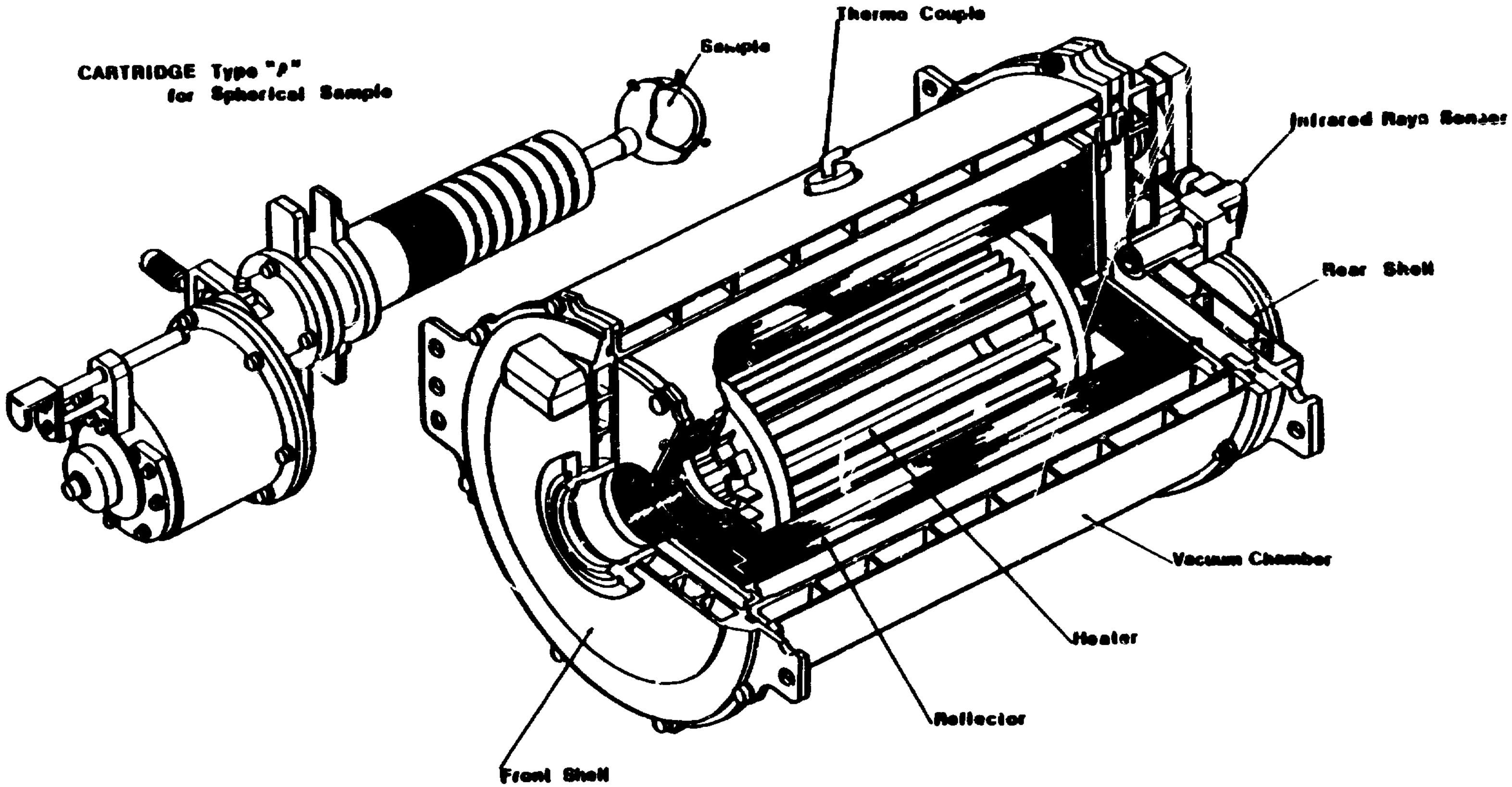

FIGURE 18 CRYSTAL GROWTH EXPERIMENT FACILITY CONCEPT (1/2)
(FOR SPHERICAL SAMPLE)

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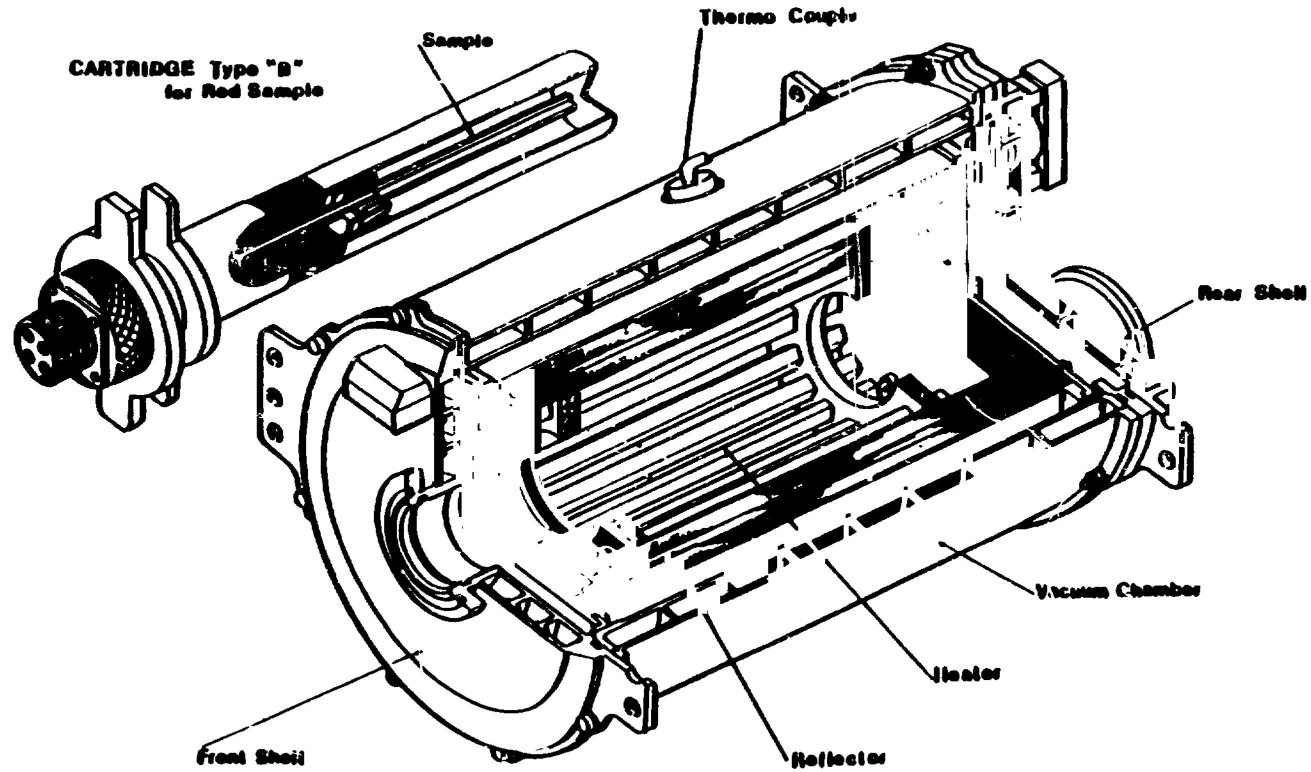


FIGURE 19 CRYSTAL GROWTH EXPERIMENT FACILITY CONCEPT (2/2)
(FOR ROD SAMPLE)

Table 7 FMPT – MEL SAMPLE DATA

Experiment /Equipment	Ingredients	Quantity (g)	Process Temperature °C	SMAC (mg/m^3)	Containment
M09 CGF	SI		1450	2	Unsealed Ball Sample Unsealed Rod Sample
M17 ALF	CaO	a. b. c.	1400	0.4	** Naked
	CaO	a. b. c.		1.4	
	GeO	a. b. c.		85.6	
	total	a. 2.000 b. 2.000 c. 2.000			

** Does Not Exceed SMAC

Acoustic Levitator Furnace (ALF)

The ALF, Figure 20, is designed for containerless refinement of glass in space. The ALF, which operates at approximately 1400°C, is very similar to the Image Furnace in that halogen lamps, located at the focii of twin ellipsoid mirrors reflect the heat to a common focus point for melting glass. The ALF sample is processed in a krypton gas flow which is at a negative pressure in relation to the module pressure. The pressure is continuously monitored and the furnace is automatically shut down if the internal pressure approaches ambient pressure. The furnace is equipped with a speaker to create an ultrasonic tunnel within the furnace. A sound reflector at the rear of the furnace is adjustable to enable sample positioning. The furnace will process sample M 17 of Table 7 which is a naked glass sample. Toxicity is low and containment will be provided by the furnace and the vacuum vent.

Organic Crystal Growth Facility (OCF)

The OCF Figure 21 is comprised of two experiment cells, a large cell and a small cell. Contents of the small cell are insufficient to result in a toxicity hazard and is controlled by dual containment. Both cells are processed at room temperature. The large cell uses an inner quartz container which has three chambers, one for the donor fluid, one for mixing and one for the acceptor fluid. The anisole, Table 8, is toxic and due to the quantity will require triple containment. The quartz container is located within an aluminum container which is housed in a sealed aluminum box. The quartz container and the inner box have some common penetrations. In order to achieve two containments, it is necessary to use dual sets of "o" rings or seals. A vigorous qualification program including a 14 month leak test is being performed.

Other Processing Facilities

Other experiments include a Bubble Behavior Unit to study fluid movement in space, A Marangoni Convection Unit, a Liquid Drop Facility (acoustic levitation) for fluid drops and a Gas Evaporation Facility. Single or dual containment is provided as required. The containments are interesting, however the experiments do not provide significant toxicity hazards.

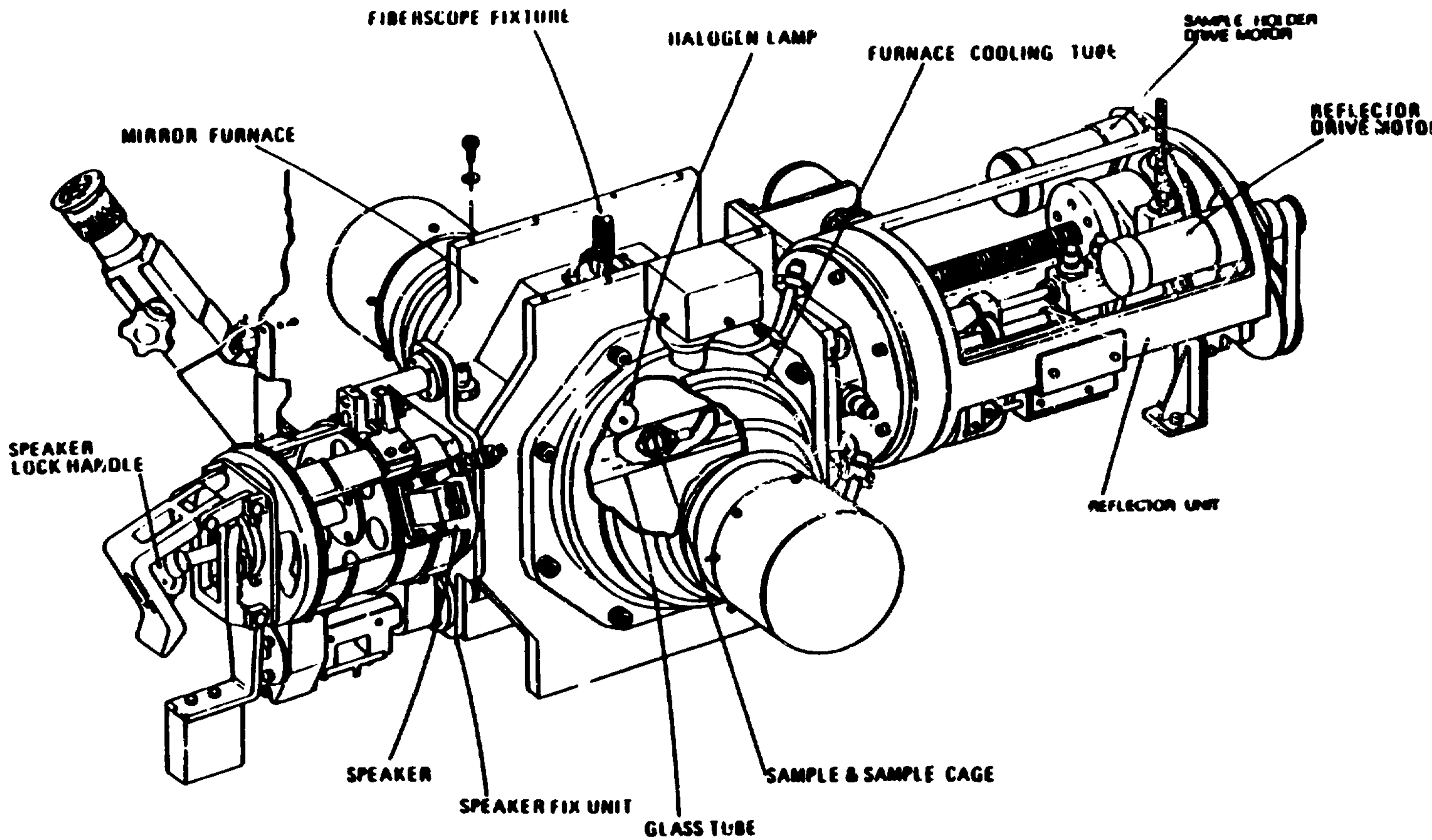


FIGURE 20 ALF-LVT FURNACE

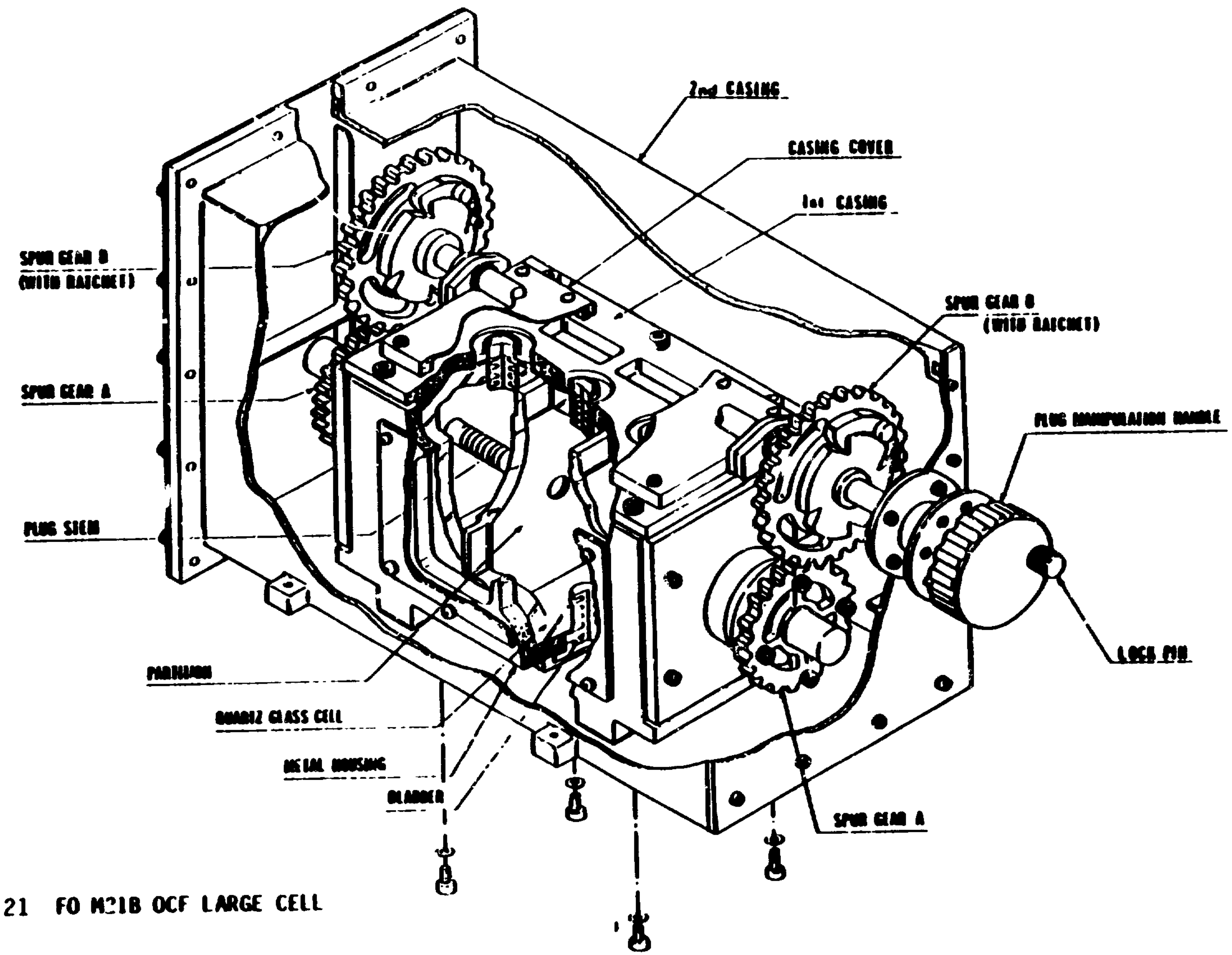


FIGURE 21 FO M21B OCF LARGE CELL

Table 8 FMPT - MEL SAMPLE DATA

Experiment /Equipment	Ingredients	Quantity (g)	Process Temperature °C	SMAC (mg/m)	Containment
M21A OCF	Anisole TMTTF TCNQ TMTTF-TCNQ Au	3.3047±03	AMBIENT	8 8 ? ? ? 1	2 Containments Small Cell Qtz. Cell Alum. Case
M21B OCF	Anisole TMTTF TCNQ TMTTF-TCNQ Ag	221.2902	AMBIENT	8 8 ? ? ? 1	3 Containments Large Cell Qtz Cell Alum. Case Sealed Box

USML-1 Spacelab

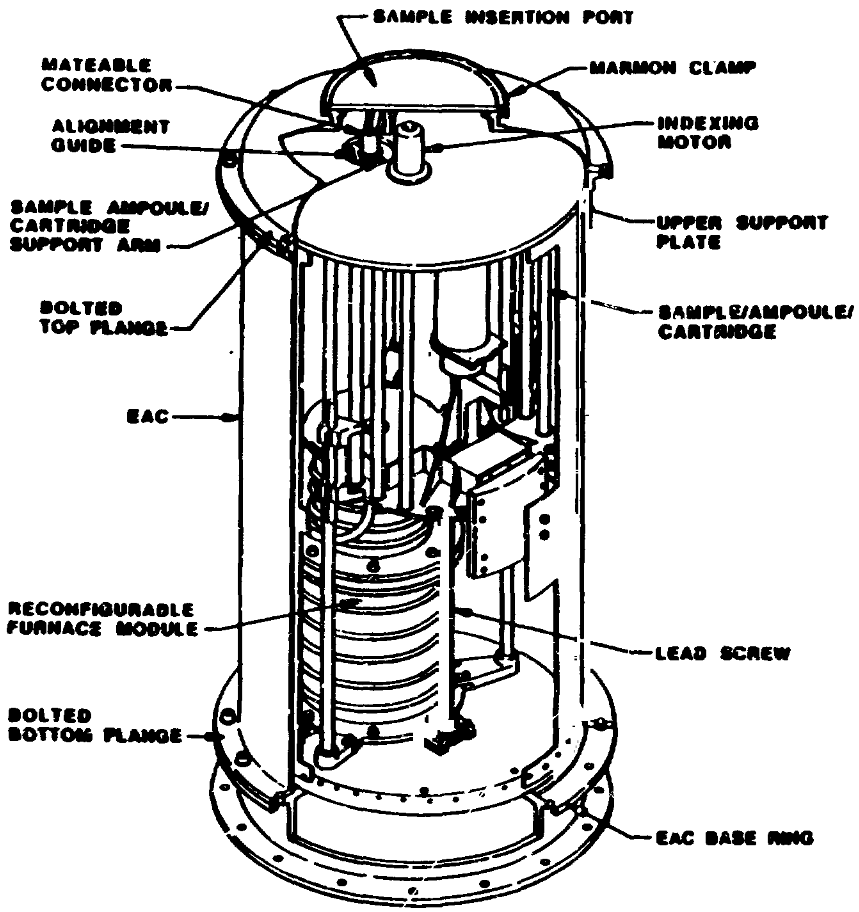
The USML-1 is still in the early design stages and concepts are not as clearly defined as Spacelab J. There will be several material processing facilities including containerless processing by acoustic levitation. Another experiment will be the Crystal Growth Facility, Figure 22, which will process numerous toxic metals at different temperatures. This facility will have some direct bearing on the space station. The facility uses a furnace core which translates along the sample axis. As in the case of some SL-J experiments, the Crystal Growth Facility will use the vacuum vent as a level of containment and will require shut down if the inner pressure becomes positive in relation to the module. Sample change out will be manually performed by the crew. To preclude toxic material release in the module during sample change out, a collapsible glove box will be used. The glove box will seal around the end of the container while the insertion port cover is removed. In the event of toxic residue in the furnace as evidenced by discolorization the cover will be reinstalled and the glove box dumped to the vacuum vent.

Recommendations/Conclusions

° Triple containment is the preferred method for prevention of toxic material release in habitable areas for catastrophic hazards. The containments must be adequate for the intended use and environment.

° When operations preclude triple containment, innovate methods should be explored. While there are several examples of use of the vacuum vent as an equivalent containment, stringent requirements exist to monitor internal pressures and shut the facility down for positive pressure. Materials must be nontoxic at ambient temperatures, and offgassed products must be compatible with the vacuum vent. Offgassed products must also be compatible with each other to the extent that exothermic reactions must not occur which would result in a hazard. It should be noted that a contaminated vacuum vent could result in ground hazards during de-integration activities and will require special procedures. It is usually the responsibility of the experiment developer to decontaminate or replace the vacuum vent after flight.

CGF INTEGRATED FURNACE/EAC ASSEMBLY



KEY FEATURES:

- FURNACE TRANSLATION
- AUTOMATED SAMPLE EXCHANGE MECHANISM (SEM) HAVING CAPABILITY TO PROCESS UP 6 SAMPLES
- CREW INTERACTION WITH THE SEM FOR MANUAL INSERTION/ RETRIEVAL OF SAMPLE(S)
- ARGON ATMOSPHERE INSIDE THE EAC DURING PROCESSING
- TWO LEVELS OF CONTAINMENT PROVIDED BY NEGATIVE OPERATING PRESSURE AND EAC DURING PROCESSING
- APPROXIMATE WEIGHT: 444 LB
- MOUNTING ORIENTATION OPTIONS: HORIZONTAL OR VERTICAL

CRYSTAL GROWTH FURNACE (CGF)

FIGURE 22

SOVIET MATERIALS PROCESSING EXPERIENCE AND EQUIPMENT

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ADVISORY SCIENTIST
TELEDYNE BROWN ENGINEERING

29 NOVEMBER 1988

SPACE STATION TOXIC AND REACTIVE
MATERIALS HANDLING WORKSHOP

HUNTSVILLE, ALABAMA

TELEDYNE
BROWN ENGINEERING
1250 ACADEMY PARK LOOP
COLORADO SPRINGS, COLORADO 80910

TBE8810-497

SCOPE OF PRESENTATION

TBE8810-498

- SOVIET SPACE STATION CONFIGURATIONS
- MATERIALS PROCESSING EQUIPMENT
  - ELECTRIC FURNACES
  - BIOTECHNOLOGICAL UNITS
- OPERATIONAL PROBLEMS ENCOUNTERED
- PHOTON UNMANNED MATERIALS PROCESSING SPACECRAFT AND EQUIPMENT
- SUMMARY

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SALYUT SPACE STATION MATERIALS SCIENCE LAYOUT

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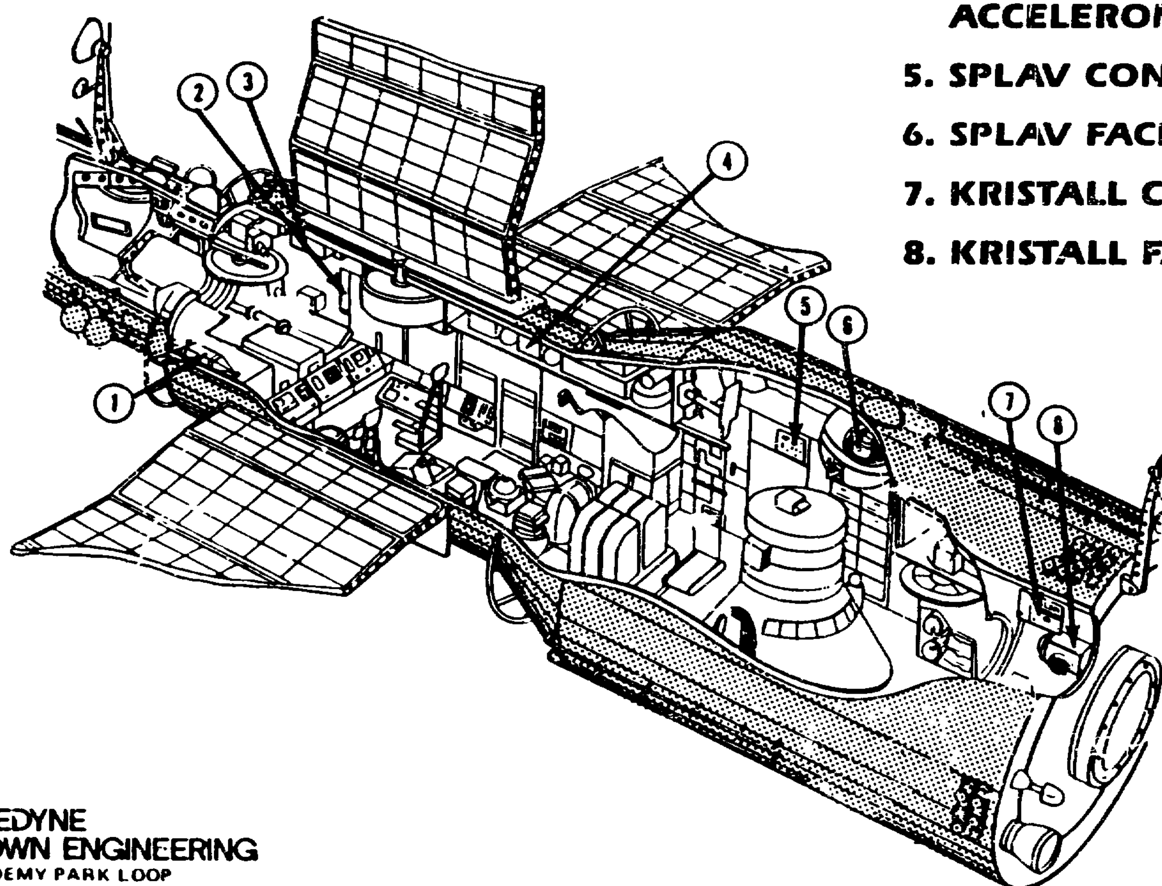
1. PION FACILITY
2. TAVRIYA FACILITY
3. GENOM FACILITY
4. TRIAXIAL HIGH-SENSITIVITY ACCELEROMETER
5. SPLAV CONTROL PANEL
6. SPLAV FACILITY
7. KRISTALL CONTROL PANEL
8. KRISTALL FACILITY



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MIR SPACE STATION PRESENT CONFIGURATION

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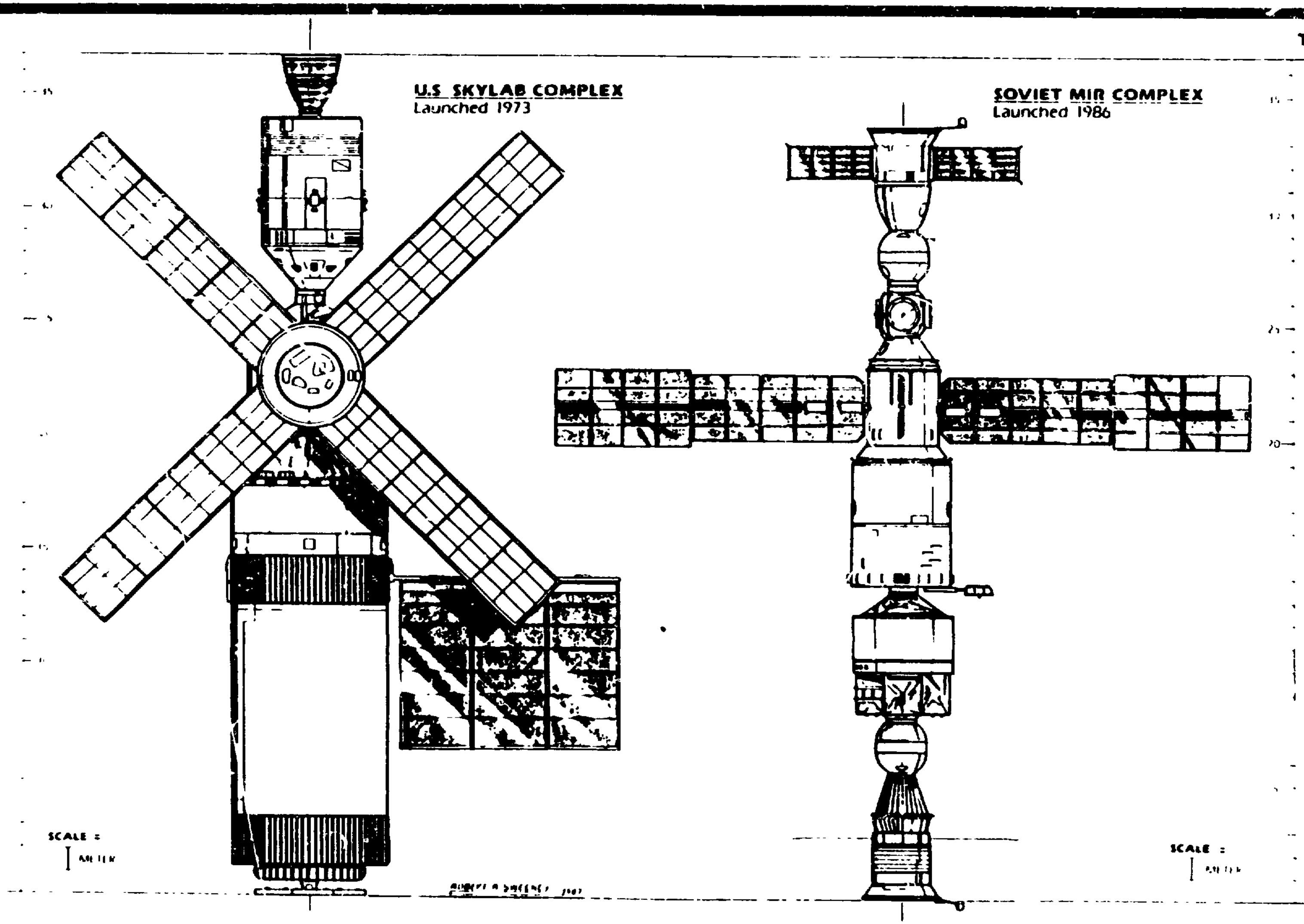

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PROGRESS UNMANNED RESUPPLY SPACECRAFT

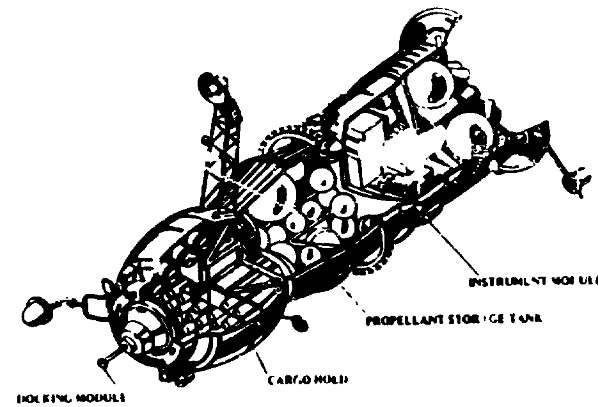
TBE8810-501

- SPECIFICATIONS
  SUCCESSFUL MISSIONS SINCE 1978: 38
  CURRENT FLIGHT RATE: ~6 PER YEAR
  MEAN LIFETIME: 34 DAYS (MINIMUM = 14
  MAXIMUM = 74)

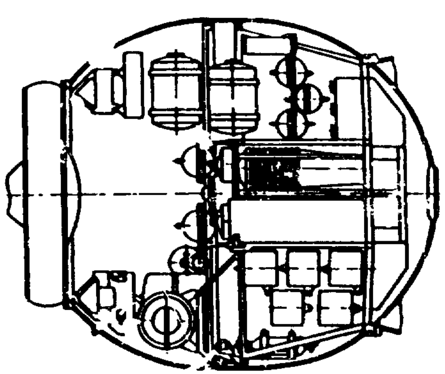
  TOTAL MASS: 7,020 kg
  PAYLOAD MASS: 2,300 kg
  (CARGO HOLD = 1,300 kg)
  (STORAGE TANKS = 1,000 kg)
  NOT RECOVERED

- PRIMARY DELIVERY MEANS OF MATERIALS PROCESSING EQUIPMENT AND EXPERIMENT SAMPLES TO SPACE STATION

- PRIMARY MEANS OF WASTE DISPOSAL FOR MIR



PROGRESS SPACECRAFT



PROGRESS 2
CARGO CONFIGURATION

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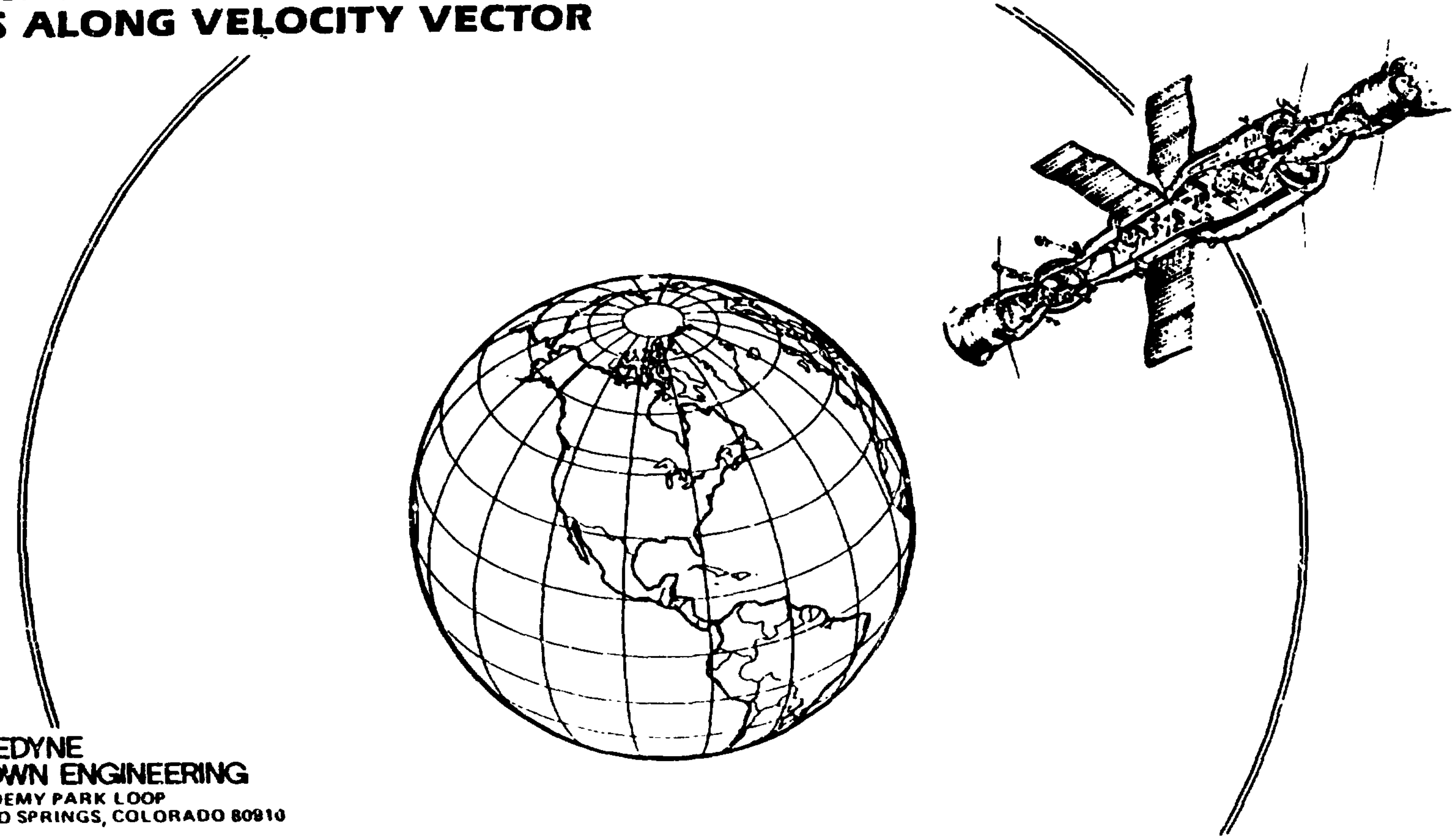
250 ACADEMY PARK LOOP
COLORADO SPRINGS, COLORADO 80910

SPACE STATION STABILIZATION

TDE8810-502

- GRAVITY-GRADIENT STABILIZATION USED FOR MOST MATERIALS PROCESSING EXPERIMENTS
- ROTATIONAL MODES ($\leq$ 0.4°/SEC) ALSO TRIED DURING GRAVITY-GRADIENT REGIMES
- SPACE STATION USUALLY ORIENTED WITH LONGITUDINAL AXIS ALONG VELOCITY VECTOR



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SOVIET MEASUREMENTS OF MICROGRAVITY CONDITIONS

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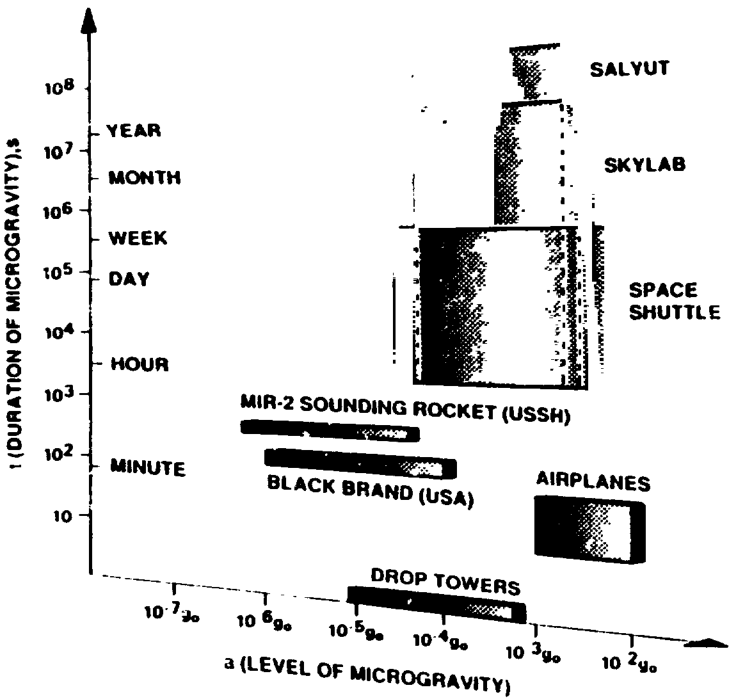

LOW-FREQUENCY ACCELERATION LEVELS UNDER VARIOUS FLIGHT CONDITIONS

PARTICULARS	LOAD FACTOR, g/g_o		
	X-AXIS	Y-AXIS	Z-AXIS
UNMANNED *PROGRESS* MISSION	1×10^{-5} -1×10^{-6}	1×10^{-5} -1×10^{-6}	1×10^{-5} -1×10^{-6}
NORMAL CREW ACTIVITY ON *SALYUT-6*	10^{-1}-10^{-5}	10^{-3}-10^{-5}	10^{-3}-10^{-5}
OPERATION OF *KASKAD* ATTITUDE CONTROL SYSTEM	2×10^{-4}	2×10^{-4}	5×10^{-4}
WITH CREW DOING PHYSICAL EXERCISES	10^{-4}	1×10^{-3} -1×10^{-2}	1×10^{-3} -1×10^{-2}

- **ACCELEROMETERS NOW FOUND ON MIR AND WITHIN MATERIALS PROCESSING EQUIPMENT**
- **5 x 10^{-7} g_o POSSIBLE WHEN COSMONAUTS ASLEEP**

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ELECTRIC FURNACES ON SOVIET SPACE STATIONS

TBE8810-504

DEVICE	LAUNCHED ON	OPERATED ON	OPERATIONAL PERIOD	MASS (kg)	POWER (w)	CARTRIDGE SIZE (mm)	CARTRIDGE CAPACITY	MAXIMUM TEMPERATURE (c)	VENT TO SPACE
SFERA	SALYUT 5	SALYUT 5	1976	?	10	?	?	< 100	N
SPLAV 1	PROGRESS 1	SALYUT 6	1978-81	23	300	170 x 20.6	1	990	Y
KRISTALL (1) KRISTALL (2)	PROGRESS 2 PROGRESS 5	SALYUT 6 SALYUT 6	1978 1979-81	27	250	175 x 13	1	1,100	N
MAGMA-F (KRISTALL MOD)	PROGRESS 13	SALYUT 7	1982-86	28	250	240 x 21	1	1,000	N
KORUND-1	PROGRESS 14	SALYUT 7	1982	130	720	310 x 33	12	1,270	N
PION-M *	PROGRESS 17	SALYUT 7	1983	41	< 100	140 x 140	1	180	N
KRISTALLIZATOR	KOSMOS 1628	SALYUT 7	1985-86	41	300	140 x 15.8	19	970	N
KORUND-1M	PROGRESS 28	MIR	1987-	136	1,000	310 x 33 (?)	6	1,270	N
KRISTALLIZATOR	PROGRESS 30	MIR	1987-	41	300	140 x 15.8	19	970	N
"MIRROR-BEAM"	PROGRESS 33	MIR	1987	?	250	?	?	1,100	?

* NOT PRIMARILY AN ELECTRIC FURNACE; USED IN 1983 TO GROW CRYSTALS BY STEPANOV METHOD, UNIT TRANSFERED TO MIR IN 1986 BY SOYUZ T-15

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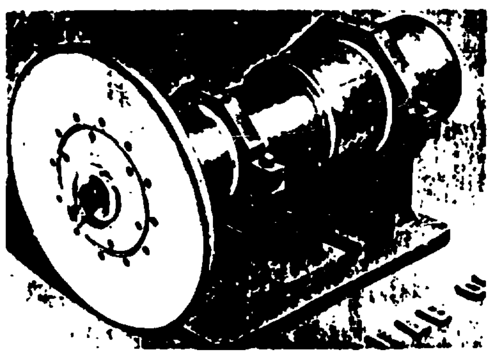
SPLAV 1 DESIGN

TBE8810-505

ELECTRIC FURNACE



CONTROL UNIT

- SPLAV 1 ONLY MATERIALS PROCESSING DEVICE VENTED TO SPACE (FOR HEAT DISSIPATION)
- VENTING NOW DISCOURAGED DUE TO CREW SAFETY CONCERNS

1980 EXPERIMENT ON SALYUT 6

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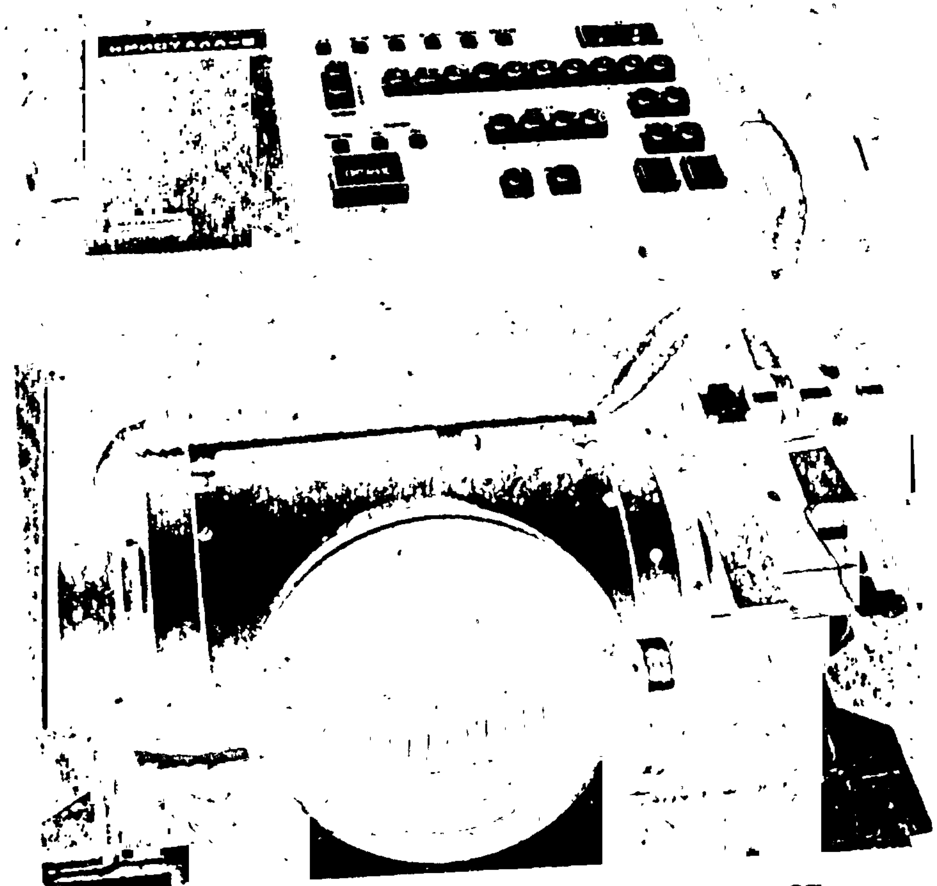
KRISTALL FAMILY OF FURNACES

TBE8810-506

- THREE GENERATIONS
  - KRISTALL: 1978
  - MAGMA-F: 1982
  - KRISTALLIZATOR: 1985
- USED FOR EARLY SCIENTIFIC INVESTIGATIONS OF MICROGRAVITY INFLUENCES
- KRISTALLIZATOR NOW IN USE ON MIR IS A SOVIET-CZECH DESIGN LED BY L.L. REGEL; CAPACITY OF 19 SAMPLES GREATLY REDUCES CREW INTERACTION TIME



ORIGINAL KRISTALL ELECTRIC FURNACE

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KORUND PILOT-PRODUCTION FURNACES

TBE8810-507

- **KORUND-1**
  - ► USED SPARINGLY ON SALYUT 7 IN 1982
- **KORUND-1M**
  - ► DELIVERED TO MIR IN 1987
  - ► SAMPLES: $\leqslant$ 25 mm DIAMETER $\leqslant$ 1.5 kg
  - ► DURATION OF EXPERIMENTS: 6-150 hr
  - ► PRIMARILY FOR "SEMICONDUCTOR" MATERIALS

KORUND-1 FURNACE AND CONTROL UNIT

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BIOTECHNOLOGY UNITS ON SOVIET SPACE STATIONS

TBE8810-508

UNIT	TYPE	SPACE STATION	DEBUTED
TAVRIYA	ELECTROPHORESIS	SALYUT 7	1982
GENOM	ELECTROPHORESIS	SALYUT 7	1984
EFU ROBOT	ELECTROPHORESIS	SALYUT 7 (TRANSFERRED TO MIR IN 1986)	1985
SVETLANA	ELECTROPHORESIS	MIR	1987
RUCHEY	ELECTROPHORESIS	MIR	1987
AYNUR	PROTEIN CRYSTALLIZATION	MIR	1987

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OPERATIONAL PROBLEMS ENCOUNTERED

TBE8810-509

- MICROGRAVITY CONDITIONS
  - MANY MATERIALS PROCESSING EXPERIMENTS DETERIORATE AT $a \geqslant 10^{-3}g_0$
  - DIFFICULT TO MAINTAIN $a < 10^{-3}g_0$ FOR LONG PERIODS (DAYS) WITH CREW ON BOARD. DAILY EXERCISE REGIME PRESENTS DIRECT CONFLICT
  - a LEVELS ENHANCED IN GRAVITY-GRADIENT STABILIZATION MODE, BUT THIS ORIENTATION CONFLICTS WITH EARTH AND DEEP-SPACE OBSERVATIONS
- QUANTITY OF RETURNED PROCESSED MATERIALS
  - PROCESSED MATERIALS MUST COMPETE WITH OTHER EXPERIMENT RESULTS (E.G. NATURAL RESOURCES AND ASTROPHYSICAL FILM CANISTERS) FOR LIMITED SOYUZ TM RETURN PAYLOAD CAPACITY, I.E. 120-150 KG
  - KOSMOS 1443-TYPE RETURN CAPSULE HAD CAPACITY OF 500 KG, BUT THE SYSTEM WAS SINGLE-USE AND HAS NOT BEEN EMPLOYED SINCE 1983

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OPERATIONAL PROBLEMS ENCOUNTERED (CONTINUED)

TBE8811-511

- **FREQUENCY OF RETURNED PROCESSED MATERIALS**
  - ► RETURN OF MATERIALS NOW LIMITED TO 2-3 TIMES PER YEAR WITH SOYUZ TM CREWS
  - ► CONSEQUENTLY, ELECTROPHORESIS EXPERIMENTS ARE NORMALLY CONDUCTED IMMEDIATELY PRIOR TO OR DURING SOYUZ TM VISITATIONS (NOTE a LEVELS MAY INCREASE WITH TEMPORARY CREW AUGMENTATIONS)

- **TEMPERATURE CONTROL**
  - ► MAINTENANCE OF PRESCRIBED TEMPERATURES HINDERED BY POWER FLUCTUATIONS DURING DAYLIGHT-NIGHTTIME PORTIONS OF ORBIT
  - ► AVAILABLE POWER ALSO AFFECTED BY SUN-ORBIT PLANE ANGLE (INCLINATION = 51.6°) AND BY LIMITED SOLAR PANEL ARTICULATION
  - ► TEMPERATURE UNIFORMITY WITHIN SAMPLE

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OPERATIONAL PROBLEMS ENCOUNTERED (CONCLUDED)

TBE8810-511

- **HEAT REJECTION**
  - ALL MATERIALS PROCESSING UNITS SINCE SMALL SPLAV 1 FURNACE MUST REJECT HEAT INTO SPACE STATION CABIN
  - INSTRUMENT OVERHEATING AND/OR UNCOMFORTABLE CREW ENVIRONMENTAL CONDITIONS MAY RESULT

- **GENERAL -VS- SPECIFIC PURPOSE DEVICES**
  - INITIAL TREND TOWARD GENERAL (MULTI) PURPOSE DEVICES TO ADVANCE KNOWLEDGE OF WIDE RANGE OF MICROGRAVITY EFFECTS; CONSEQUENTLY, EXPERIMENT SELECTION WAS SOMETIMES DRIVEN BY INSTRUMENT CAPABILITIES, E.G. KRISTALL FURNACE
  - LARGER, SPECIAL PURPOSE DEVICES NOW BEING PRODUCED FOR LIMITED MANUFACTURING

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FUTURE OF SOVIET MATERIALS PROCESSING ON MANNED SPACE STATIONS

TBE8810-512

- NEW DEDICATED MATERIALS PROCESSING MODULE EXPECTED IN 1989
- LARGER CAPACITY INSTALLATIONS

DEVICE	SAMPLE DIAMETER
ORION	25 mm
DYUNA	40 mm
KRATER	50 mm
MENISK	50 mm

- ISSUES
  - ➤ STATION STABILIZATION
  - ➤ FREE-FLYING MODULE OPERATIONS

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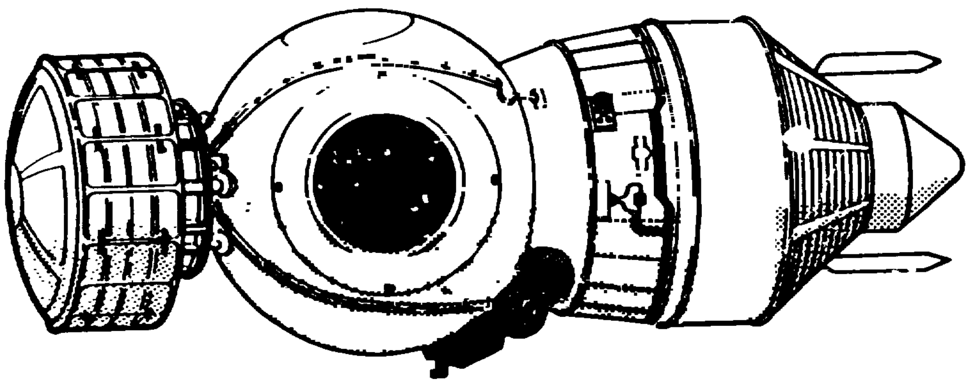
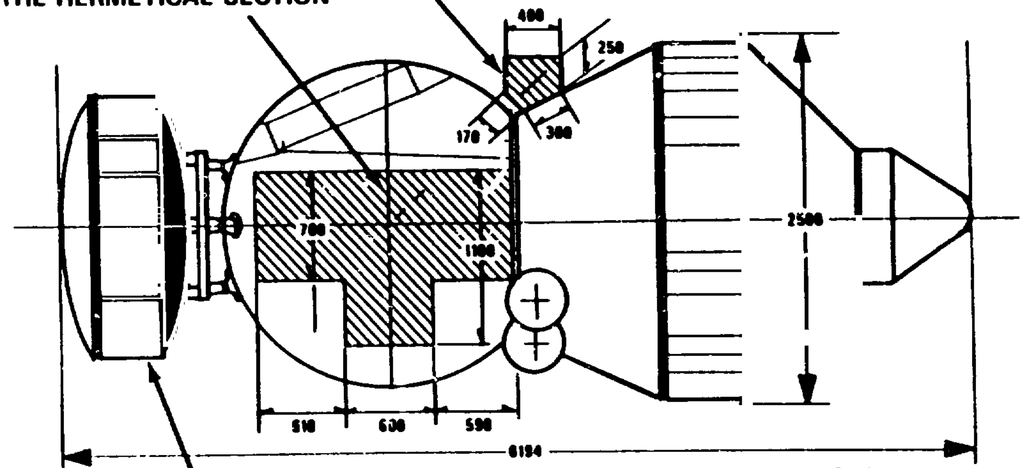
PHOTON MATERIALS PROCESSING SPACECRAFT

TBE8811-513



- LAUNCHED ANNUALLY EACH SPRING SINCE 1985



- ALL MEASUREMENTS ARE IN MM

- OFFERED ON A COMMERCIAL BASIS AT $15,000 PER KG PAYLOAD

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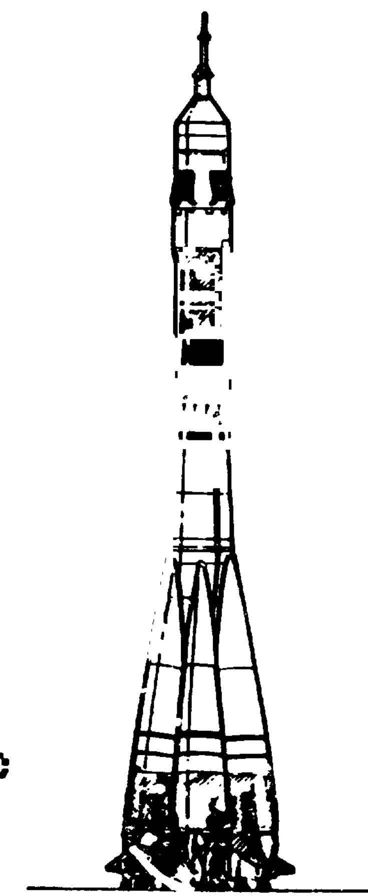
PHOTON SPACECRAFT SPECIFICATIONS

TBE8810-514

- **FLIGHT DATA**
  - LAUNCH VEHICLE: SOYUZ, SL-4
  - FLIGHT DURATION: 14-30 DAYS
  - INCLINATION: 62.8°
  - APOGEE: 300-400 KM
  - PERIGEE: 220-250 KM

- **PAYLOAD DATA**
  - MASS: 500 kg
  - VOLUME: 4.7 m^3
  - AVERAGE DAILY POWER: 400 W
  - PEAK DAILY POWER (1.5 HR/DAY): 700 W
  - IN-FLIGHT DATA TELEMETRY/COMMANDS PERMITTED
  - PAYLOAD RETURNED WITHIN 24 HR OF LANDING
  - MPUs AVAILABLE: ZONA 1, SPLAV 2, KASHTAN
  - MICROGRAVITY LEVELS RECORDED

- **PROCURED FLIGHTS**
  - KAYSER-THREDE (WEST GERMANY): THREE FLIGHTS BEGINNING IN 1989-1990; 50-60 kg PAYLOAD FIRST FLIGHT; 80-100 kg PAYLOAD FOR SECOND AND THIRD FLIGHTS
  - CNES (FRANCE): ONE FLIGHT IN 1989; 20-30 KG PAYLOAD



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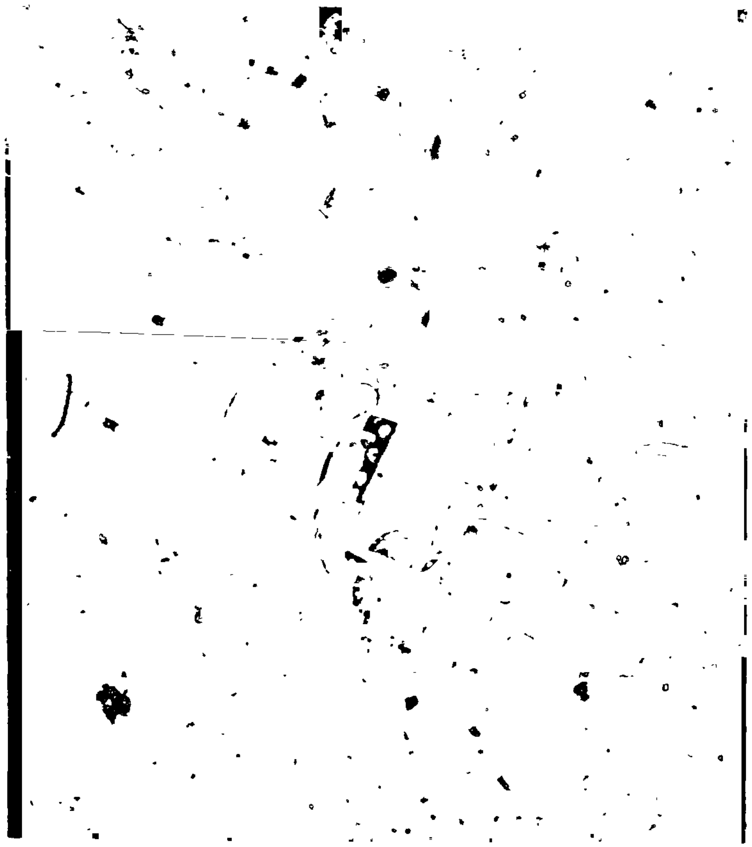
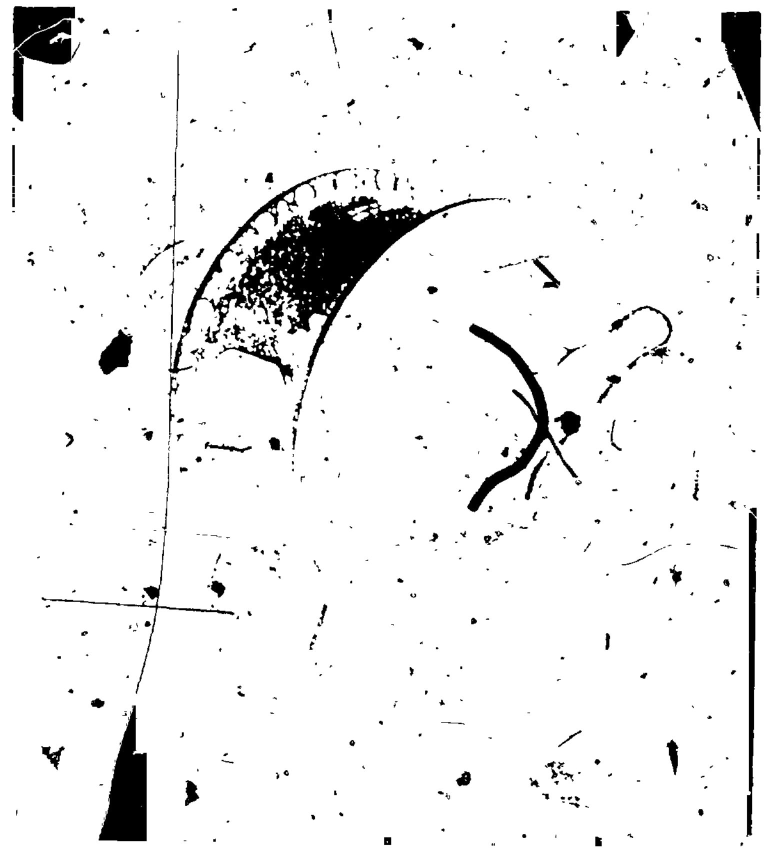
SOVIET MATERIALS PROCESSING UNITS

TBE8811-584



ZONA 1



SPLAV 2

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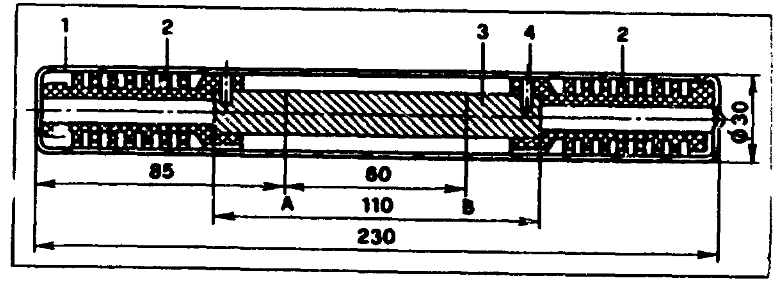
ZONA 1 SPECIFICATIONS

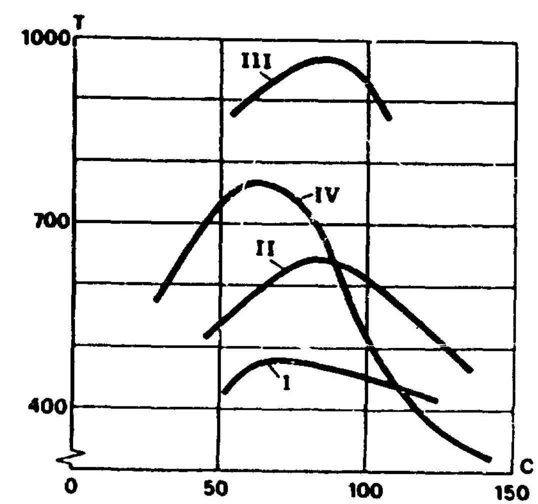
TBE8810-516

BASIC SPECIFICATIONS OF THE ZONA 01 UNIT	
Spacecraft	Photon
Year of Introduction	1985
Mass, kg	90
Power Required, W	300
DIMENSIONS OF OBTAINED SAMPLE, mm:	
length	:0
diameter	15
Thermal characteristics, °C:	
heating temperature	400—1,070
temperature increment	5
specified temperature accuracy	±5
temperature maintenance accuracy	±1
Maximum time of temperature maintenance prior to advance, h	2
Advance speed, mm/h	1-15



RESEARCH AMPOULE IN THE ZONA 01 UNIT.
1 - housing; 2 - graphite holder; 3 - material being studied; 4 - retaining pin.
A - initial position; B - final position of the ampoule during operation.

Chart of temperature distribution over the ampoule length depending on the heater
(I, II, III and IV—types of heaters).
T - temperature, °C
C - length, mm.



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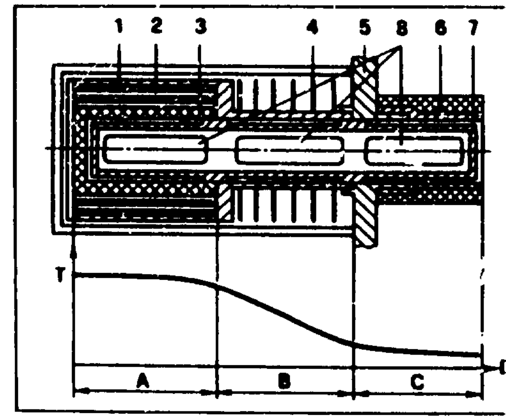
SPLAV 2 SPECIFICATIONS

BASIC SPECIFICATIONS OF THE SPLAV 02 UNIT

Spacecraft	Photon
Year of Introduction	1985
Mass, kg	120
Power Required, W	350
DIMENSIONS OF OBTAINED SAMPLE, mm:	
length	100
diameter	12
Number:	
of samples in a capsule	3
of capsules in the unit	12
Thermal Characteristics, C°	
heating temperature	400—1,070
specified temperature accuracy	±10
temperature maintenance accuracy	±3
Holding time at a given temperature, H	4.6, 9.2, 13.8, 18.2
Cooling rate, °C/h	2.8, 5.6, 11.3, 22.5
Temperature at the end of cooling, °C	300

Diagram of the electric heating chamber of Splav 02 and distribution of temperatures in the chamber.

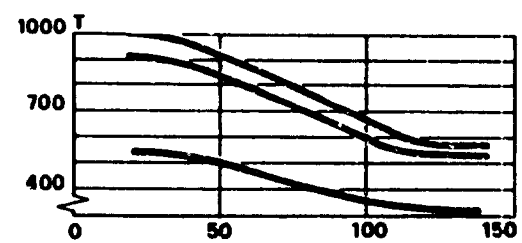
1 - muffle pipe; 2 - heater; 3 - thermoequalizer; 4 - screens; 5 - flange; 6 - casing; 7 - capsule; 8 - ampoules with materials. Zones: A - high-temperature, isothermal; B - transitional; C - low-temperature, isothermal. T - temperature; D - dimensions, mm.



Distribution of temperatures over the length of the capsule of the Splav 02 unit after holding for 4 hours 40 minutes at different specified temperatures of heating in the high-temperature isothermal zone.

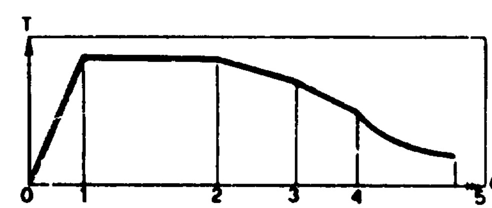
T - temperature, °C

D - dimension according to the capsule, mm.



Conditions of carrying out experiments on the Splav 02 unit.

0-1 - heating; 1-2 - holding time; 2-3 - controllable cooling at the rate of S1; 3-4 - controllable cooling at the rate of S2; 4-5 - passive cooling T - temperature; C - time.



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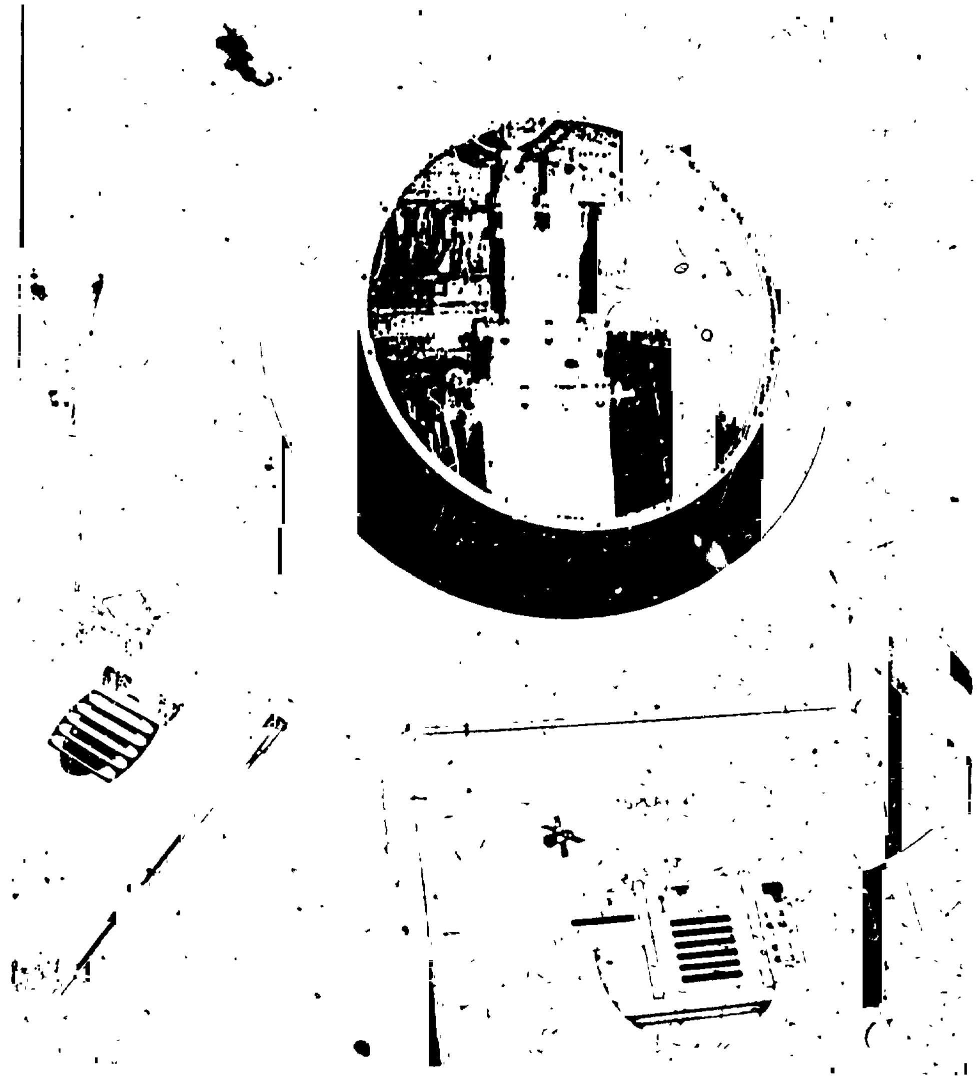
KASHTAN SPECIFICATIONS

TBE8310-518

BASIC SPECIFICATIONS OF THE KASHTAN UNIT	
Spacecraft	Photon
Mass, kg	60
Power Required, W	100
Electrode Voltage, V	500—5,000
Separation Chamber Length, mm	1,200
Cross-section of Separation Chamber mm²	5x5 or 10x5
Separation Chamber Capacity, ml	35 or 70
Single cell capacity, ml	0.7 or 1.4
Maximum Isolated Cells	49
Thermostatic Control Temperature, °C	5-25
Photographic Rate, Exposures/min	1



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SUMMARY

TBE8810-519

- SOVIET MATERIALS SCIENCE PROGRAM IN SPACE CAN BE DIFFICULT TO ASSESS ACCURATELY DUE TO SYNTAX, INCONSISTENT DEFINITIONS, AND ERRORS IN SOVIET DOCUMENTS
- PROGRAM RETAINS HIGH PRIORITY AND IS CHARACTERIZED BY LARGE QUANTITY OF EXPERIMENTS ALTHOUGH DIVERSITY AND QUALITY SOMETIMES SUFFER
- EXPERIMENTS ON MIR ARE STILL RESTRICTED UNTIL DEDICATED MATERIALS PROCESSING MODULE ARRIVES — PROBABLY 1989
- MATERIALS SCIENCE EXPERIMENTS ON SOVIET SPACE STATIONS ACCOUNT FOR ONLY A SMALL PORTION OF CREW ACTIVITY
- UNMANNED MATERIALS PROCESSING SPACECRAFT (E.G. PHOTON) WILL CONTINUE DESPITE SPACE STATION ACTIVITIES

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TOXIC AND REACTIVE MATERIALS HANDLING WORKSHOP
29 NOVEMBER 1988

MODULAR CONTAINERLESS PROCESSING FACILITY

E.H. TRINH
JET PROPULSION LABORATORY

MODULAR CONTAINERLESS PROCESSING FACILITY

OUTLINE

- MCPF GENERAL DESCRIPTION
  - PRIMARY FUNCTIONS
  - RATIONALE FOR CONTAINERLESS EXPERIMENTS
  - FACILITY EQUIPMENT
  - RELEVANT SCIENTIFIC DISCIPLINES
- MCPF GENERIC EXPERIMENT TIMELINE
  - CHAMBER PREPARATION / ENVIRONMENT CHARACTERIZATION
  - SAMPLE PREPARATION / DEPLOYMENT
  - ENVIRONMENT CONTROL ACTIVATION / SAMPLE PROCESSING / DATA ACQUISITION
  - POST-PROCESSING FUNCTIONS
  - CHAMBER PREPARATION / CHARACTERIZATION
- GENERAL CLOSING REMARKS

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MCPF GENERAL DESCRIPTION

PRIMARY FUNCTIONS:

TO PROVIDE THE

. CONTROLLED ENVIRONMENT

. SAMPLE HANDLING DEVICES

. DATA ACQUISITION, STORAGE AND TRANSFER DEVICES

. CREW AND GROUND CONTROL INTERFACES WITH THE PAYLOAD

NECESSARY FOR THE PERFORMANCE OF CONTAINERLESS SCIENTIFIC OR TECHNOLOGICAL EXPERIMENTS IN MATERIALS SCIENCE, FLUID PHYSICS, BIOTECHNOLOGY, AND EXOBIOLOGY IN MICROGRAVITY

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MCPF GENERAL DESCRIPTION

RATIONALE FOR CONTAINERLESS EXPERIMENTS IN MICROGRAVITY

- USE OF LOW MAGNITUDE POSITIONING FORCES POSSIBLE
- STUDY OF SMALL MAGNITUDE CAPILLARY PHENOMENA ON FREE LIQUID SURFACES
- POTENTIAL FOR PROCESSING OF HIGH PURITY MATERIALS
- POTENTIAL FOR PROCESSING HIGH TEMPERATURE AND HIGHLY REACTIVE MATERIALS
- POSSIBILITY FOR NON-CONTACT SHAPING OF MELTS AND MANUFACTURE OF APPLICATION-READY PARTS
- OPPORTUNITY TO DEVELOP NON-CONTACTING DIAGNOSTIC TECHNIQUES TO REFINE GROUND-BASED TECHNOLOGY
- SPACE STATION OPPORTUNITY: LONG DURATION, MANY REPETITIVE CYCLES EXPERIMENTS

MCPF GENERAL DESCRIPTION

MULTI-MODULE FACILITY:

. HIGH TEMPERATURE ACOUSTIC POSITIONER

. HIGH TEMPERATURE ELECTROMAGNETIC POSITIONER

. ELECTROSTATIC-ACOUSTIC HYBRID POSITIONER

. GAS-GRAIN MODULE (*)

PRECURSOR FLIGHT HARDWARE :

. 3 AAL (61C)
. ACES (41C)
. DDM (51B)
. EML (61C)

SHUTTLE/SPACELAB PREVIOUSLY FLOWN EQUIPMENT

. SAAL (D1)

FUTURE EQUIPMENT FOR USML / IML SPACELAB FLIGHTS:

. DROP PHYSICS MODULE (DPM, CODE EN)
. ACOUSTIC LEVITATION FURNACE (ALF, CODE EN)
. MODULAR ELECTROMAGNETIC LEVITATOR (MEL, CODE EN)
. TEMPUS (~~ESA~~) (*)
DFVLR

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MCPF GENERAL DESCRIPTION

SCIENTIFIC DISCIPLINES SERVED:

. GLASSES AND CERAMICS: CRYSTAL NUCLEATION, GLASSIFICATION, PHASE TRANSFORMATION AND SEPARATION, ULTRA-HIGH TEMPERATURE GLASSES PROPERTIES, SPECIAL PROPERTY GLASSES AND CERAMICS

. METALS AND ALLOYS: NUCLEATION STUDIES, METASTABLE STRUCTURES, HIGH TEMPERATURE PROCESSING AND PROPERTIES, HIGH PURITY, CONTROLLED REACTIONS EXPERIMENTS

. ELECTRONIC MATERIALS: HIGH TEMPERATURE MELT PROPERTIES

. FLUID PHYSICS: FREE LIQUID SURFACE BEHAVIOR, THERMO-CAPILLARY PHENOMENA, NONLINEAR DYNAMICS, TURBULENCE, GEOPHYSICAL MODELLING

. BIOTECHNOLOGY: CONTAINERLESS PROTEIN CRYSTAL GROWTH, POLYMERIZATION STUDIES

. EXOBIOLOGY: METEORITICS MODELLING, PLANETARY ATMOSPHERES NUCLEATION STUDIES

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MCPF GENERIC EXPERIMENT TIMELINE

A. CHAMBER PRPEARATION / ENVIRONMENT CHARACTERIZATION

B. SAMPLE PREPARATION / DEPLOYMENT

C. ENVIRONMENT CONTROL ACTIVATION / SAMPLE PROCESSING / DATA ACQUISITION

D. EXPERIMENT REPETITION

E. POST-PROCESSING SAMPLE RETRIEVAL / CHARACTERIZATION / STORAGE

F. CHAMBER PREPARATION / PURIFICATION / CHARACTERIZATION

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MCPF GENERIC EXPERIMENT TIMELINE

A. CHAMBER PREPARATION / ENVIRONMENT CHARACTERIZATION

. HIGH VACUUM --------- (VENTING)

. VACUUM BAKEOUT ---------(GAS TRAPPING, POWER)

. INERT GAS BACKFILL (1 BAR OR >1 BAR)-----(HIGH PURITY GAS SUPPLY AND MONITORING)

. PARTICULATE CONTAMINATION MONITORING AND CONTROL ------- (DIAGNOSTIC INSTRUMENTATION)

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MCPF GENERIC EXPERIMENT TIMELINE

B. SAMPLE PREPARATION / DEPLOYMENT

- NO PREPARATION (SAMPLE DIRECTLY DEPLOYED BY MCPF DEVICE)
- SAMPLE CHARACTERIZATION (PREPARATION REQUIRED IN MANNED ENVIRONMENT) --------- (MATERIALS SCIENCE GLOVEBOX, SAMPLE TRANSPORT AND HANDLING PROCEDURES, CREW)
- SAMPLE IS PREPARED PRIOR/ AFTER CHAMBER PREPARATION
- SAMPLE SIZES : 500 MICRONS TO 2 CM
- SAMPLE NUMBER: SINGLE, MULTIPLE, OR SAMPLE SWARM (LESS THAN 500 MICRONS SIZE)
- SAMPLE STATE: LIQUID OR SOLID, GASES ALSO DEPLOYED
- SAMPLE DEPLOYMENT (INSERTION INTO CHAMBER) ------(CREW)

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MCPF GENERIC EXPERIMENT TIMELINE

C. SAMPLE PROCESSING

. ENVIRONMENT CONTROL ACTIVATION ------ (FURNACE POWER, THERMAL OVERLOAD CONTROLS, STATIC PRESSURE CONTROL, GAS COMPOSITION MONITORING, PARTICULATE CONTAMINATION MONITORING)

. FACILITY DIAGNOSTICS ACTIVATION ------ (DATA ACQUISITION, STORAGE AND DOWNLINK)

. SAMPLE MANIPULATION (MELTING, SUPERHEATING, ROTATION, OSCILLATION, ETC...) -------- (SAMPLE OBSERVATION / DOWNLINK)

. PROPERTIES MEASUREMENT --------- (DATA ACQUISITION, STORAGE, AND DOWNLINK)

. RADIANT (BEAM) HEATING ACTIVATED ------- (BEAM POWER, SAFETY CONTROLS)

. SAMPLE SOLIDIFICATION ---------(HEAT REMOVAL)

. END OF EXPERIMENT (SAMPLE RETRIEVAL OR EXPERIMENT REPEAT)

. FLUID REMOVAL AND TRAPPING (GASES AND LIQUIDS) ----(PMMS)

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MCPF GENERIC EXPERIMENT TIMELINE

D. EXPERIMENT REPETITION

. MULTI-CYCLE RUNS --------(POWER, PMMS)

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MCPF GENERIC EXPERIMENT TIMELINE

E. POST-PROCESSING SAMPLE RETRIEVAL / CHARACTERIZATION / STORAGE

. SAMPLE RETRIEVAL (LIQUID, SOLIDS, SUSPENSION)------ (SAMPLE HANDLING, CREW)

. SAMPLE NOT ANALYZED ------ (STORAGE IN MCPF OR IN USL FACILITY)

. SAMPLE CHARACTERIZATION (SEM, ETCHING, MICROSCOPY,...)--- USL COMMON FACILITIES, CREW)

EHT 11/88 JPL

MCPF GENERIC EXPERIMENT TIMELINE

F. CHAMBER PREPARATION / PURIFICATION / CHARACTERIZATION

. ANALYSIS OF ENVIRONMENT PRIOR TO SAMPLE REMOVAL ----- (MCPF OR USL DIAGNOSTICS)

. CHAMBER EVACUATED ------------(VENTING, GAS TRAPPING)

. CHAMBER PURIFIED (BAKEOUT OR PURGING) ------ (POWER, VENTING)

. CHAMBER CHARACTERIZATION

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NASA JPL

Modular Containerless Processing Facility

MCPF EXPERIMENTS <u>NOT</u> YET DEFINED

- Experiments & Principal Investigators are selected by orderly process
- Selection based upon responses to NASA Announcement of Opportunity (AO)
- MCPF work now based upon capabilities
    - Capabilities include most known candidate experiments

R. Grumm

Huntsville November 29, 1988 ToxicWSExper

Modular Containerless Processing Facility

MCPF Conducts Multiple Experiments

- Baseline configuration has three (3) experiment modules at PMC
  - Experiment modules may have multiple chambers
  - Additional experiments may be added
    - Simple and small experiments not in reference set
    - Quick-is-Beautiful class to be defined later
    - Get Away Special class
    - Commercial experiments that can use the facility
    - MCPF engineering development
    - Any other relevant experiments that make good use of facility
- Experiments can run concurrently

R. Grumm

NASA JPL

Modular Containerless Processing Facility

MCPF Experiments Change
- MCPF is Modular so it can change on- oit

MCPF is Evolutionary

- MTC Phase Experiments
  - Remote and automatic without crew
  - Power to fit whats available
  - Data to fit capability
- Early PMC
  - Start Experiment changeout
    - New experiment every 90 days
- PMC + 1 year
  - Changeout of experiments comple e
  - This is the MCPF version described at Payload Accommodations Workshop
    - Guntersville, Jan 1988

R Grumm
ToxicWSChange

Huntsville November 29, 1988

NASA JPL

Modular Containerless Processing Facility

FLEXIBILITY

- Not just a manifestation of uncertaintly
- Its a requirement

NEED

- An orderly process
- Face-to-face contact with Work Package contractors
  - Who are they?
  - When do they need what?
- Plan
  - AO is major milestone
    - When is AO needed to match Work Package needs?

R. Grumm

ToxicWSNe_us

Huntsville November 29, 1988

11. SPACE STATION FURNACE FACILITY

NOTE: No hardcopy of this presentation was provided for the Workshop Proceedings.

SPACE STATION
TOXIC AND REACTIVE MATERIALS HANDLING WORKSHOP

HUNTSVILLE, ALABAMA
NOV 29, 30 & DEC 1, 1988

OVERVIEW OF MODULAR COMBUSTION FACILITY

NASA

LEWIS RESEARCH CENTER
CLEVELAND, OHIO

ENGINEERING DIRECTORATE P.M. : RON CHUCKSA
SPACE EXPERIMENTS DIV P.M. : BOB THOMPSON
FACILITY PROJECT SCIENTIST : KURT SACKSTEDER
STUDY TEAM MEMBER (PMMS) : DON PERDUE

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MODULAR COMBUSTION FACILITY

OBJECTIVE: DEVELOP A MODULAR, MULTIUSER MICROGRAVITY SCIENCE FACILITY ,FOR USE BY THE COMBUSTION SCIENCE COMMUNITY ON BOARD THE SPACE STATION FREEDOM LABORATORY

CURRENT EFFORT: DEFINITION STUDY & CONCEPTUAL DESIGN

APPROACH:

- START WITH A REPRESENTATIVE LIST OF POTENTIAL MICROGRAVITY SCIENCE EXPERIMENTS FOR COMBUSTION OVER A BROAD RANGE OF CONDITIONS/REQUIREMENTS
- WORK WITH REPRESENTATIVES OF EACH OF THESE POTENTIAL EXPERIMENTS TO DETERMINE REQUIREMENTS
- GENERATE PRELIMINARY CONCEPTUAL SCHEMATIC DIAGRAM FOR EACH POTENTIAL EXPERIMENT AS IT MIGHT EX[illegible] IN THE USL ENVIRONMENT
- GENERATE [illegible]ATABASE OF EXPERIMENTAL REQUIREMENTS
- EXTRACT COMMON SYSTEMS TO FORM THE BASIS FOR A HOST FACILITY
- MERGE COMMON SYSTEMS REQUIREMENTS WITH KNOWN SPACE STATION REQUIREMENTS/CAPABILITIES TO FORM A HOST FACILITY

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CLEVELAND, OHIO

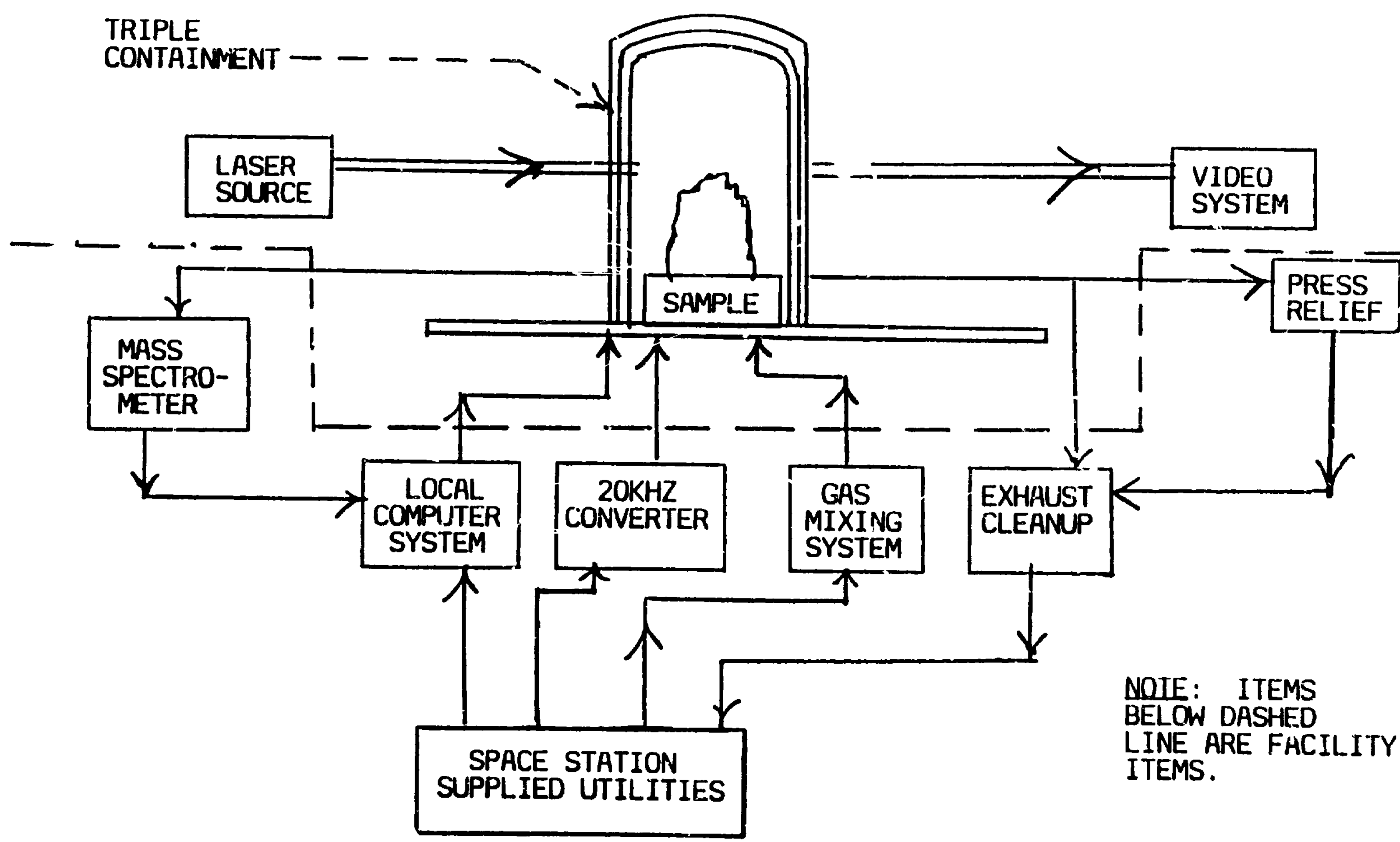
MODULAR COMBUSTION FACILITY (MCF)

REFERENCE EXPERIMENT SETS

[C01]	GASEOUS FUEL COMBUSTION	STOCKER - LeRc
[C02]	FLAMING AND SMOLDERING COMBUSTION IN LOW VELOCITY FLOWS	OLSON - LeRc FREIDMAN - LeRC SACKSTEDER - LeRc
[G03]	POOL FIRES	ROSS - LeRc
[C04]	EFFECTIVENESS OF CANDIDATE EXTINGUISHANTS FOR USE ON SMOLDERING OR FLAMING COMBUSTION IN LOW GRAVITY	FREIDMAN - LeRc
[C05]	DROPLETS COMBUSTION	SACKSTEDER - LeRc
[C07]	METALS COMBUSTION	BENZ - WHITE SANDS

REVISED 11 AUG 88

BLOCK DIAGRAM FOR TYPICAL COMBUSTION EXPERIMENT



NOTE: ITEMS BELOW DASHED LINE ARE FACILITY ITEMS.

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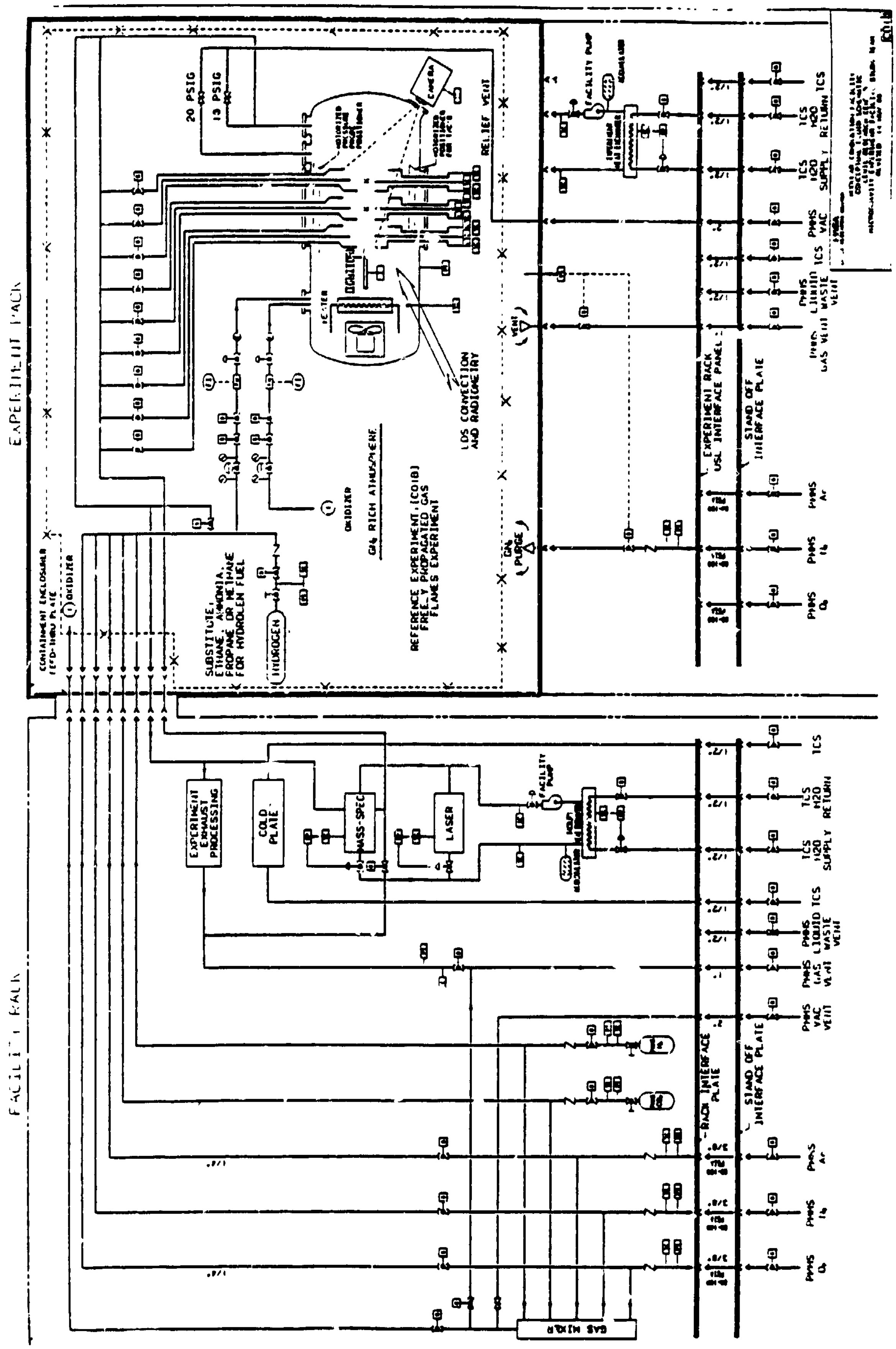

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MODULAR COMBUSTION FACILITY

EXPERIMENTAL REQUIREMENTS DATABASE FORMATS

SECTION 1.1: GENERAL INFORMATION

EXPERIMENT NAME (NO.) / UPDATED	S R C	SOURCE OF REQUIREMENTS: CONTACT PHONE NUMBER	SOURCE OF REQUIREMENTS: ORGANIZATION	EXPERIMENT DESCRIPTION

SECTION 1.2: GENERAL INFORMATION

EXPERIMENT NAME (NO.) / UPDATED	S R C	TOTAL NUMBER OF RUNS REQ'D	SETUP		PRE-TEST		TEST		POST-TEST		SHUTDOWN		COMMENTS
			TIME REQ'D	% CREW TIME	TIME REQ'D	% CREW TIME	TIME REQ'D	% CREW REQ'D	TIME REQ'D	% CREW REQ'D	TIME REQ'D	% CREW REQ'D	

SECTION 1.3: GENERAL INFORMATION

EXPERIMENT NAME (NO.) / UPDATED	S R C	ITEMS IN CURRENT CEI SPEC				S R C	ITEMS NOT IN CURRENT CEI SPEC		
		LSE NO.	LAB SUPPORT EQUIPMENT ITEM TITLE	N	D		LAB SUPPORT EQUIPMENT ITEM TITLE	N	D

2.1: ELECTRIC POWER DISTRIBUTION

EXPERIMENT NAME (NO.) /UPDATED	S R C	SUBSYSTEM	LOAD DESCRIPTION	VOLTAGE (volts)	FREQUENCY (hZ)	NUMBER OF PHASES	PEAK POWER (watts)	DUTY FACTOR	AVE. POWER (watts)	COMMENTS

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MODULAR COMBUSTION FACILITY

EXPERIMENTAL REQUIREMENTS DATABASE FORMATS

SECTION 3.1 - TRANSDUCERS & SIGNAL CONDITIONERS

EXPERIMENT NAME (NO.) /UPDATED	S R C	GENERIC MEASUREMENT TYPE	NO. CHAN PER TYPE	RANGE	TOLERANCE	TRANSDUCER: DESCRIPTION	TRANSDUCER: OUT TYP & LVL	TRANSDUCER: EX REQ'D TYP & LVL	SIGNAL CONDITIONER: DESCRIPTION	SIGNAL CONDITIONER: OUTPUT TYP & LVL	SIGNAL CONDITIONER: LOCATION	ON-BOARD DISPLAY REQ'D

SECTION 3.2: VIDEO SYSTEMS

EXPERIMENT NAME (NO.) /UPDATED	S R C	VIDEO QUALITY REQ'D (RS170, SUB RS170, OR N NF)	N U M B E R	F I X E D	C O L O R	CAMERA STAT/ ST.P SIGNAL	CAM. AMBT. TEMP. RANGE (C)	GRAY SCL.	SUB FRAME REQ'D (Y/N)	SPAT. RES. pels	FRAME RATE (fps)	STORED FRAMES PER RUN/ FLIGHT	EQ. ISO	SPEC RESP	NO. VIEW PER CAM- ERA	DATA ANNO. REQ'D (Y/N)	ON- BOARD DISP. REQ'D (Y/N)	DOWNLINK REQUIREMENTS: DOWN- LINKED FRAMES PER RUN	DOWNLINK REQUIREMENTS: MAX. ACCEPT. DOWNLINK TIME	DOWNLINK REQUIREMENTS: CALC'D REQ'D DATARATE (bps)	SPECIAL OPTICS

SECTION 3.3 - FILM CAMERA SYSTEMS

EXPERIMENT NAME (NO.) /UPDATED		NO. OF CAM- ERAS	FORMAT SIZE 35mm-STILL 70mm-STILL 16mm-MOTN	COLOR OR B&W (C/B)	FIXED OR HAND- HELD (F/H)	DEPTH OF FIELD (cm @ cm)	FIELD OF VIEW (deg)	FRAMES PER RUN	AMBIENT OR ARTI- FICIAL LIGHT	SPECTRAL RESPONSE	NO. VIEWS PER CAMERA	DATA ANNO- TATION REQ'D (Y/N)	COMMENTS

SECTION 3.4 - DATA ACQUISITION

EXPERIMENT NAME (NO.) /UPDATED	S R C	ANALOG LINES IN	ANALOG LINES OUT	DIGITAL LINES IN	DIGITAL LINES OUT	SERIAL LINES (RS232 ETC.)	SAMPLES PER SECOND (MAX)	DATA RATE BITS PER SECOND (MAX)	MASS STORAGE (KB) PER RUN	VIDEO	DATA ENCRYP- TION	HIGH RATE DATA LINE	COMMENTS

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EXPERIMENTAL REQUIREMENTS DATABASE FORMATS

SECTION 3.5: LASER DIAGNOSTIC SYSTEMS/OPTICAL MEASUREMENTS

EXPERIMENT NAME [NO.] /UPDATED	S R C	GENERIC MEASUREMENT TYPE	RANGE	TOLERANCE	PROFILE / POINT / BULK	SPATIAL RESOLUTION	TIME RES. / DATA RATE / DURAT'N	SUITABLE TECHNIQUES	LIMITATIONS / DEVELOPMENT ISSUES	SPECIAL REQUIREMENTS	POWER NOMINAL/ PEAK	DATA PROCESS. / REAL TIME OR DEFERRED	OUTPUT FORMAT	DISPLAY

SECTION 4: ELECTRIC CONTROLS

EXPERIMENT NAME [NO.] /UPDATED	S R C	CONTROLLED DEVICE OR SUBSYSTEM TITLE	CONTROL SIGNALS: OUTPUT DISCRETE	CONTROL SIGNALS: OUTPUT ANALOG VALUE	CONTROL SIGNALS: INPUT DISCRETE	CONTROL SIGNALS: INPUT ANALOG VALUE	CONTROL SIGNALS: INPUT S/W OR TIME	CLOSED LOOP XDCR	REQUIRED FAILURE TOLERANCE LEVEL: MISSION CRITICAL (YES-NO)	REQUIRED FAILURE TOLERANCE LEVEL: SAFETY CRITICAL (YES-NO)	REQUIRED FAILURE TOLERANCE LEVEL: FAILURE TOLERANCE LEVEL (0,1 OR 2)	ALL SUBSYSTEM REQUIREMENTS MET (YES-NO)

SECTION 5.1 - CONSUMABLES

EXPERIMENT NAME [NO.] /UPDATED	S R C	MATERIAL NAME AND FORMULA	GAS LIQUID SOLID OR OTHER	NUMBER OF RUNS PER 90 DAYS (min/max)	TYPICAL RUN DURATION (minutes)	MASS FLOW (kg/run)	VOLUME FLOW (l/min)	TOTAL MASS CONSUMED/ 90-DAYS (kg)	USL SUPPLIED (yes/no)	TEST CHAMBER PRESSURE (Kpa)	TEST CHAMBER TEMP (K)

SECTION 5.2: WASTE DISPOSAL

EXPERIMENT NAME [NO.] /UPDATED		MATERIAL NAME AND FORMULA	VAPOR MASS PER RUN (kg)	LIQUID MASS PER RUN (kg)	SOLID MASS PER RUN (kg)	SOLID PARTICULAT SIZE MICRONS	TOTAL MASS PER 90-DAYS (kg)	RISK ASSESSMENT	TEMP. OF WASTE (K)	PRESS. OF WASTE Kpa	HAZARD LEVEL

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SECTION 5.3: VENTING

EXPERIMENT NAME [NO.] /UPDATED	S R C	MATERIAL NAME AND FORMULA	TOTAL MASS TO VENT PER 90-DAYS (kg)	MASS FLOW (kg/run)	VENT FLOW (l/min)	VENT INITIAL PRESSURE (Kpa)	VENT FINAL PRESSURE (torr)	VENT FLUID TEMP. (K)	COMMENTS

SECTION 5.4: THERMAL COOLING

EXPERIMENT NAME [NO.] /UPDATED	S R C	HEAT LOAD PER RUN (kw)	TEMPER-ATURE RANGE (K)	COOLING METHOD			MASS FLOW OF COOLANT (kg/min)	VOLUME FLOW OF COOLANT (l/min)	MINIMUM COOLING FLUID TEMP. (K)	COOLANT FLUID PRESSURE (KPa)	COMMENTS
				AVIONICS AIR COOLING	COLDPLATE	LIQUID/ GAS HEAT XCHANGER					

SECTION 6.1: TEST SECTION

EXPERIMENT NAME [NO.] /UPDATED	S R C	TYPE (i.e. PRESSURE VESSEL, SEALED)	DIMENSIONS			VOLUME (cubic meters)	MASS (kg)	FEATURES			COMMENTS
			WIDTH meters	LENGTH meters	DEPTH meters			WINDOWS	DOORS	MECHA-NISMS	

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EXPERIMENTAL REQUIREMENTS DATABASE FORMATS

SECTION 6.2: ITEMS OTHER THAN TEST SECTION

EXPERIMENT NAME [NO.] /UPDATED	S R C	ITEMS TO BE INCLUDED IN EXPERIMENTAL SPECIFIC VOLUME	DIMENSIONS			VOLUME (cubic meters)	MASS (kg)	COMMENTS
			WIDTH meters	LENGTH meters	DEPTH meters			

SECTION 6.3 - ADDITIONAL EXPERIMENT PECULIAR STRUCTURAL REQUIREMENTS IN RACK

EXPERIMENT NAME [NO.] /UPDATED	S R C	VIBRATION ISOLATION	EMC (ELECTROMAGNETIC CONTROL)	THERMAL INSULATION	CONTAINMENT REQUIRED FOR SAFETY	OTHERS

SECTION 7.1: ACCELERATION

EXPERIMENT NAME [NO.] /UPDATED	S R C	DIRECTION	SUSTAINED ACCELERATION			TRANSIENT g -sec	ALIGNMENT REQUIREMENTS	COMMENTS
			g/g	hz	duration			

MODULAR COMBUSTION FACILITY

PRESENT FACILITY CONCEPTS

- MODULAR CONCEPT

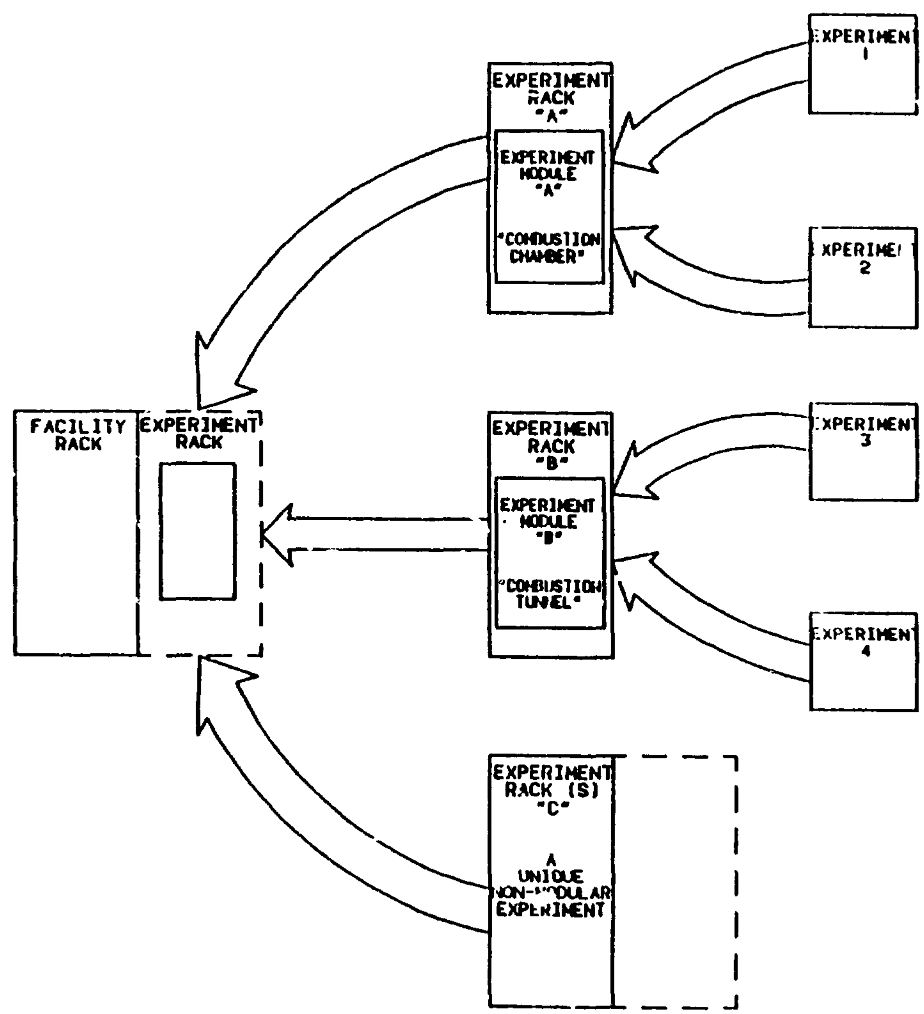
- TWO RACK FACILITY
  - PERMANENT FACILITY RACK
  - INTERCHANGEABLE EXPERIMENT RACK

- FACILITY RACK
  - INTERFACE BETWEEN USL & EXPERIMENT
  - HOUSES SUPPORT SYSTEMS
    - POWER CONVERSION & DISTRIBUTION SYSTEM
    - DATA ACQUISITION & CONTROL COMPUTER SYSTEM
    - GAS MIXING & DISTRIBUTION SYSTEM
    - EXPERIMENTAL BY-PRODUCTS CONDITIONING SYSTEM
    - LASER DIAGNOSTIC SUPPORT SYSTEM
    - HIGH RESOLUTION HIGH FRAME RATE VIDEO SUPPORT SYSTEM
    - MASS SPECTROMETER
    - SAFETY SYSTEMS
    - OPERATOR INTERFACE PANEL

- EXPERIMENT RACK
  - RACK INTEGRATED ON GROUND
  - POSSIBLE CHANGE-OUT EVERY 12 TO 18 MONTHS
  - HOUSES CONTAINMENT ENCLOSURE
  - VARIOUS EXPERIMENT MODULES
    - COMBUSTION CHAMBER
    - VERY LOW SPEED COMBUSTION TUNNEL

MODULAR COMBUSTION FACILITY

MODULAR CONCEPT



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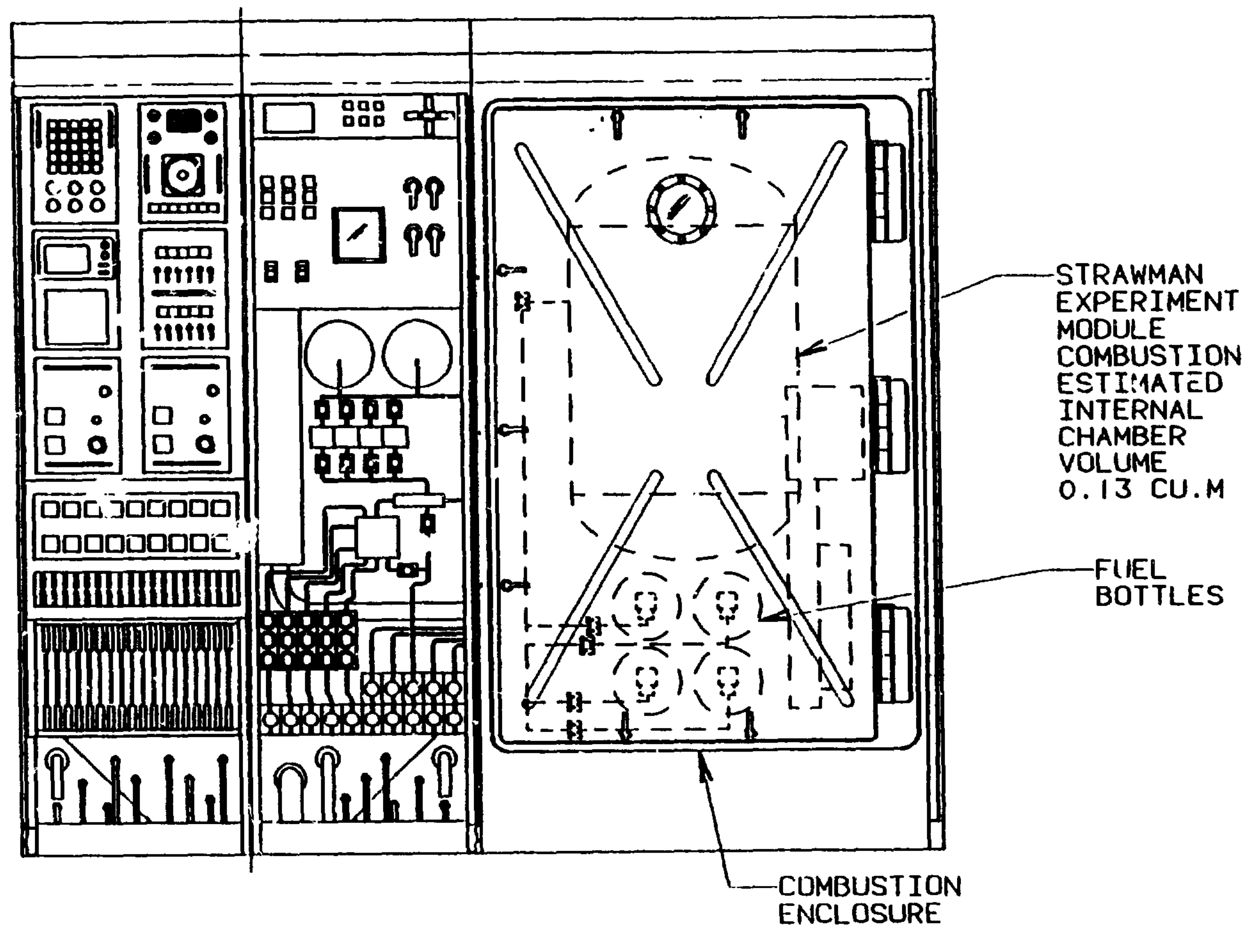
MODULAR COMBUSTION FACILITY

(SHOWN WITH STRAWMAN COMBUSTION CHAMBER EXPERIMENT MODULE INSTALLED)



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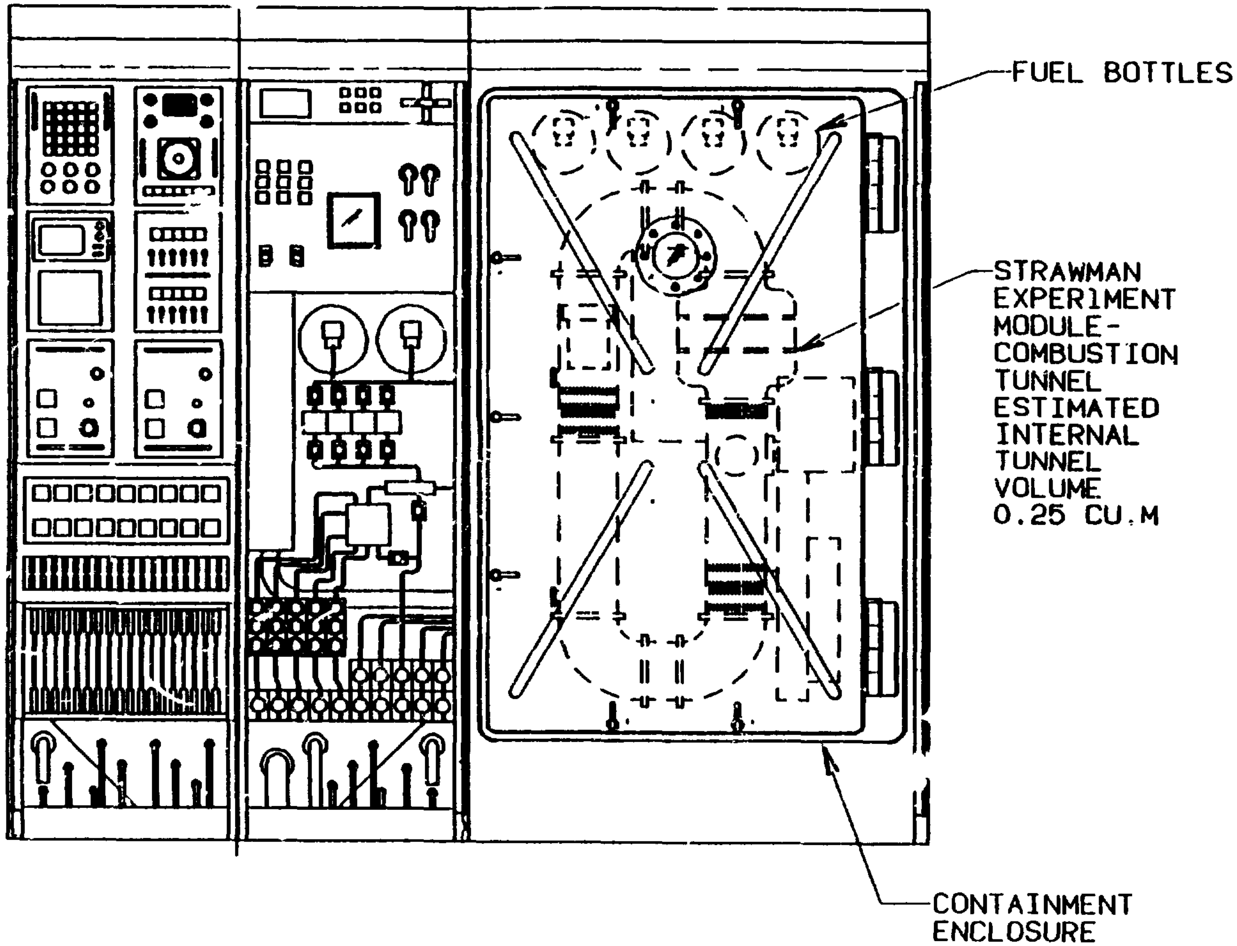
(SHOWN WITH LOW-SPEED COMBUSTION TUNNEL EXPERIMENT MODULE INSTALLED)



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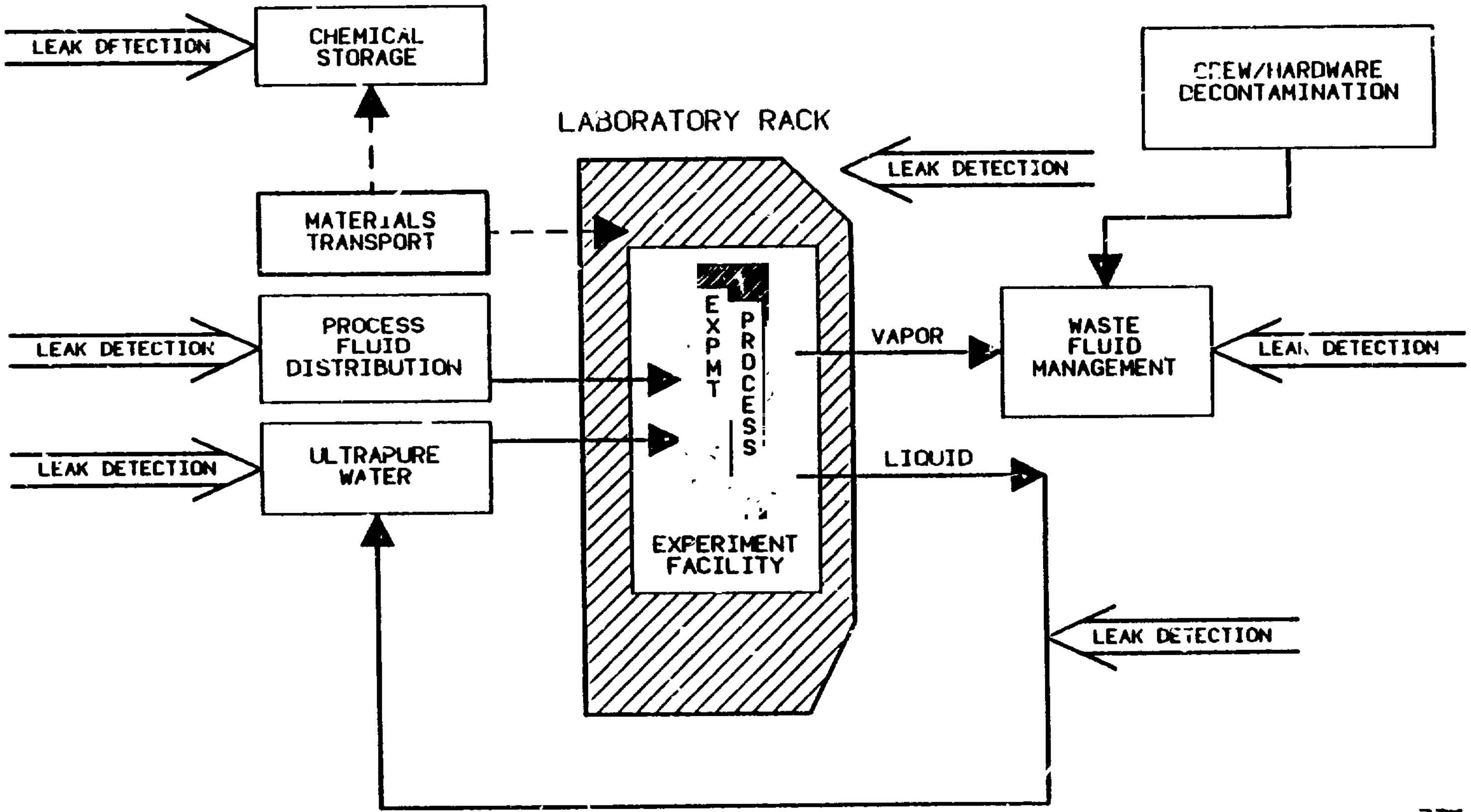
U.S. LABORATORY REVIEW WORKSHOP

(HUNTSVILLE - AUGUST 1988)

PMMS FUNCTIONAL DIAGRAM



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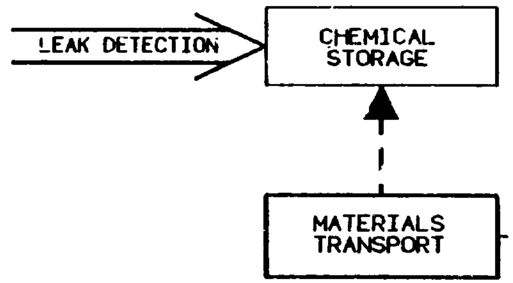
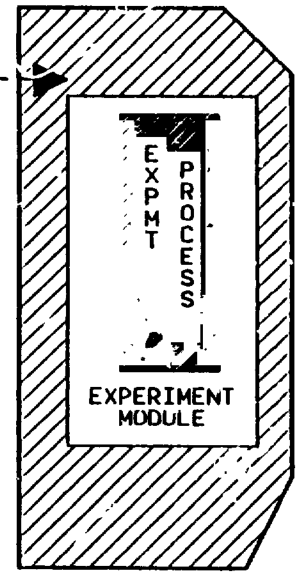
CHEMICAL STORAGE & MATERIALS TRANSPORTS USAGES





STORAGE/TRANSPORT REQUIRED PER 90 - DAYS	
METHANE	7.5 Kg
PROPANE	1.9 Kg
AMMONIA	0.7 Kg
ETHANE	1.3 Kg
METHONOL	4.4 Kg
ETHANOL	4.4 Kg
PROPANOL	4.4 Kg
BUTANOL	4.5 Kg
DECANE	0.1 Kg
HEPTANE	0.1 Kg
HALONS	4.2 Kg
MULTI COMPONENT FUELS	1.6 Kg
PLEXIGLASS	2.6 Kg
PAPER	1.1 Kg

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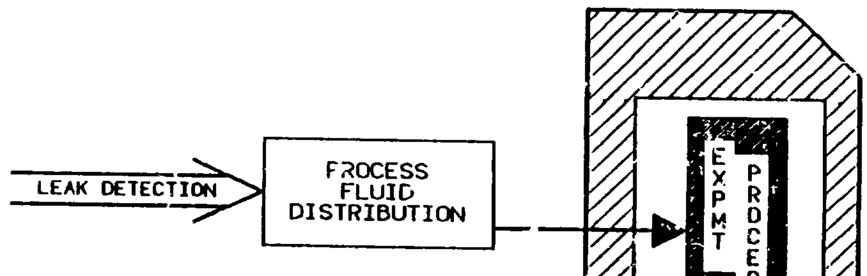
MODULAR COMBUSTION FACILITY

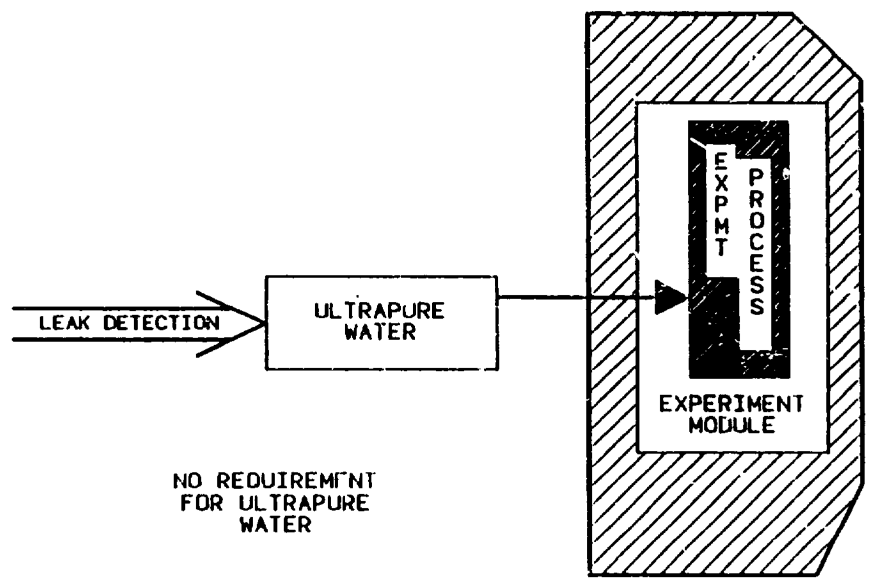
USL SUPPLIED CONSUMMABLES USAGE



REQUIREMENTS PER 90-DAY	
OXYGEN	6.8 Kg
NITROGEN	1.1 Kg
CARBON DIOXIDE	1.5 Kg
ARGON	12.4 Kg
HELIUM	1.2 Kg
HYDROGEN	0.1 Kg
WATER	25 Kg

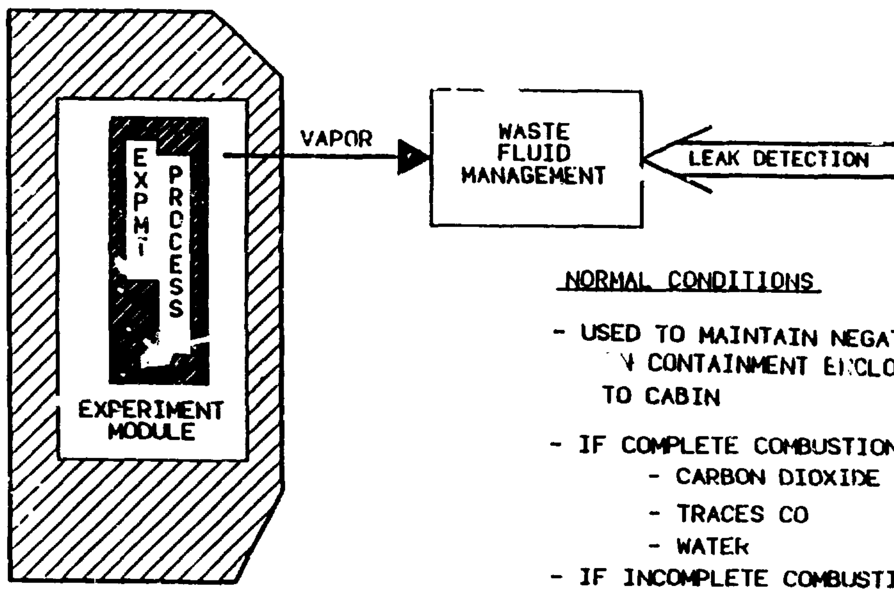
MODULAR COMBUSTION FACILITY

ULTRAPURE WATER USAGE



MODULAR COMBUSTION FACILITY

WASTE FLUIDS MANAGEMENT USAGE



NORMAL CONDITIONS

- USED TO MAINTAIN NEGATIVE PRESSURE IN CONTAINMENT ENCLOSURE RELATIVE TO CABIN
- IF COMPLETE COMBUSTION GET:
  - CARBON DIOXIDE
  - TRACES CO
  - WATER
- IF INCOMPLETE COMBUSTION GET:
  - UNBURNT FUEL - (PROPANE, METHANE, ETC.)
  - SMALL PERCENT CO_2, CO & WATER
  - SOOT (CARBON)
- IN EITHER CASE
  - COULD GET EXTINGUISHANTS ADDED
    - HALONS
    - WATER
    - CO_2
  - TOXICS FORMED
    - IF TEMPERATURE HIGH ENOUGH
    - NITROGEN & SULFUR COMPOUNDS
    - ADDITIONAL STUDY REQD

ABNORMAL CONDITIONS - (EXAMPLE, NO IGNITION)

- UNBURNT FUELS - (PROPANE, METHANE, ETC.)

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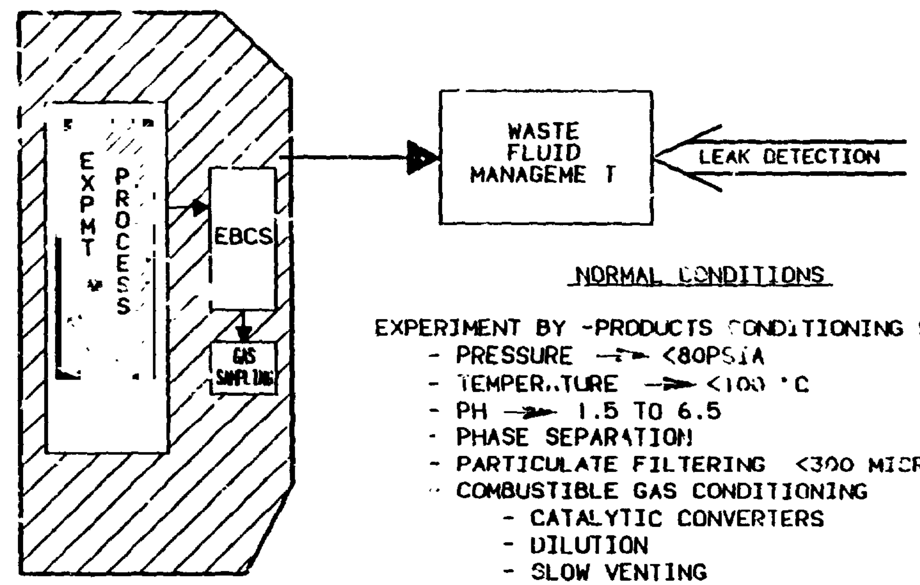
CONCEPT DESIGN



NORMAL CONDITIONS

EXPERIMENT BY-PRODUCTS CONDITIONING SYSTEMS
- PRESSURE → <80PSIA
- TEMPERATURE → <100 °C
- PH → 1.5 TO 6.5
- PHASE SEPARATION
- PARTICULATE FILTERING <300 MICRONS
- COMBUSTIBLE GAS CONDITIONING
  - CATALYTIC CONVERTERS
  - DILUTION
  - SLOW VENTING

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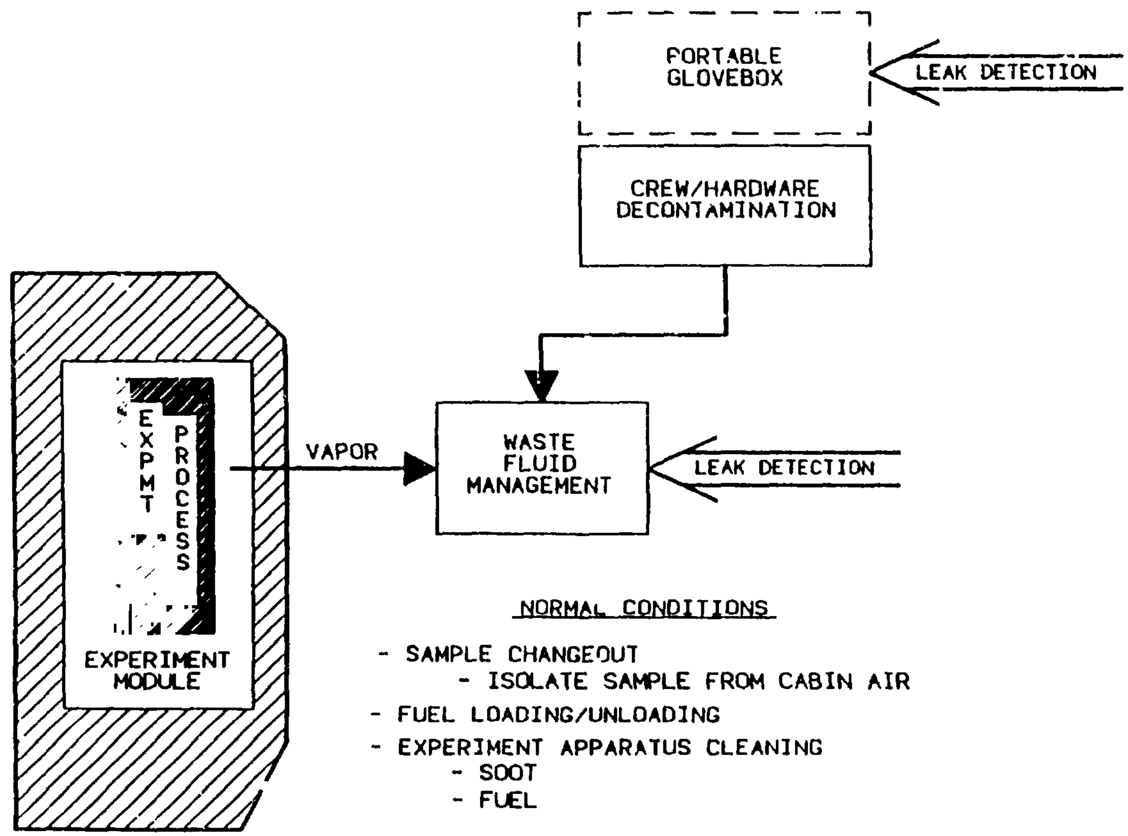
MODULAR COMBUSTION FACILITY

"PORTABLE GLOVEBOX USES"



NORMAL CONDITIONS

- SAMPLE CHANGEOUT
  - ISOLATE SAMPLE FROM CABIN AIR
- FUEL LOADING/UNLOADING
- EXPERIMENT APPARATUS CLEANING
  - SOOT
  - FUEL

ABNORMAL CONDITIONS

- MAJOR CLEANUP
- POSSIBLE APPARATUS CHANGEOUT

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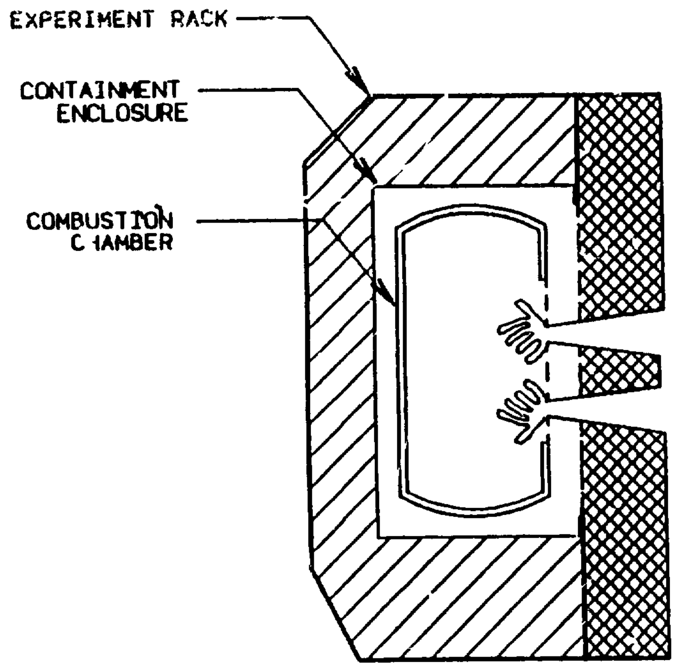
MODULAR COMBUSTION FACILITY

(EARLY CONCEPTS FOR PORTABLE GLOVEBOX USES)

CONCEPT I FIXED FORM STANDARD ATTACHMENT TO ENTIRE RACK



POSTIVE FEATURES

- STANDARD INTERFACE TO ALL RACKS

NEGATIVE FEATURES

- DOES NOT ISOLATE CONTAINMENT ENCLOSURE FROM REST OF RACK
- DIFFCULT PROBLEM WITH CONTAINMENT ENCLOSURE & CHAMBER ACCESS DOOR
- MAY BE UNABLE TO REACH ALL PARTS OF CHAMBER

POSSIBLE STUDY AREAS

- FREE FORM GLOVEBOX
- DISPOSAL GLOVEBOX
- ADAPTERS

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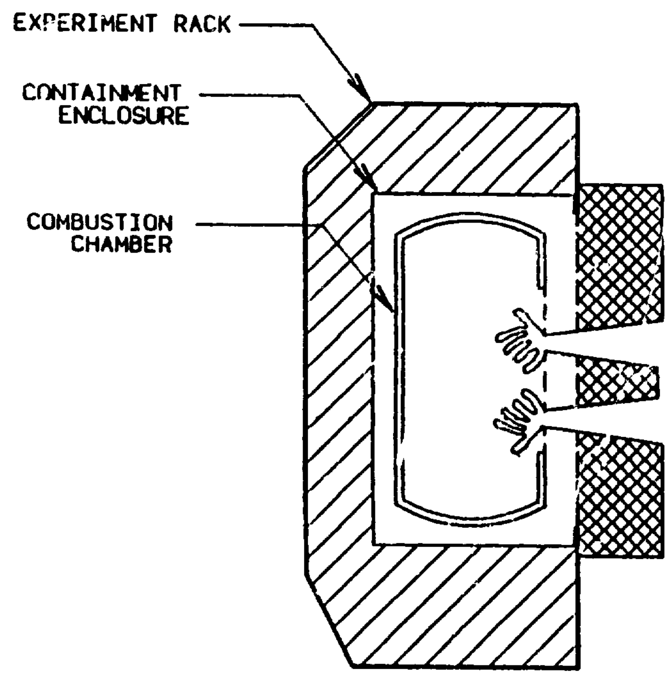
MODULAR COMBUSTION FACILITY

(EARLY CONCEPTS FOR PORTABLE GLOVEBOX USES)

CONCEPT II FIXED FORM ATTACHMENT TO USER'S CONTAINMENT ENCLOUSURE



POSITIVE FEATURES

- FLAT FIXED ATTACHMENT SURFACE

NEGATIVE FEATURES

- DOES NOT ISOLATE CONTAINMENT ENCLOSURE FROM CHAMBER
- DIFFCULT PROBLEM WITH CONTAINMENT ENCLOSURE & CHAMBER ACCESS DOORS
- MAY BE UNABLE TO REACH ALL PARTS OF CHAMBER

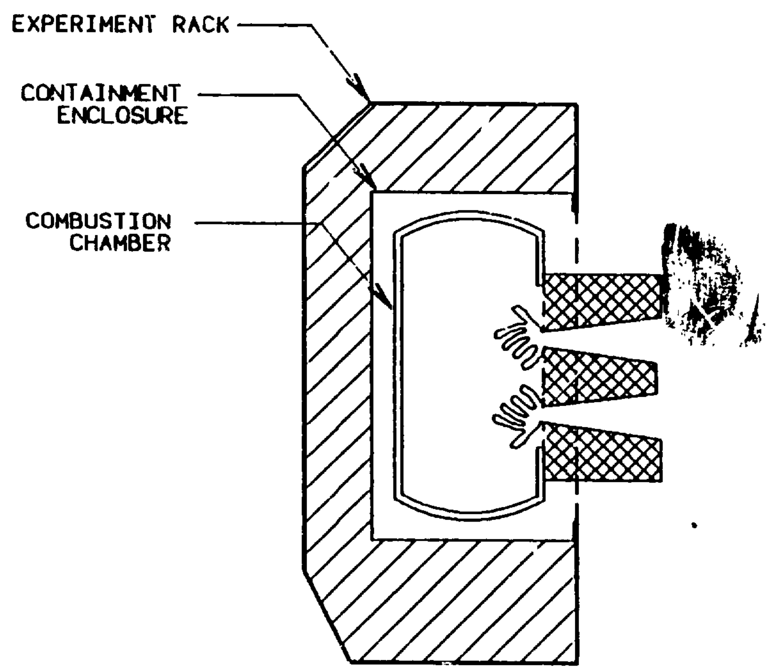
POSSIBLE STUDY AREAS

- FREE FORM GLOVEBOX
- DISPOSAL GLOVEBOX
- ADAPTER

MODULAR COMBUSTION FACILITY

(EARLY CONCEPTS FOR PORTABLE GLOVEBOX USES)

CONCEPT III FIXED FORM ATTACHMENT TO USER'S CHAMBER



POSTIVE FEATURES

- SMALLER
- ISOLATES CHAMBER

NEGATIVE FEATURES

- ROUND VARIABLE ATTACHMENT SURFACE
- DIFFICULT PROBLEM WITH CHAMBER ACCESS DOOR
- BETTER- BUT REACHING BACK OF CHAMBER MAY BE A PROBLEM

POSSIBLE STUDY AREAS

- FREE FORM GLOVEBOX
- DISPOSAL GLOVEBOX

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MICROGRAVITY EXPERIMENT FACILITY STUDY TEAM

LEWIS RESEARCH CENTER
CLEVELAND, OHIO

MODULAR COMBUSTION FACILITY

ISSUES AND CONCERNS

- MULTI-RACK FACILITY - INTER-RACK CONNECTIONS
- CONTAINMENT
- PMMS AVAILABILITY
- USL SUPPLIED FLUIDS
- EMERGENCY/CREW RESPONSE, ETC.
- PORTABLE GLOVEBOX
- USER INTERFACE WITH WP-01
- TECHNOLOGY DEVELOPMENT OF SYSTEMS
- COMPATIBILITY WITH JEM , COLUMBUS & CDSF

SPACE STATION
TOXIC AND REACTIVE MATERIALS HANDLING WORKSHOP

HUNTSVILLE, ALABAMA
NOV 29, 30 & DEC 1, 1988

OVERVIEW OF FLUID PHYSICS/DYNAMICS FACILITY

NASA

LEWIS RESEARCH CENTER
CLEVELAND, OHIO

ENGINEERING DIRECTORATE P.M. : RON CHUCKSA
SPACE EXPERIMENTS DIV P.M. : BOB THOMPSON
FACILITY PROJECT SCIENTIST : JACK SALZMAN
STUDY TEAM MEMBER (PMMS) : DON PERDUE

FLUID PHYSICS/DYNAMICS FACILITY

OBJECTIVE: DEVELOP A MODULAR, MULTIUSER MICROGRAVITY SCIENCE FACILITY ,FOR USE BY THE FLUID/DYNAMICS SCIENCE COMMUNITY ON BOARD THE SPACE STATION FREEDOM LABORATORY

CURRENT EFFORT: DEFINITION-STUDY & CONCEPTUAL DESIGN

APPROACH:

- START WITH A REPRESENTATIVE LIST OF POTENTIAL MICROGRAVITY SCIENCE EXPERIMENTS FOR FLUIDS OVER A BROAD RANGE OF CONDITIONS/REQUIREMENTS
- WORK WITH REPRESENTATIVES OF EACH OF THESE POTENTIAL EXPERIMENTS TO DETERMINE REQUIREMENTS
- GENERATE PRELIMINARY CONCEPTUAL SCHEMATIC DIAGRAM FOR EACH POTENTIAL EXPERIMENT AS IT MIGHT EXIST IN THE USL ENVIRONMENT
- GENERATE A DATABASE OF EXPERIMENTAL REQUIREMENTS
- EXTRACT COMMON SYSTEMS TO FORM THE BASIS FOR A HOST FACILITY
- MERGE COMMON SYSTEMS REQUIREMENTS WITH KNOWN SPACE STATION REQUIREMENTS/CAPABILITIES TO FORM A HOST FACILITY

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FLUID PHYSICS/DYNAMICS FACILITY

REFERENCE EXPERIMENT SETS

[F01A]	SURFACE TENSION INDUCED INSTABILITIES AND FLOW	CHAI - LeRc
[F01B]	SURFACE TENSION DRIVEN CONVECTION	PLINE - LeRc
[F02]	FREE SURFACE PHENOMENA	CHAI - LeRc
[F03]	IMMERSED BUBBLE/DROPLET DYNAMICS AND INTERACTIONS	BALA - LeRc
[F04]	THERMAL AND DOUBLE-DIFFUSIVE NATURAL CONVECTION	KASSEMI - LeRc
[F05]	MULTIPHASE FLOW	McQUILLEN - LeRc
[F06]	FIRST ORDER PHASE TRANSITIONS	CHIARAMONTE - LeRc
[F14]	CHEMICAL VAPOR DEPOSITION (CVD)	CLARK - LaRc
[F16]	THERMAL GRADIENT EFFECTS ON ENTRY FLOW DEVELOPMENT	CLARK - LaRc
[F17]	QUANIFICATION OF FLUID PHENOMENA THAT OCCUR DURING SOLIDIFICATION	McCAY - UTSI/MSFC
[F18]	FLUIDS MIXTURES HEAT AND MASS TRANSFER	GIARRATANO - NBS

REVISED 16 NOV 86

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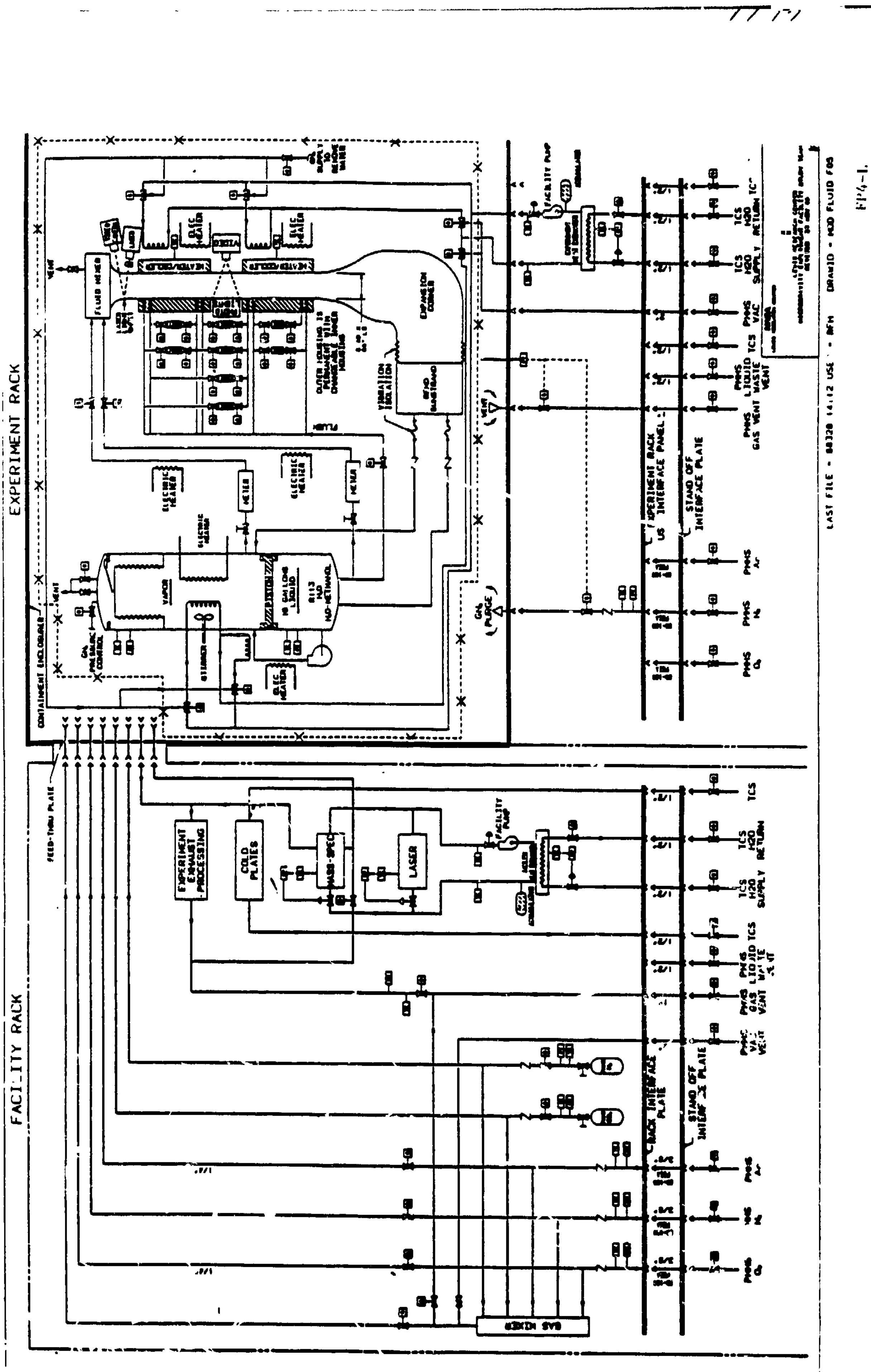

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FLUID PHYSICS/DYNAMICS FACILITY

PRESENT FACILITY CONCEPTS

- NOW REVIEWING EXPERIMENTAL REQUIREMENTS AND JUST STARTING CONCEPT DESIGN

- MODULAR CONCEPT

- TWO RACK FACILITY
  - PERMANENT FACILITY RACK
  - INTERCHANGEABLE EXPERIMENT RACK

- FACILITY RACK
  - INTERFACE BETWEEN USL & EXPERIMENT
  - HOUSES SUPPORT SYSTEMS
    - POWER CONVERSION & DISTRIBUTION SYSTEM
    - DATA ACQUISITION & CONTROL COMPUTER SYSTEM
    - LASER DIAGNOSTIC SUPPORT SYSTEM
    - HIGH RESOLUTION HIGH FRAME RATE VIDEO SUPPORT SYSTEM
    - MASS SPECTROMETER
    - SAFETY SYSTEMS
    - OPERATOR INTERFACE PANEL

- EXPERIMENT RACK
  - RACK INTEGRATED ON GROUND
  - POSSIBLE CHANGE-OUT EVERY 12 TO 18 MONTHS
  - HOUSES CONTAINMENT ENCLOSURE
  - VARIOUS EXPERIMENT MODULES
    - MULTI-PHASE FLOW LOOP

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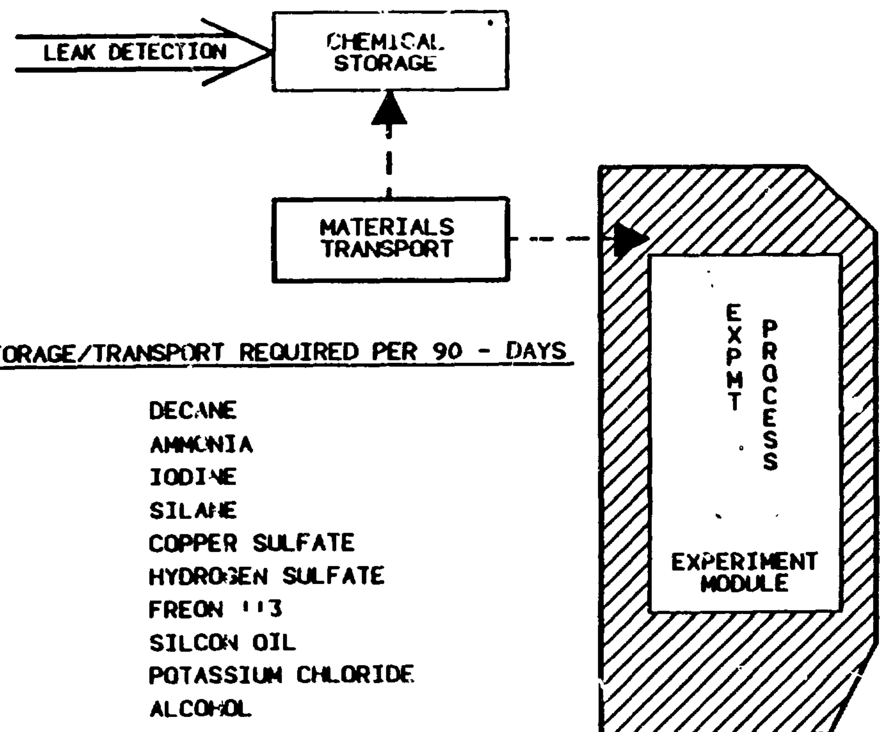
FLUID PHYSICS/DYNAMICS FACILITY

CHEMICAL STORAGE & MATERIALS TRANSPORTS USAGES



STORAGE/TRANSPORT REQUIRED PER 90 - DAYS

DECANE
AMMONIA
IODINE
SILANE
COPPER SULFATE
HYDROGEN SULFATE
FREON 113
SILCON OIL
POTASSIUM CHLORIDE
ALCOHOL
METHONOL

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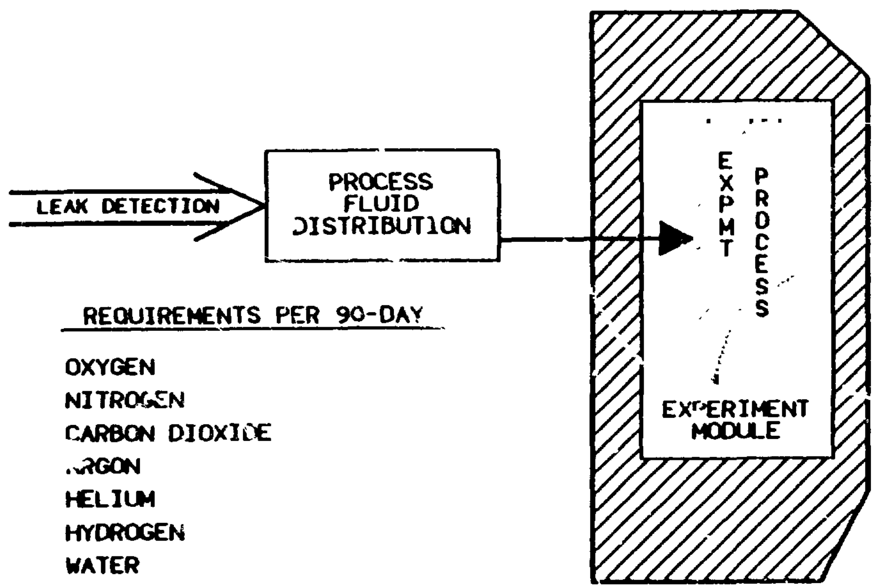
FLUID PHYSICS/DYNAMICS FACILITY

USL SUPPLIED CONSUMMABLES USAGE



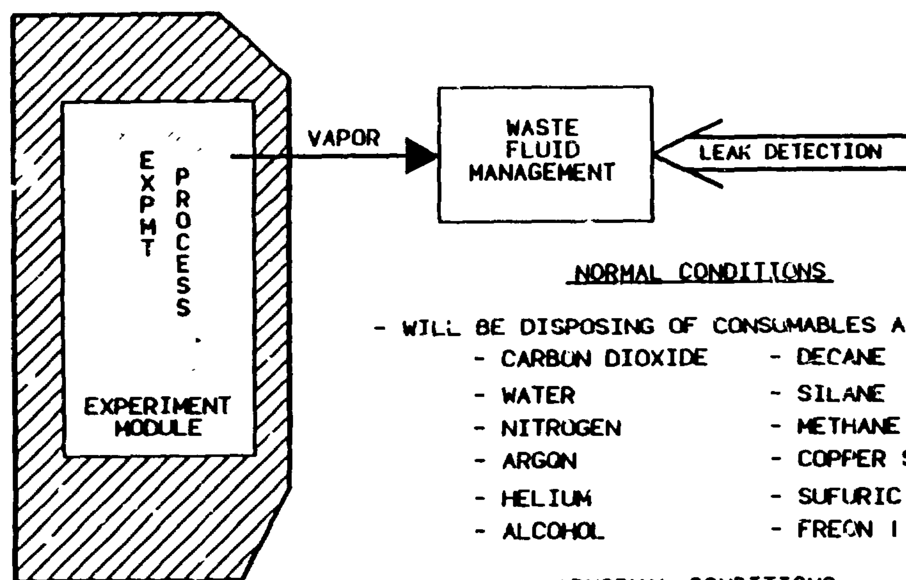
REQUIREMENTS PER 90-DAY

OXYGEN
NITROGEN
CARBON DIOXIDE
ARGON
HELIUM
HYDROGEN
WATER

- AMOUNTS WILL BE IN DATABASE

FLUID PHYSICS/DYNAMICS FACILITY

WASTE FLUIDS MANAGEMENT USAGE



NORMAL CONDITIONS

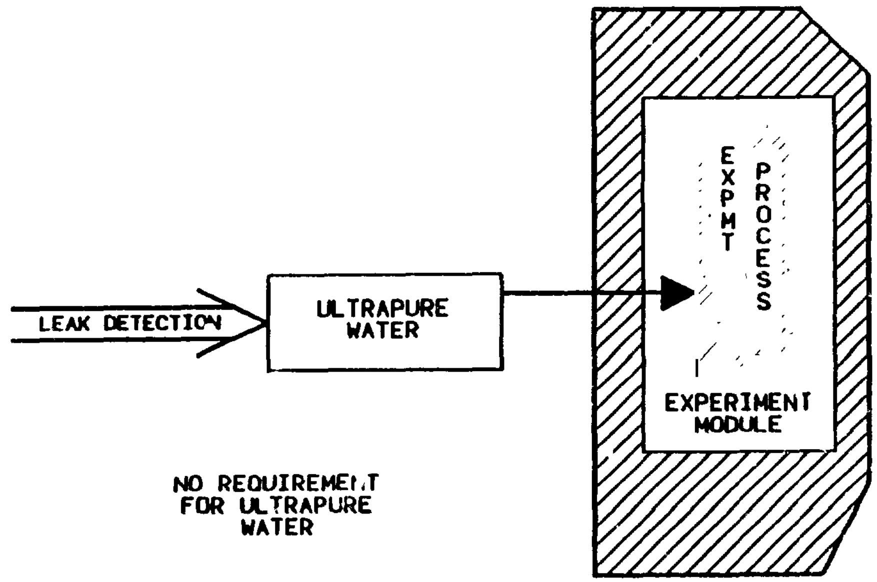
- WILL BE DISPOSING OF CONSUMABLES AT END OF EACH RUN:
  - CARBON DIOXIDE
  - WATER
  - NITROGEN
  - ARGON
  - HELIUM
  - ALCOHOL
  - DECANE
  - SILANE
  - METHANE
  - COPPER SULFATE
  - SUFURIC ACID
  - FREON 113

ABNORMAL CONDITIONS

- IF A SEALED CELL WERE TO LEAK
  - AMMONIA CHLORIDE
  - IODINE
  - SILCON OIL
- AMOUNTS WILL BE IN DATABASE

FLUID PHYSICS/DYNAMICS FACILITY

ULTRAPURE WATER USAGE



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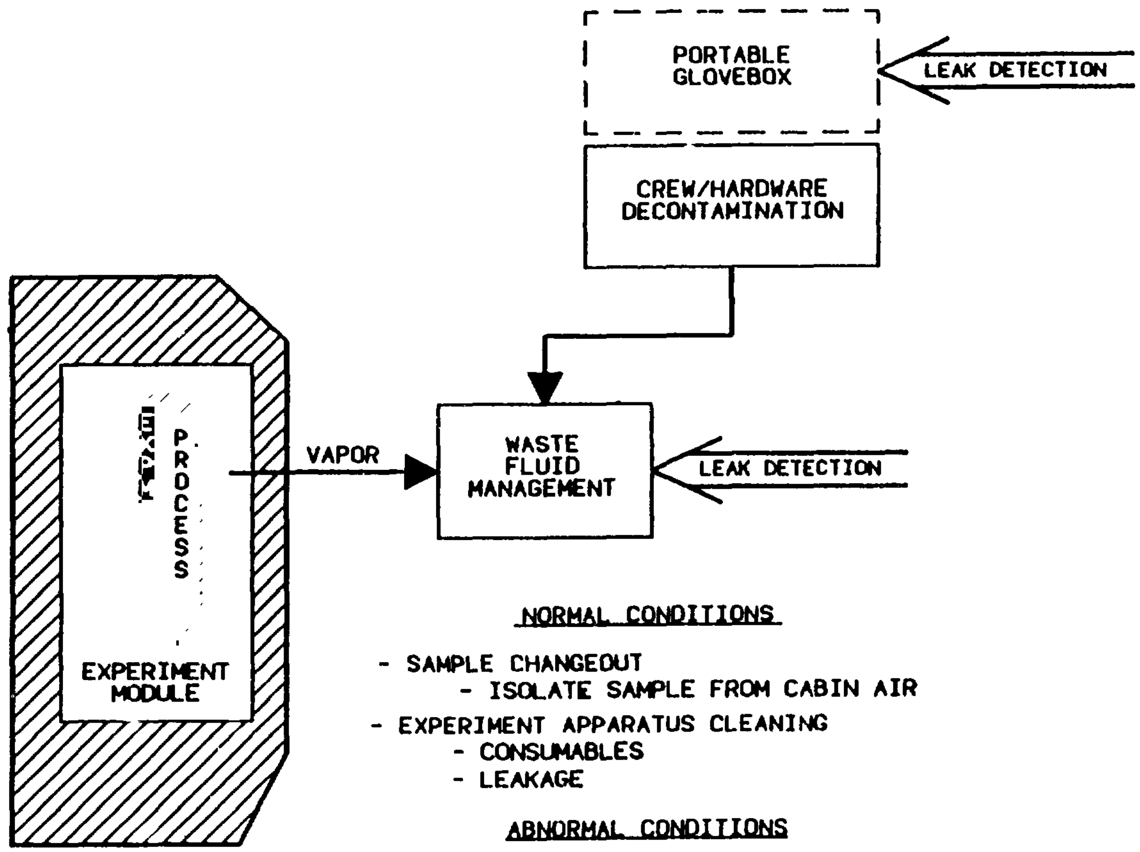
FLUID PHYSICS/DYNAMICS FACILITY

"PORTABLE GLOVEBOX USES"



NORMAL CONDITIONS

- SAMPLE CHANGEOUT
  - ISOLATE SAMPLE FROM CABIN AIR
- EXPERIMENT APPARATUS CLEANING
  - CONSUMABLES
  - LEAKAGE

ABNORMAL CONDITIONS

- MAJOR CLEANUP
- POSSIBLE APPARATUS CHANGEOUT

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MICROGRAVITY EXPERIMENT FACILITY STUDY TEAM

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CLEVELAND, OHIO

ADVANCED PROTEIN CRYSTAL GROWTH

Robert S. Snyder
Space Science Laboratory
Marshall Space Flight Center

ADVANCED PROTEIN CRYSTAL GROWTH FACILITY (APCGF)

OBJECTIVES:

Grow large, high-quality crystals of proteins and other biological materials for use in studies of molecular structure

Analyze crystals in space by high resolution optical techniques and x-ray diffraction (as an optimum goal)

Investigate the kinetics of protein crystallization from solution by incorporating experiment diagnostics into the APCGF

CHARACTERISTICS OF PROTEIN CRYSTALS

- Small size 0.5 mm
- 30 to 80% solvent
- Few intermolecular contacts - mechanically unstable
- Sensitive to temperature changes
- Sensitive to pH changes
- Sensitive to solvent loss or changes in solvent composition
- Weak to moderate diffraction observed
- Sensitive to x-rays
- Finite lifetimes

PCG DEVELOPMENT

Most protein crystals are grown by variations of the hanging drop method

Handheld PCG space apparatus esssentially duplicates this laboratory's vapor diffusion apparatus

Deficiencies of experiment in space include:

- Uncertain initial conditions of experiment
- Unpredictable protein crystal growth operations and environment in space
- Relatively short growth time
- Delay in collecting and analyzing crystals

PRESENT PCG REQUIREMENTS

- Load samples onboard within 24 hours of launch
- Provide a method of carrying proteins and growth initiator separately, and observing deployment and mixing of each as required
- Initiate crystallization as soon as possible after reaching orbit.
- Maintain low gravity conditions to prevent droplet loss and optimum crystal growth conditions
- Maintain constant temperature ($4^{o}C$ or $22^{o}C$)
- Limit temperature excursions $\pm$ 0.5 degrees C
- Provide manned access for operation and monitoring
- Carry as many samples as possible (60 or more)
- Retract sample into syringe as late as possible before re-entry
- Remove from orbiter within approximately 2 hours after landing

FLIGHTS OF HANDHELD PCG EXPERIMENTS

o	STS 51-D	April 1985
o	STS 51-F	July 1985
o	STS 61-B	November 1985
o	STS 61-C	January 1986

FLIGHTS OF PCG EXPERIMENTS WITH GANGED DEPLOYMENT

o	STS-26	September 1988
O	STS-29	February 1989

<u>TRANSITION FROM HANDHELD TO PRESENT GANGED MECHANISM</u>

New flight hardware incorporates:

- Initial stages of automation of experiment operation
- Accommodation in constant temperature flight enclosures
- Control of nucleation and growth based upon extensive laboratory research and testing
- In-flight crystal growth analysis by photography

PROTEIN CRYSTAL GROWTH EXPERIMENTS ON THE SPACE STATION

- o Requests for protein crystals grown in space exceed our capability to process them

- o Protein crystal growth is a dynamic flight program

  - Present flight experiments are flexible to stay ahead of the technology development on Earth

  - The dominant processes controlling protein crystallization are not known

  - Although hardwarse and operations are evolving as we gather information, basic facilities can bae outlined

- o Space Station should provide the laboratory for preparing the protein solutions and analyzing the grown crystals by x-ray diffraction

EXPERIMENT PLAN FOR SPACE STATION

- Protein samples will be prepared on orbit
  - Most proteins will be carried to orbit as frozen pellets or lyophillized
  - Mixing proteins with buffers, precipitants, etc., will be done at experiment initiation
- Protein Crystal Growth facility will incorporate techniques such as:
  - Vapor Diffusion
  - Liquid-Liquid Diffusion
  - Dialysis
  - "Containerless"
  - Epitaxy
- Most isothermal experiments will be done at 4 degrees C and 22 degrees C; some experiments will require temperature gradients
- Experiment duration will extend from several days to many weeks
- Some analysis of the crystals will have to be done on orbit

UTILIZATION OF LABORATORY FACILITIES AND UTILITIES

APCGF will need:

- Controlled temperature storage for the proteins (before the experiment) and grown crystals (before analysis and/or transport)
- Glovebox for handling toxic proteins
- High resolution video of critical crystallization steps
- Facilities for analyzing crytals
  - Microscopy
  - X-ray Diffraction

TOXIC AND REACTIVE MATERIALS

Many proteins of interest are toxic, e.g., scorpion toxin and sea anemone toxin flown on STS-51D

Quantities required for growing crystals are small (less than 1 milligram per 40 microliter drop)

Handling requirements will depend on facility and operations selected for the Space Station

CONCLUSIONS

Protein Crystal Growth on the Space Station will involve handling of fluids, some containing toxic proteins

Robotic systems are available for multiple samples in the laboratory but goal of these systems is control over repetitive operations not limitation of toxic material handling

Telescience can be designed and developed to monitor and transfer proteins from solution to growth to analysis

System flexibility must be retained, however, as the APCG Science Working Group defines the goals, requirements and facility capabilities for the Space Station

Biotechnology Facility
and
Bioreactor Sterilization

Presented at:

Space Station Freedom
Toxic and Reactive Materials Handling Workshop

Nov. 1988

William H. Bowie M.S.
Krug International
(presenter)

and

Steve R. Gonda Ph.D.
NASA / JSC

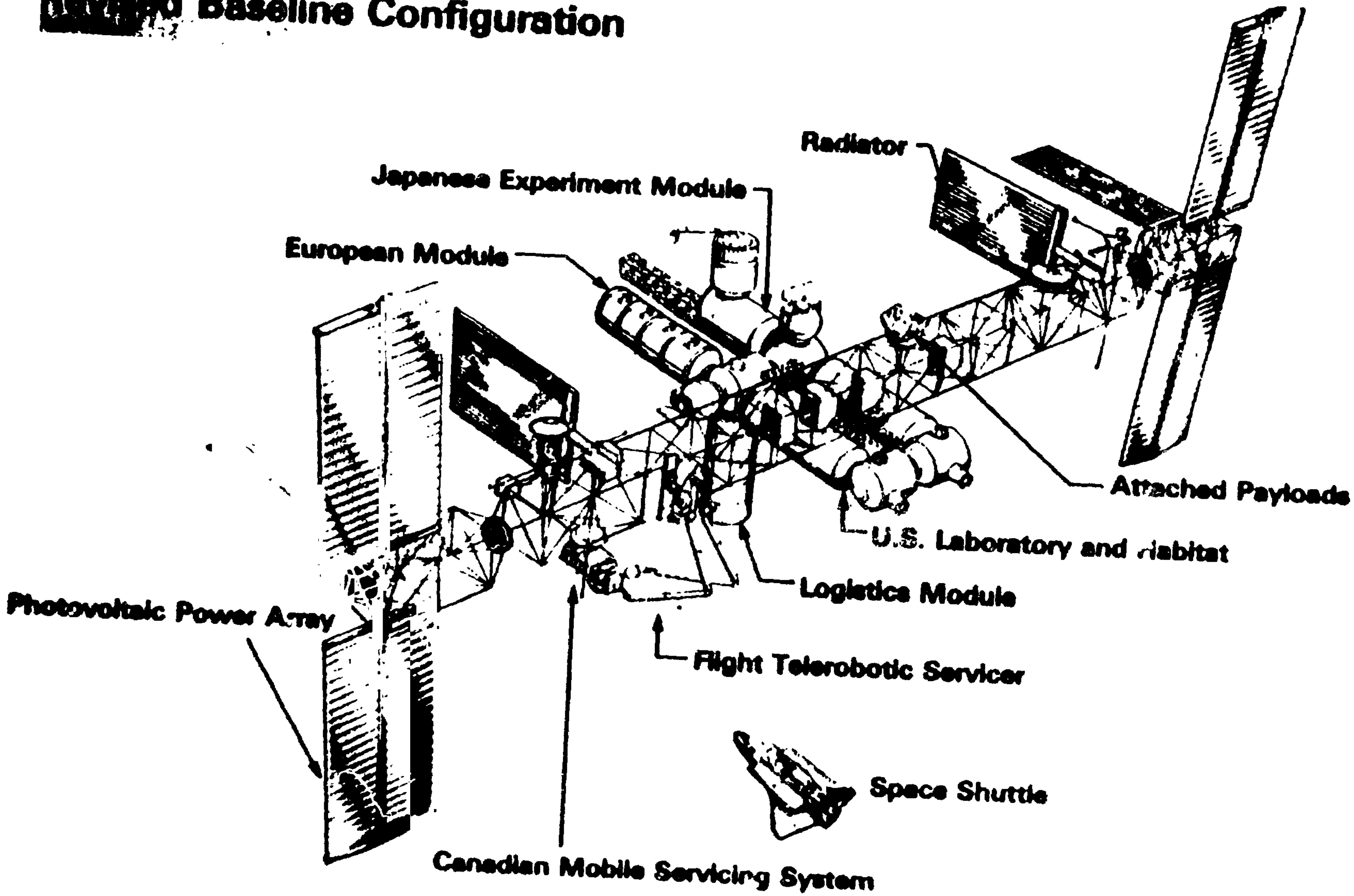
SPACE & LIFE SCIENCES

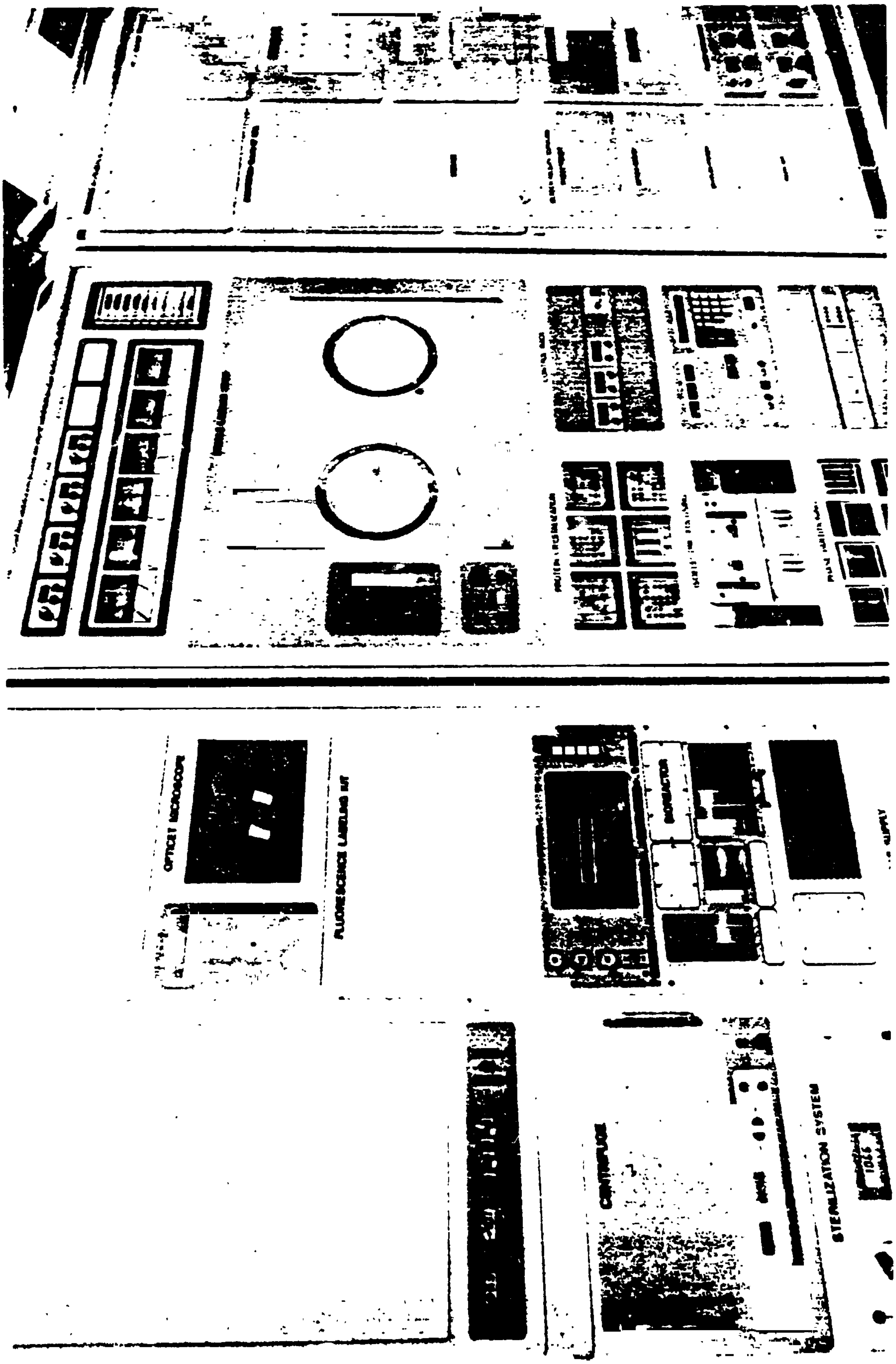
JSC

National Aeronautics and
Space Administration

Lyndon B. Johnson Space Center
Houston, Texas

Revised Baseline Configuration





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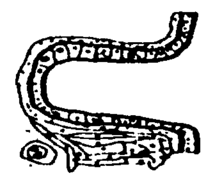
BIOREACTOR USES

BIOREACTOR SYSTEM PROVIDES

BIOLOGICALS

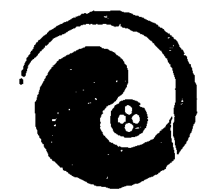
Cells and tissues



colon tissue showing crypt structure

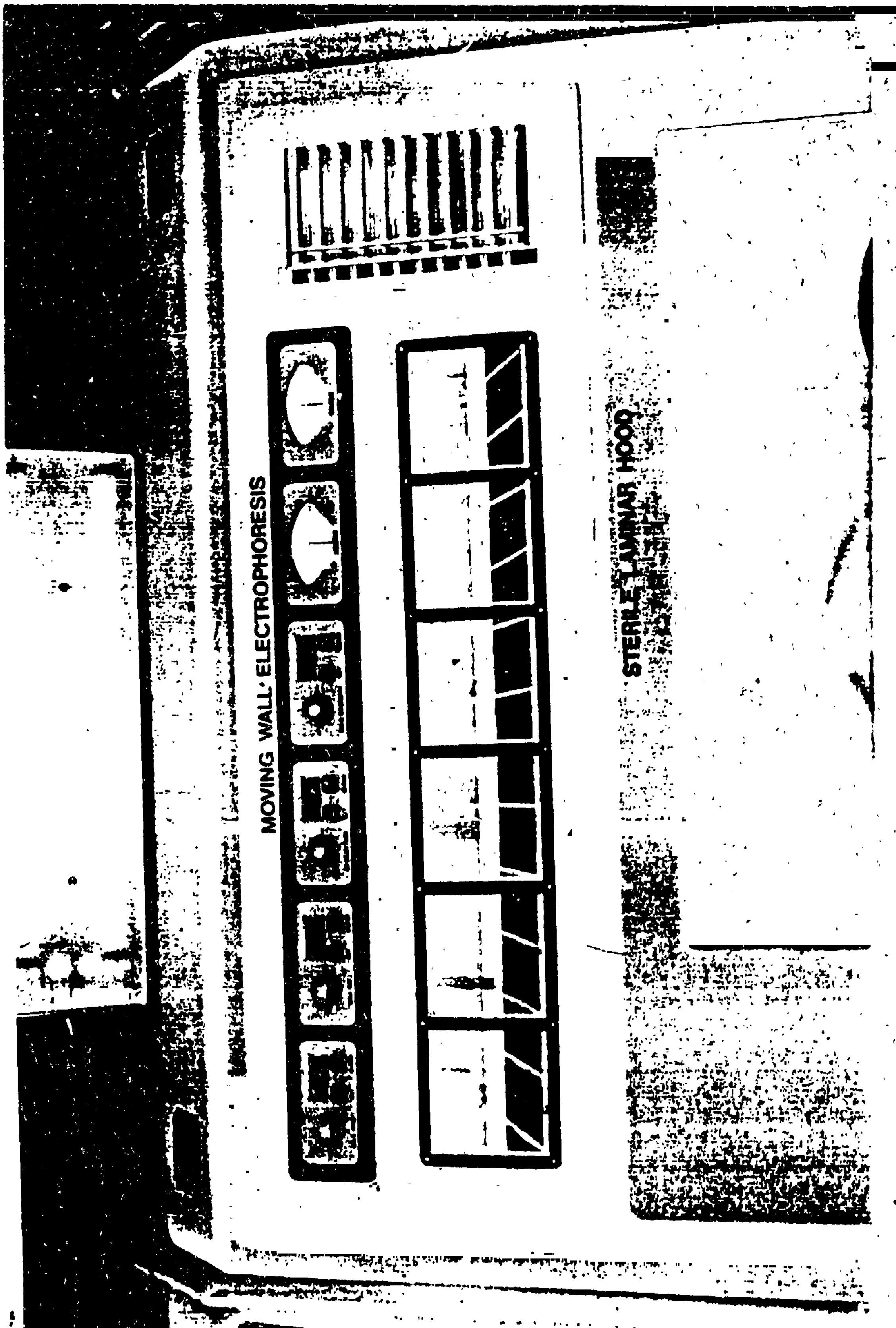
AN APPARATUS IN WHICH TO STUDY THE EFFECTS OF

Shear, turbulence, and mixing



RAW MATERIAL FOR PRODUCT EXTRACTION

Cell and Tissue secretory and excretory materials



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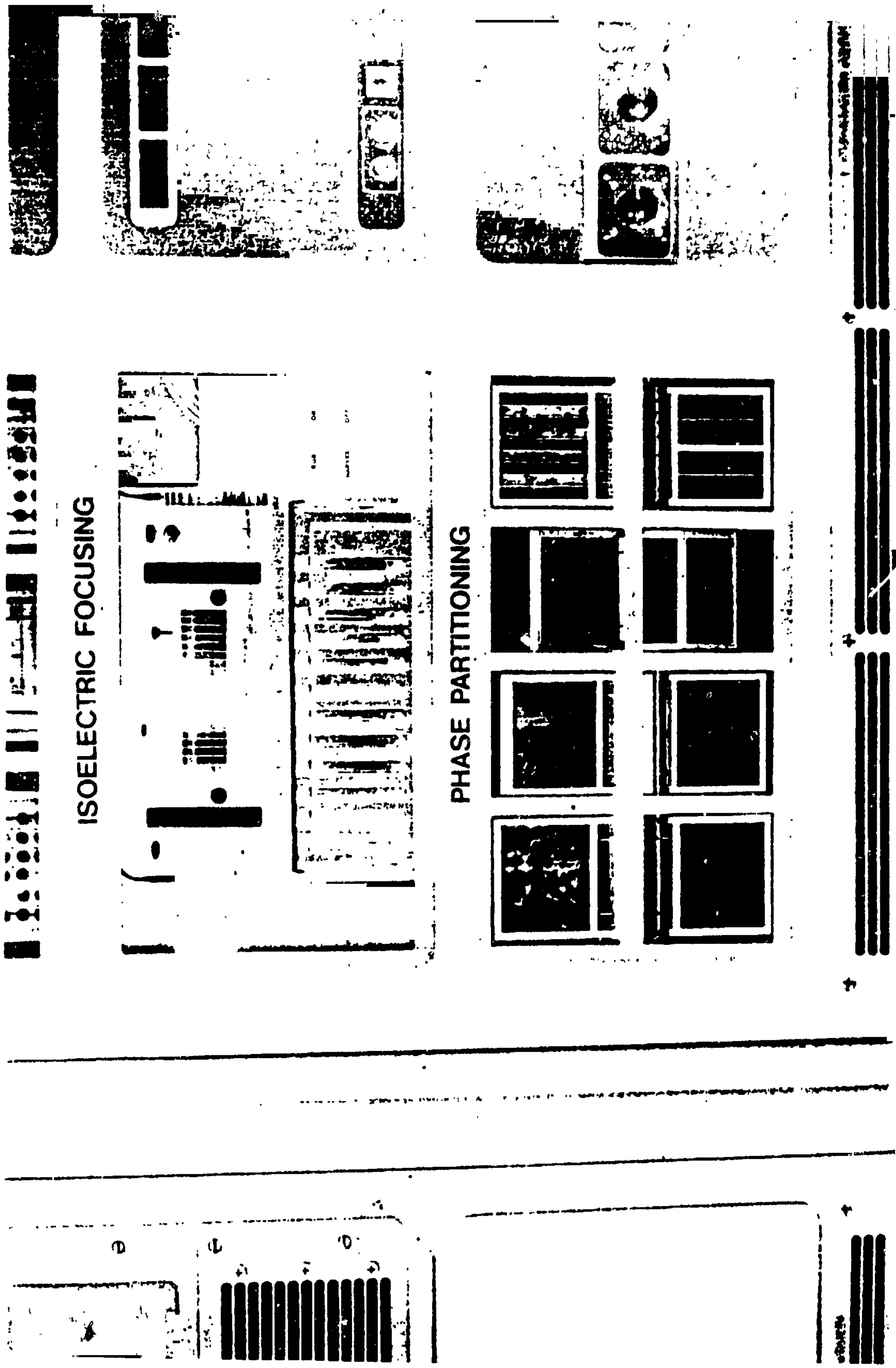

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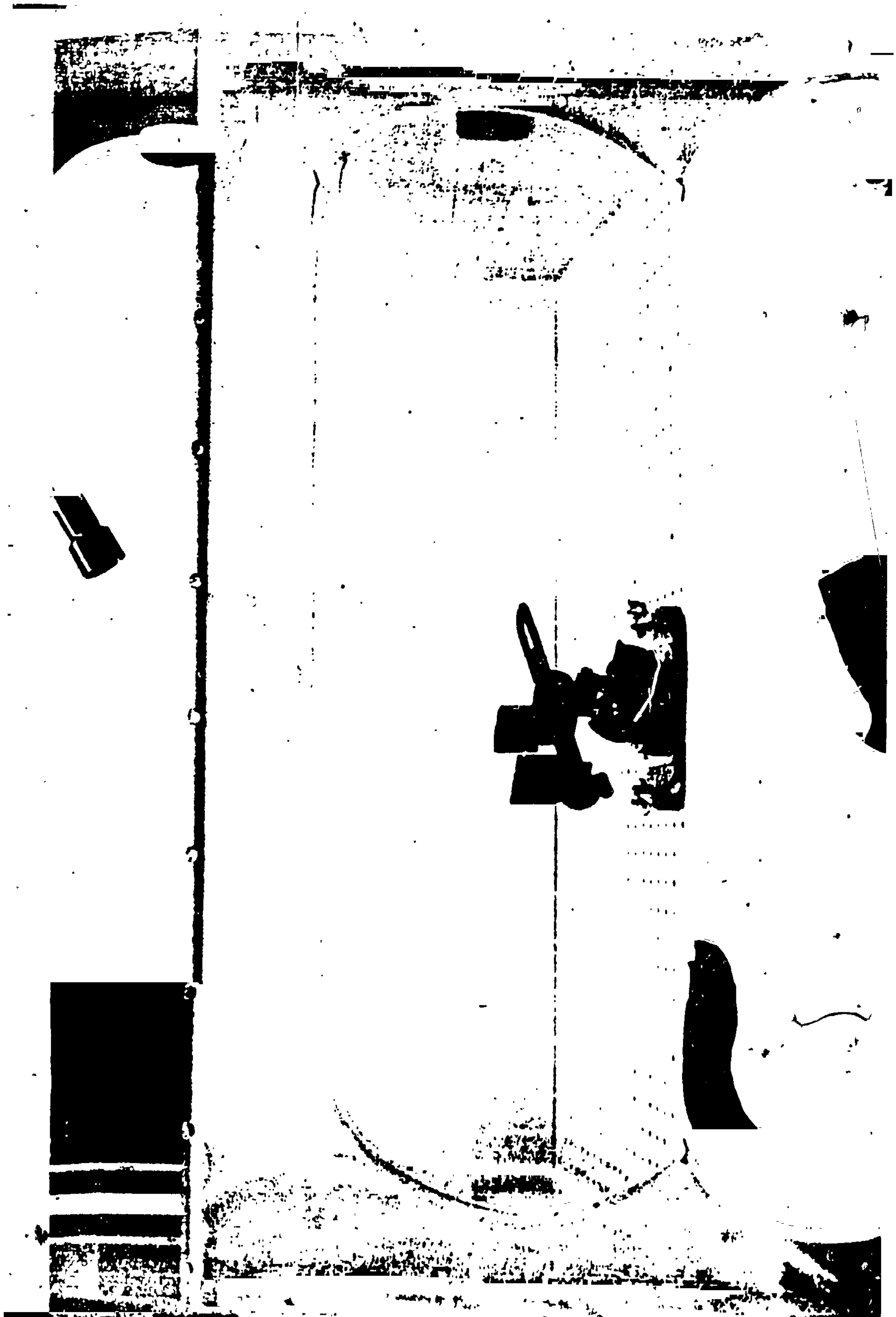

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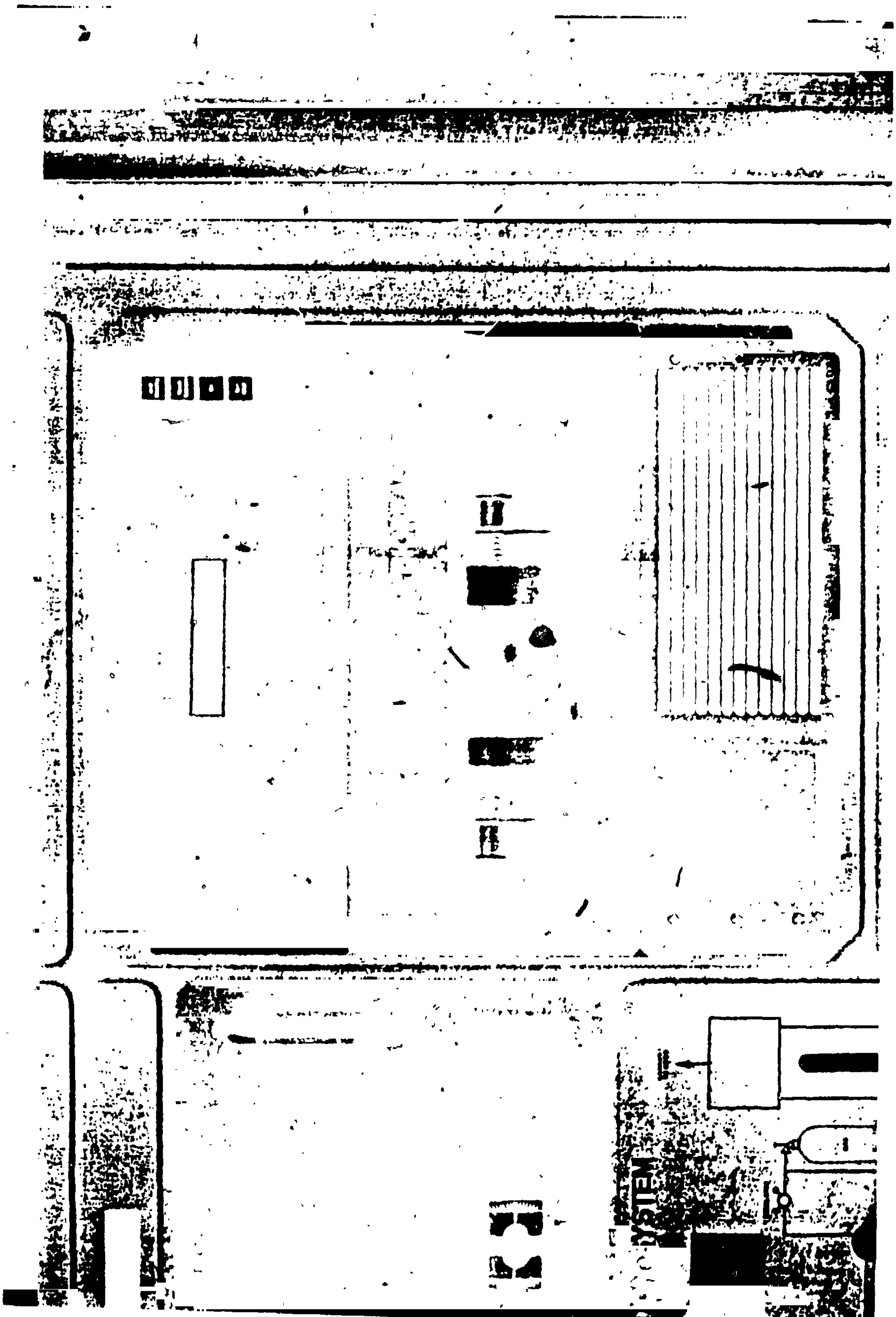

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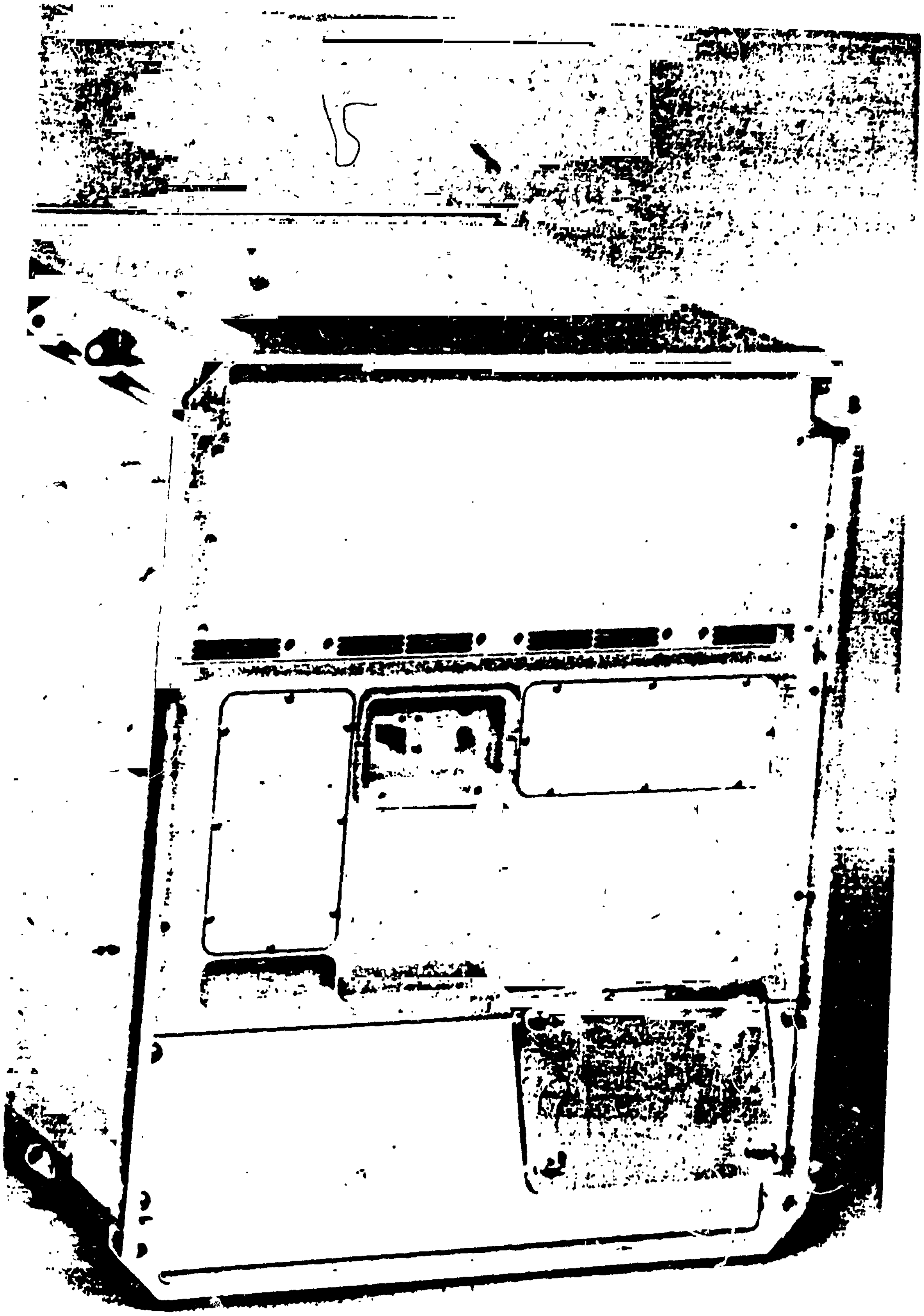

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Circumstance	Compound	SMAC	Use	Hazard
Biorack FE VC	Sulfuric ether (Diethyl ether)	242.0		Irritant, CNS depressant
Spacelab D2	Triethanolamine	10.0	buffer component	Low level irrtant and toxicity
	Dimethyl sulfoxide	200.0	carrier	Mild resp irritant
Refrigeration	Freon R-502	100.0 ppm	cooling	displace cmpds from scrubber
Fixative VC	glutaraldehyde	0.2 - 0.4	tissue processing	rritant
	Formaldehyde	0.1 - 0.12	tissue processing	Irritant
Batteries	dimethyl sulfite	1.0	electrolyte	
	arsenate	0.002		
	Terechlorate (ClO_2)	0.083		Irritant
	Molecular iodine	0.1		Irritant, pulmonary edema
CR	Ag_2CrO_4	0.03		Corrosive
Sterilants, disinfectants	Alcide A (ClO_2)	0.03 ppm	CFES	
	(Cl_2)	0.03 ppm	CFES	Toxic irritant
	Ethylene oxide	0.2 ppm	Floreactor	carcinogen
	Glutaraldehyde			Irritant
Acids CR	Acetic acid	7.4	tissue processing	Irritant, chemical burns
	Phosphoric acid	[illegible]		Irritant
	Sodium Cacodylate (dimethyl asrsenic acid sodium salt)	0.18	tissue processing	
	Propionic		CFES	
Metals	arsenic	0.1	Tissue processing	
Stains	methylene blue		RBC fix stain	
	OsO_4	0.0004	tissue processing	Irritant, stain [illegible]
Alcohols FE	ethanol	940	Tissue processing	
VC	Butanol	121.0	Phase partitioning	
Metabolic studies R	^3H-uridine	1000 u Ci		carcinogen
R	^{14}C-thymidine	100 u Ci		carcinogen
	colchinin (colchicine)	0.5 (fine mist)		Mild eye irritant
Electrophoresis	Urea		CFES	
	diethanolamine	5.0	CFES	skin, eye irritant
	Sodium azide		perservative	irritant, lower BP, headache
Others	$AgNO_3$	0.008		
	potassium oxalate		RBC fix stain	
	potassium cyanide		RBC fix stain	

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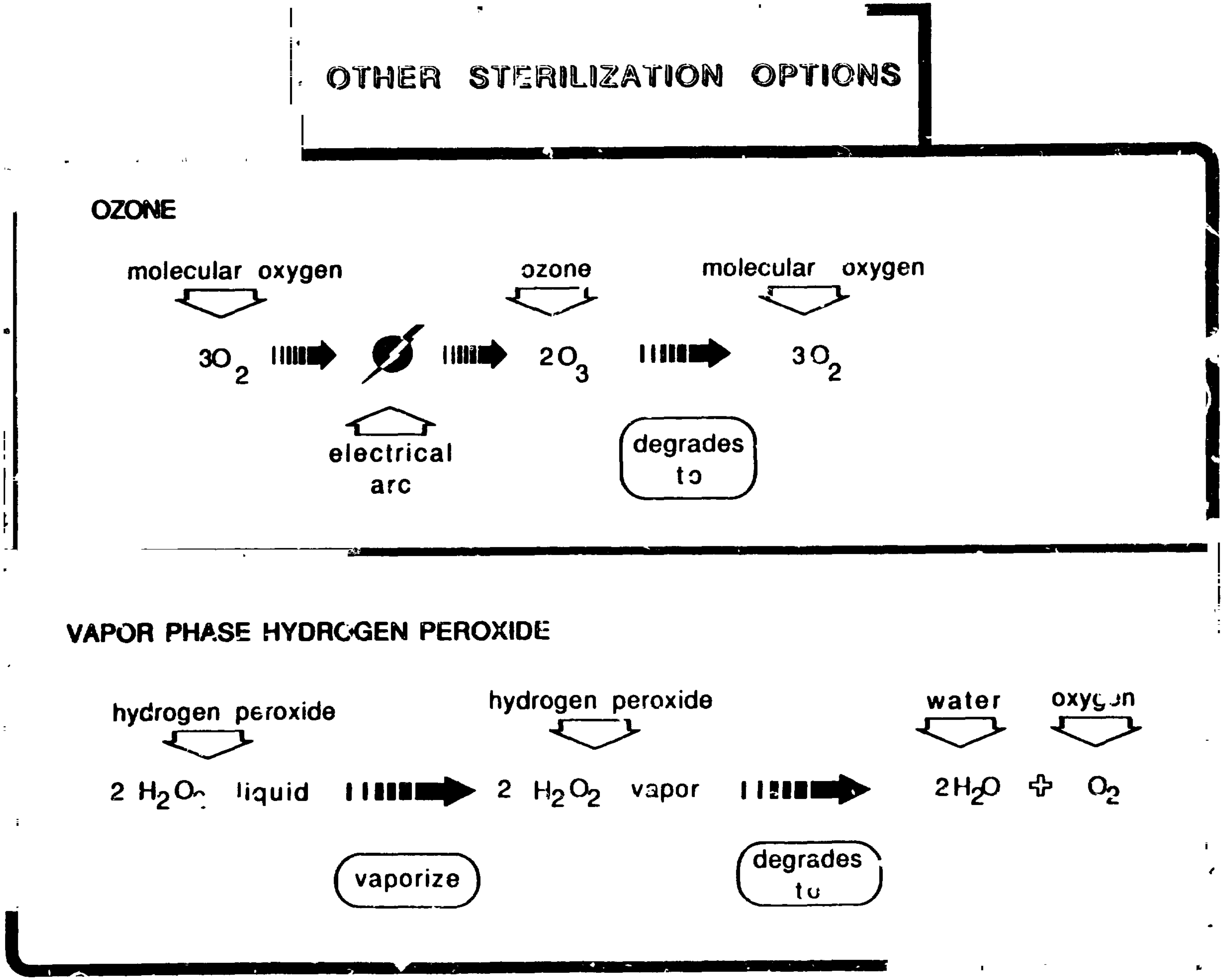
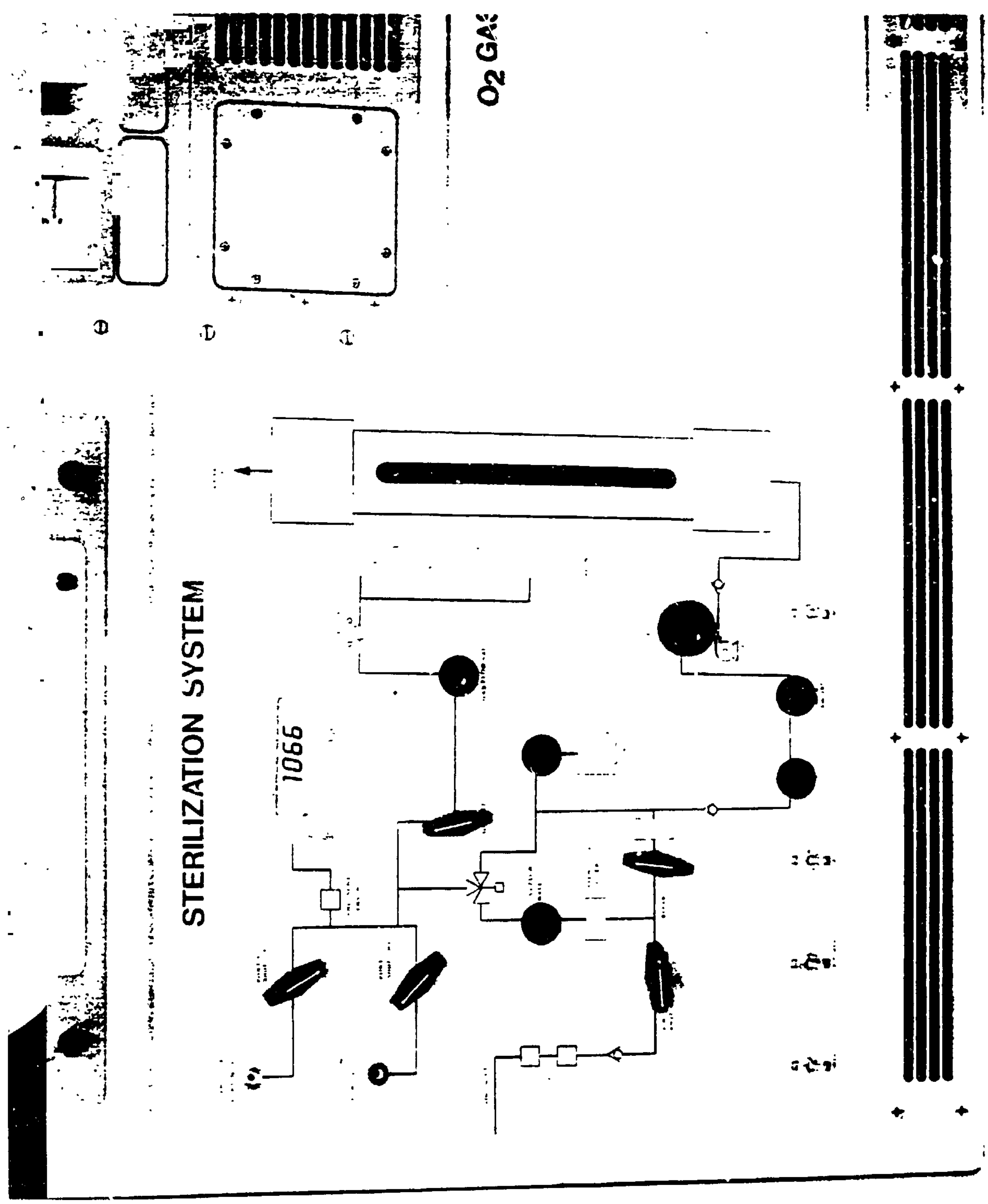

OTHER STERILIZATION OPTIONS
OZONE
molecular oxygen
$3O_2$
electrical arc
ozone
$2O_3$
degrades to
molecular oxygen
$3O_2$
VAPOR PHASE HYDROGEN PEROXIDE
hydrogen peroxide
$2\ H_2O_2$ liquid
vaporize
hydrogen peroxide
$2\ H_2O_2$ vapor
degrades to
water
oxygen
$2H_2O + O_2$



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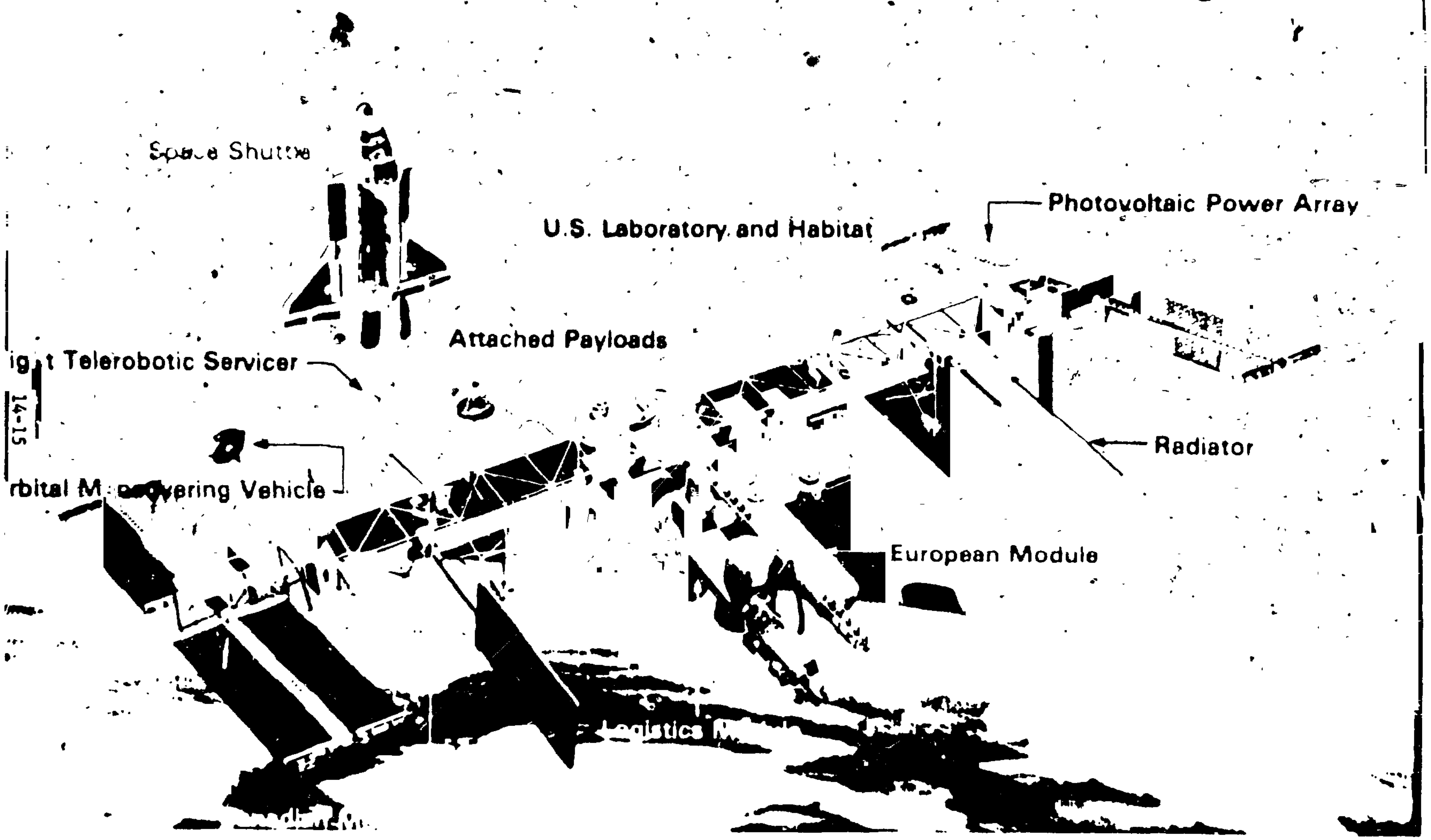
Revised Baseline Configuration



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TOXIC AND REACTIVE MATERIALS HANDLING WORKSHOP

NON-HUMAN LIFE SCIENCE PAYLOADS

CONDUCTED IN THE

1.8 METER CENTRIFUGE FACILITY

CATHERINE C. JOHNSON
BIOLOGICAL RESEARCH PROJECT OFFICE
NASA/AMES RESEARCH CENTER
MOFFETT FIELD, CALIFORNIA
NOVEMBER 29, 1988

OUTLINE

- 1.8 M CENTRIFUGE FACILITY
- OPERATIONS
- INTERFACES
- ISSUES
- RECOMMENDATIONS
- SUMMARY

1.8 M CENTRIFUGE FACILITY

- 1.8 METER CENTRIFUGE
- ZERO-G HOLDING FACILITY
- LIFE SCIENCES GLOVEBOX
- SPECIMEN CHAMBER SERVICE UNIT (SCSU)
- MODULAR HABITATS FOR CENTRIFUGE AND HOLDING FACILITY
  - PLANTS
  - RODENTS
  - SMALL PRIMATES
  - GENERAL BIOLOGY

SCIENCE DISCIPLINES

- CALCIUM HOMEOSTASIS
- CARDIOVASCULAR SYSTEM
- MUSCLE STRUCTURE AND FUNCTION
- ENDOCRINOLOGY/FLUID AND ELECTROLYTES
- HEMATOLOGY
- IMMUNOLOGY
- METABOLIC REGULATION
- NEUROSCIENCES
- PLANT PHYSIOLOGY
- RADIOBIOLOGY
- REPRODUCTION AND DEVELOPMENT

LIFE SCIENCES OPERATIONS

- ANIMAL TRANSFER BETWEEN FACILITIES
- SPECIMEN CHAMBER AND WASTE TRAY CHANGE OUT
- ANIMAL FOOD CHANGEOUT
- PLANT CHAMBER CLEANING
- PLANT NUTRIENT SOLUTION REPLENISHMENT
- SPECIMEN BLOOD DRAW
- URINE AND FECES COLLECTION
- ANIMAL INJECTIONS
- COMPLETE ANIMAL AND PLANT DISSECTIONS
- SNAP FREEZING OF TISSUE SAMPLES
- CHEMICAL FIXING OF TISSUE SAMPLES

LIFE SCIENCES OPERATIONS (cont.)

- MASS MEASUREMENT OF TISSUE SAMPLES
- MASS MEASUREMENT OF PLANT AND ANIMAL SPECIMENS
- VISUAL OBSERVATION OF PLANT AND ANIMAL SPECIMENS
- ANIMAL ANESTHESIA
- MUSCLE BIOPSY
- SALIVA COLLECTIC
- SPECIMEN LABELING
- MICROSCOPY
- SEED "PLANTING"
- PLANT MANIPULATION FROM GERMINATOR TO PLANT CHAMBER
- PLANT HARVEST

REPRESENTATIVE RODENT SCENARIO

- PREPARE GLOVEBOX
- UNSTOW AND TRANSFER NECESSARY EQUIPMENT
  - SMALL MASS MEASUREMENT DEVICE
  - RODENT SUPPORT EQUIPMENT
  - SPECIMEN STORAGE SUPPLIES
  - SNAP FREEZER
- TRANSFER HABITAT TO GLOVEBOX AND REMOVE ANIMAL
- PERFORM OPERATIONS
  - WEIGH ANIMAL
  - DRAW BLOOD
  - SACRIFICE, DISSECT
  - PRESERVE SAMPLES (FIXATIVE OR SNAP FREEZE)
- TRANSFER SAMPLES TO REFRIGERATOR, FREEZER, ETC.
- STOW EQUIPMENT
- SANITIZE/DECONTAMINATE GLOVEBOX
- BAG AND TRANSFER TRASH TO TRASH MANAGEMENT SYSTEM

ANTICIPATED CHEMICALS

- FIXATIVES
  - FORMALDEHYDE
  - FORMALIN
  - GLUTARALDEHYDE
- CORROSIVES
  - HYDROCHLORIC ACID
  - SODIUM HYDROXIDE
  - ACETIC ACID
- OTHER
  - ETHANOL
  - EDTA
  - HOAGLAND'S SOLUTION

- DRUGS
  - ACEPROMAZINE
  - ATROPINE
  - KETAMINE HYDROCHLORIDE
  - OXYMORPONE HYDROCHLORIDE
  - PENTAZOCINE (TALWIN)
  - PENTOBARBITAL SODIUM
  - XYLAZINE (ROMPUN)
- RADIOISOTOPES

  ^{3}H, ^{51}Cr, ^{59}Fe, ^{125}I

S. S. FREEDOM SERVICES AND SUPPORT FUNCTIONS

- PMMS
  - TRASH MANAGEMENT
    - BIOSTABILIZED MATERIALS
    - RADIOACTIVE WASTES
  - WATER REQUIREMENT
    - ELECTRONIC GRADE FOR PLANTS
    - HYGIENE QUALITY FOR SCSU
  - WASTE WATER
    - CONDENSATE FROM HABITATS
    - BRINE FROM SCSU
    - SPENT NUTRIENT FROM PLANTS
  - LN_2
  - CO_2, O_2

S.S. FREEDOM SERVICES AND SUPPORT FUNCTIONS (cont.)

- ECLSS
  - O_2 RESUPPLY AND CO_2 REMOVAL FOR ANIMALS
  - POTABLE WATER FOR ANIMALS
- LAB FACILITY EQUIPMENT
  - REFRIGERATOR
  - FREEZERS, -20° C, -70° C
- LAB SUPPORT EQUIPMENT
  - CRYOFREEZER (SNAP AND STORAGE)
  - FREEZE DRIER
  - GAS CHROMATOGRAPH/MASS SPEC.
  - HIGH PERFORMANCE LIQUID CHROMATOGRAPH

ISSUES

- INCREASED BIOBURDEN
  FROM CREW TO SPECIMEN
- TRACE CONTAMINENTS
  FROM CABIN TO SPECIMEN CHAMBER
- SPILLS/CLEANUP
- REPLACEMENT UNITS
- HUMIDITY RANGE

RECOMMENDATIONS

- BUILD ON "LESSONS LEARNED" FROM SPACELAB
- CLOSE COORDINATION BETWEEN CFP AND PMMS DESIGNERS
- GOOD OPERATIONAL PROCEDURES
- CHEMICAL PACKAGING
- CONTINGENCY PLANNING

SUMMARY

- 1.8 M CENTRIFUGE FACILITY PROVIDES BIOISOLATION
- ALL ANIMAL PROCEDURES IN GLOVEBOX
- ALL CHEMICALS HANDLED IN GLOVEBOX
- PMMS DESIGN CRITICAL TO CFP OPERATIONS

SESSION 2

SUMMARY AND KEY ISSUES IDENTIFICATION

by

Session 2 Chairman: Judith Robey

NASA - Code SU

N91-15936

SPACE STATION TOXIC AND REACTIVE MATERIALS HANDLING WORKSHOP

Judith Robey
Session 2 Chairman

Below is a summary of the workshop objectives. From the presentations and the panel discussions some of the objectives were satisfied and others still need some follow-up work involving more details than the workshop time permitted.

WORKSHOP OBJECTIVES

IDENTIFY SPECIFIC AREAS FOR TECHNOLOGY DEVELOPMENT

From the discussions and presentations on the current space station subsystem designs it was not clear whether new technology is needed to handle a centralized waste system capable of mixing multiple chemicals or whether development of existing technology can do the job. The safe treatment of waste in a centralized system includes identification of incompatible chemicals, purging the waste lines and verifying their cleanliness, separating, filtrating and compressing waste material for storage. How this is to be done with existing technology was not clear. Another area that needs development is the technology for sensors and detectors. Many of the existing ground based detection systems are large resource consumers (volume, power, vacuum, cooling, etc.), and would require considerable modification for use in space. Space station subsystems designers should clearly identify how the current designs will accommodate the users requirements with existing technology and what, if anything, necessitates the development of new technology.

ADDRESS PAYLOAD/FACILITY REQUIREMENTS SUCH AS SAMPLE SIZE RESTRICTIONS, LEVELS OF CONTAINMENT, ETC. BY BRINGING TOGETHER THE SCIENTIFIC INVESTIGATORS AND THE SAFETY EXPERTS

To satisfy this objective much more detailed information is needed than was available at the workshop. Experiment operational scenarios are needed from the users that address how much on board characterization will be performed and how much automation versus crew interaction will be required during this analysis. Further communications between safety experts, space station subsystems designers and the user payload designers will need to take place before any conclusions about restrictions on samples or payload designs can be addressed. User sponsored workshops or studies including crew utilization, on-orbit characterization and operations is needed to fulfill this objective.

INSURE THAT CREW SAFETY IS THE HIGHEST PRIORITY FOR SPACE STATION

Although the focus of every presentation was on safety concerns past, present and future, there was not a clear space station programmatic line of responsibility to address safety issues. The question "How does space station insure that crew safety is the highest priority?" was not answered. Safety representatives from the workpackage centers addressed many safety related questions, however, safety is a program wide responsibility and to satisfy this objective more participation from space station safety organizations is needed.

IDENTIFY PRELIMINARY OPERATIONAL CONSTRAINTS

-IDENTIFICATION OF FACILITIES/EXPERIMENTS REQUIRING SPECIALIZED EQUIPMENT AND/OR PROCEDURES

-CREW LIMITATIONS AND PROTECTIVE GEAR REQUIREMENTS

The equipment or operational procedures required to accommodate some users, such as, a pressurized furnace (to 80 atm), radioisotopes used in life sciences experiments and a high vacuum (10-6 torr) were not identified. It was unclear whether these payload requirements could or would be accommodated in the current space station designs. Preliminary payload or operational constraints were not identified. These examples all have safety and/or PMMS design implications.

It was pointed out by a university participant that the Spacelab crew carrying out experiments on orbit were not required to wear the minimum ground based lab protective gear, such as goggles, lab coats, gloves etc.

ESTABLISH A FRAME OF REFERENCE OR BASELINE OF APPLICABLE WASTE HANDLING EXPERIENCE

Lessons learned from Skylab and Spacelab were presented, as well as how things have changed based on that experience. This information provided a frame of reference for on orbit experience. Industry presented some ground based examples of waste handling, such as, microbial systems, exhaust gas conditioning and reactive bed plasma systems. How much, if any, of this information is being studied for incorporation into space station systems was not clear.

USE THE WORKSHOP AS A BASIS FOR ASSESSING THE CURRENT AND APPLICABLE SPACE STATION REQUIREMENTS

The space station subsystems designs (PMMS, FMS, ECLSS), are currently undergoing revision as a result of the Program Requirements Review (PRR). To satisfy this objective and to establish a greater fidelity in the subsystems capabilities, user payload experiment and facility developers need to provide their best estimate of operational requirements for volumes of fluids needed, volumes of waste expected, pressures, temperatures, flow rates, concentration and purity levels. The workshop has encouraged dialogue in these areas.

PROVIDE AN EDUCATIONAL AND INFORMATIONAL FORUM FOR GOVERNMENT EMPLOYEES, CONTRACTORS, EXPERIMENTAL FACILITY DEVELOPERS, AND POTERNTIAL HARDWARE SUPPLIERS INVOLVED WITH THE SPACE STATION PROGRAM

Presentations were given by 22 government, 16 industry and 2 university participants. These included contractors, experimental facility developers and potential hardware suppliers. There was information exchange during the discussion periods, as well as exchange of business cards and telephone numbers during the coffee and lunch breaks. Communications have been initiated and it is to the benefit of all of us to keep them going.

DOCUMENT THE WORKSHOP RESULTS AND IDENTIFY FOLLOW-ON STUDY ISSUES

The workshop proceedings will be mailed to the participants in January, 1989. This will include the summary report and recommendations from the Discussion Panel as well as summary reports from the Session Chairmen and any written questions submitted from the participants. It will also include Xerox copies of the material presented at the workshop. The Environmental Steering Committee, co-chaired by the Office of Space Station and the Office of Space Science and Applications, will review the workshop results and propose a follow-up plan. This plan should include the involvement of the appropriate space station level II panels and working groups as well as the applicable workpackage representatives. It should also include close cooperation with, and representatives from, the user community.

SPACE STATION TOXIC AND REACTIVE MATERIALS HANDLING WORKSHOP

Judith Robey
Session 2 Chairman

Many questions were asked during the course of the workshop. Some answers may exist in the space station documentation being revised after the Program Requirements Review (PRR) or are currently being worked in studies or working groups and panels. However, since satisfactory answers were not available at the workshop, some of these questions were flagged as issues and concerns and some resulted in recommendations. For the session 2 summary report, rather than try to recommend design solutions for systems that cross many technical discipline borders, I have summarized the essence of the questions that were asked during the course of the workshop.

SUMMARY QUESTIONS

1. It was stated that ECLSS would provide 7 locations for contaminant detection. Is this sufficient given the lack of gravity driven air flows in micro-g?

2. Does PMMS have the sole responsibility for payload leak detection? Does ECLSS have any responsibility? Are there back-up systems for payload contaminant detection? What is the users responsibility?

3. What is the range of contaminants that space station subsystems (PMMS, ECLSS, FMS) provided sensors can detect?

4. Will the warning, caution and alarm displays and systems be common in all pressurized modules?

5. In the event of a toxic or hazardous material spill within the lab module, is the responsibility for the cleanup redundant between ECLSS and PMMS, or do they have specific areas of responsibility? If

so what are they? Who provides the contingency plans and the necessary tools?

6. Which safety office provides overview of the systems design and development, particularly in cases where the subsystems cross workpackage assignments or where their interfaces meet? What safety office will be responsible for developing user payload facility and operational guidelines and regulations? How do shuttle safety regulations get folded into space station?

7. What kinds of user safety guidelines or regulation manuals are, or will be, available to the user facility/payload designers? What safety office, panel or review board will be responsible for verifying compliance of these regulations? Where and when will this information be available?

8. PMMS, FMS and ECLSS design requirements are driven to a large extent by operational scenarios, such as, the amount of on orbit characterization of toxic or reactive materials and vacuum/vent, glovebox, and lab support equipment usage. Strawman operational scenarios are needed by the subsystems designers for greater definition of their requirements. Information is needed in the area of fluid volumes (supply and waste), pressures, temperatures, flow rates, concentration levels and purity specifications.

9. What is meant by triple containment and two-failure-tolerant? (It was unclear as to whether triple containment was the method by which the requirement of two-failure-tolerant is met, or whether they were two separate requirements, both with independent methods for compliance.) Is there consistent agreement across NASA centers? Will vacuum vent be considered one level of containment? Will there be a station wide policy on what triple containment is, or will it be on a case by case bases as it has been on shuttle flights in the past?

10. Will gallium arsenide, mercury cadmium teluride, and mercury iodide samples be processed and characterized on orbit? How will any restrictions, regulations or guidelines be developed for the handling of these toxic materials?

11. How much processing and containment will be required at each level of responsibility: payload, lab level (PMMS for USL) and station wide (FMS)?

12. Will the PMMS be capable of handling biotoxins and biohazardous material?

13. What is the space station plan for handling radioactive waste?

14. Will the emergency shower for crew decontamination provide enough water to meet flushing requirements?

15. Will the waste water reclamation system be capable of processing the waste water (brine) from the cage washer (approximately .75 gallons per cage) and the biotechnology facilities requirement to wash and sterilize between each run?

16. What are the international partners planning for waste management in their modules? What plans does ESA have for handling payload waste in their module? What capability does the JEM waste system have?

17. Does a centralized waste system make sense given the problems of combining multiple chemicals? Ground processing systems do not, in general, operate using a centralized system.

18. Is this centralized waste system used simultaneously by multiple users, or in series? If used one at a time, how will the contaminants from one dump be purged and cleanliness verified?

19. Is there a period when venting to space will be allowed, such as during station reboost or shuttle visits?

20. Is the vacuum vent for purging experiments a separate line from the hard space vacuum provided for isolation purposes?

21. If the vacuum system is provided to 4 quadrants of the USL, does this mean a user (in the USL) will risk cross contamination with another user in the same quadrant?

22. What is the planned disposition of "large" solid waste such as contaminated "Kimwipes" or empty sample containers?

23. What are the resource costs for the PMMS and FMS in terms of volume, power and mass, considering such things as compressors and high pressure storage tanks for the waste material?

24. Is space station (PMMS, FMS, safety, operations, logistics, etc.) looking at how systems are designed and procedures are carried out on the ground? For example:

a. College chemical laboratories are required to store their chemicals in a protected area, such as, behind a "blow out wall".

b. Department of Transportation has categorized chemicals for storage and transport purposes.

c. Some laboratories precipitate and distill their chemicals to reduce their storage volume.

d. Ground laboratory safety regulations require lab workers to wear protective gear, i.e. goggles, gloves, lab coats, shoes etc.

25. Is space station developing a chemical labeling system that is consistent, accurate, common and "user friendly" across all lab modules?

26. What are the trade-offs and safety concerns of having an experiment which processes hazardous or toxic materials and is operated autonomously reducing crew risk, but requires fluid supply and waste management scheduling with the inherent risk of disposal schedule overlap of two incompatible chemical waste products?

27. Is fluid delivery. waste disposal and vacuum/venting a scheduled service? Is the scheduling local to PMMS, or is it a station wide operational schedule?

28. Has space station considered safety implications in USL rack layout? For example:

a. Placing payloads involving hazardous operations in locations such that they do not block the exit route in the event of a leak of a toxic substance?

b. Placing the emergency, decontamination shower in a node?

29. Are the space station leak detection and contaminant control systems looking at the ground based sensors and detectors currently available? Are they doing any research or development in the new technology areas such as fiber optics and laser systems?

30. Are the waste management system designers looking at ground based systems, such as, microbial systems, reactive bed plasma and exhaust gas conditioning systems?

31. In micro-g conditions, stagnant air pockets may reside where toxins could collect, is the ECLSS air circulation sufficient to flush out these areas?

32. With the build up of perspiration, dust and dirt particles, due to micro-g conditions, is there a regular maintenance plan to "wash" the internal surfaces of space station? Who has this responsibility?

33. Will an individual module be capable of "dumping" its contaminated atmosphere and repressurizing to normal conditions?

All of these questions were asked in some form or another during the course of the workshop. Some had no answers, others had partial answers, still others had definitive answers, but the answers were not acceptable as solutions. Any follow on work the space station or the users agree to sponsor should, as a first step, answer the questions raised at this workshop.

Space Station Freedom Toxic and Reactive Materials Handling Workshop

U.S. Laboratory Overview

November 30, 1988
Frank J. Jackson

Boeing Aerospace
P. O. Box 1470
MS JA-94
Huntsville AL 35807-3701

Work phone: 205/461-2473
FAX No.: 205/461-2787

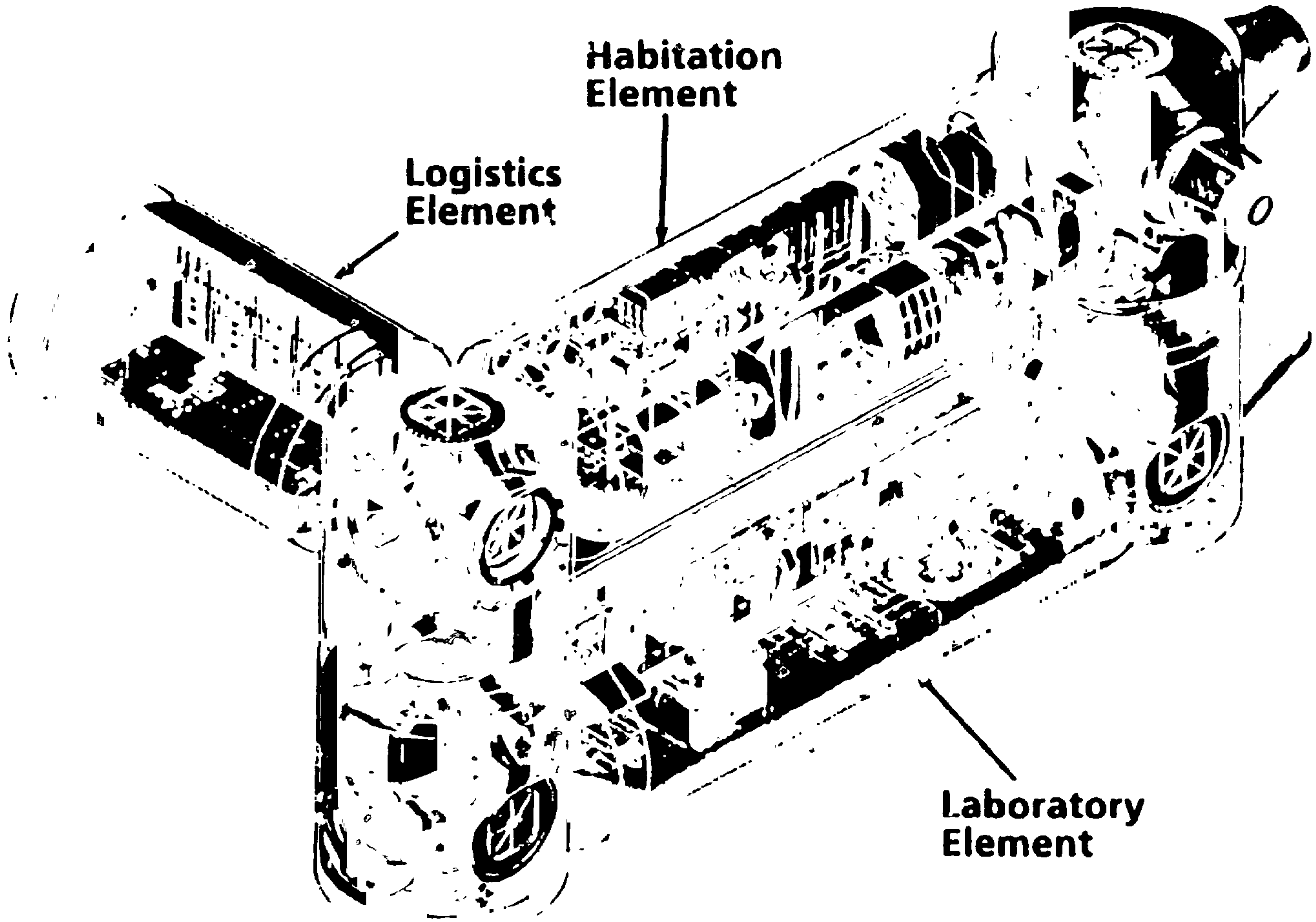
U. S. Laboratory

- $\boxed{\text{Features}}$
- Equipment Summary
- Subsystems

Space Station Freedom

Space Station Freedom
Pressurized Element Arrangement

BOEING



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U.S. Laboratory Features

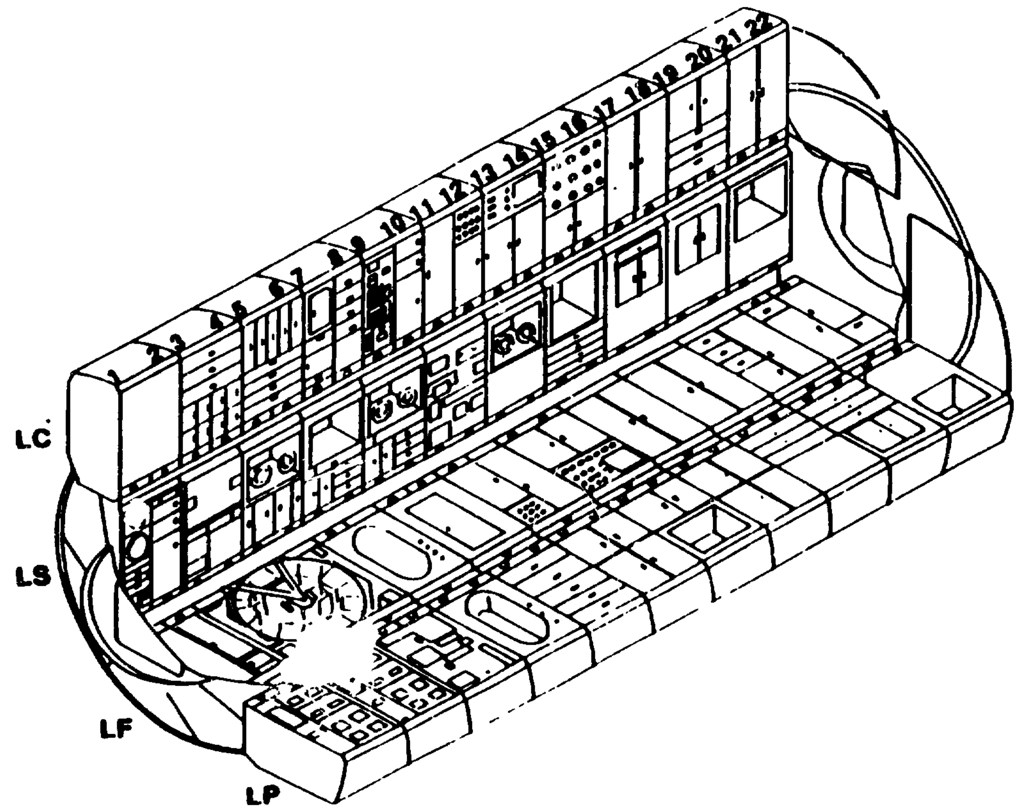
- Accommodate, multidiscipline payloads
- Provide for evolutionary growth
- Process materials management system
- Accelerometer mapping system
- Space vacuum access
- Generic laboratory equipment for multidiscipline activities

U. S. Laboratory

- Features
- Equipment Summary
- Subsystems

U. S. Laboratory Modules Systems

Distributed Systems + Laboratory Unique Systems + Payloads



SSP88/0313

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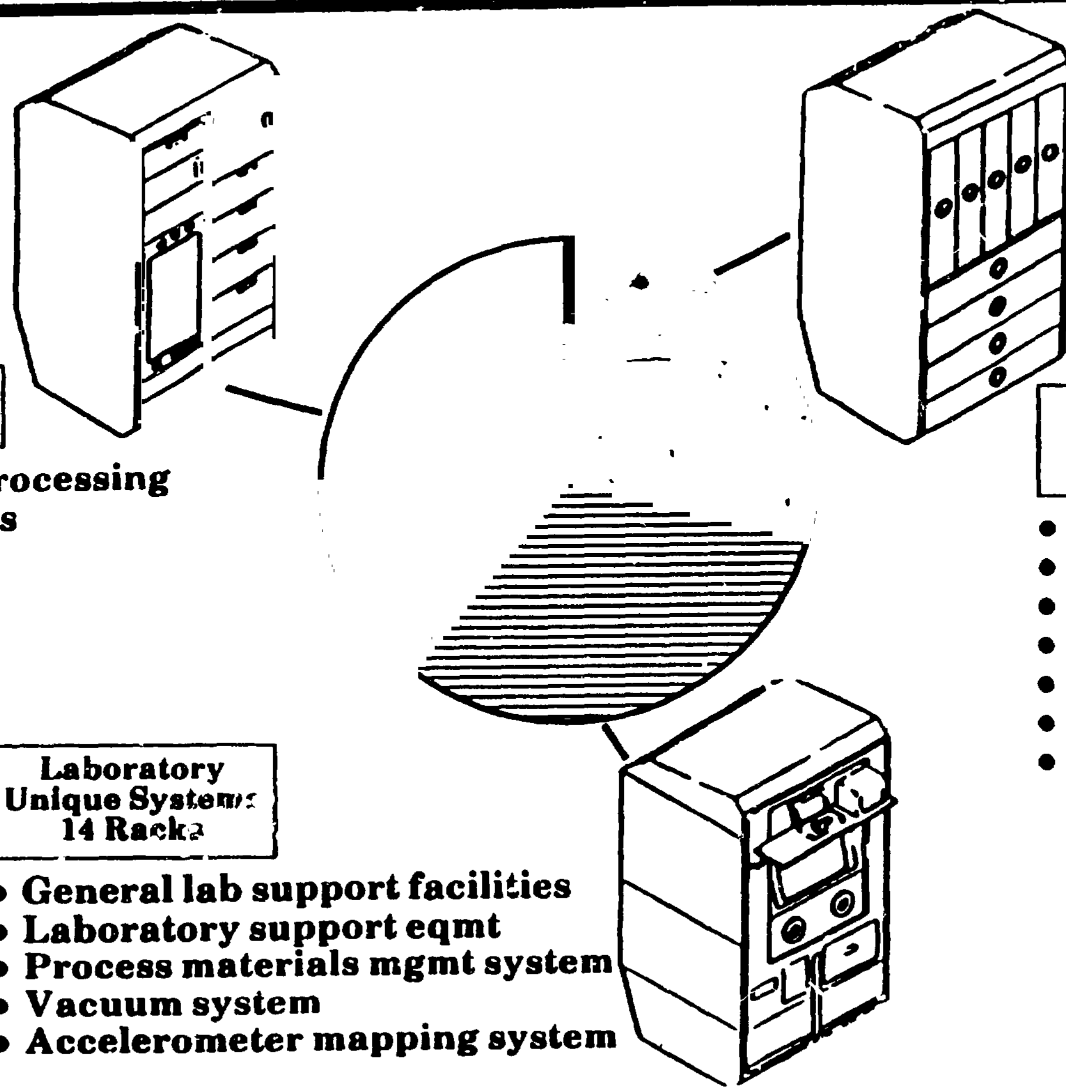
U. S. Laboratory Equipment Summary



Payloads
17 Racks

- Materials processing
- Life sciences

Distributed
Systems
13 Racks

- ECLSS
- Thermal Control
- Electrical Power
- Data Management
- Software
- Internal Audio/Video
- Man-systems

Laboratory
Unique Systems
14 Racks

- General lab support facilities
- Laboratory support eqmt
- Process materials mgmt system
- Vacuum system
- Accelerometer mapping system

U. S. Laboratory

- Features
- Equipment Summary
- Subsystems

U.S. Laboratory Module Subsystems

Laboratory subsystems
- Vacuum vent system
- Process materials management system
- Accelerometer mapping system

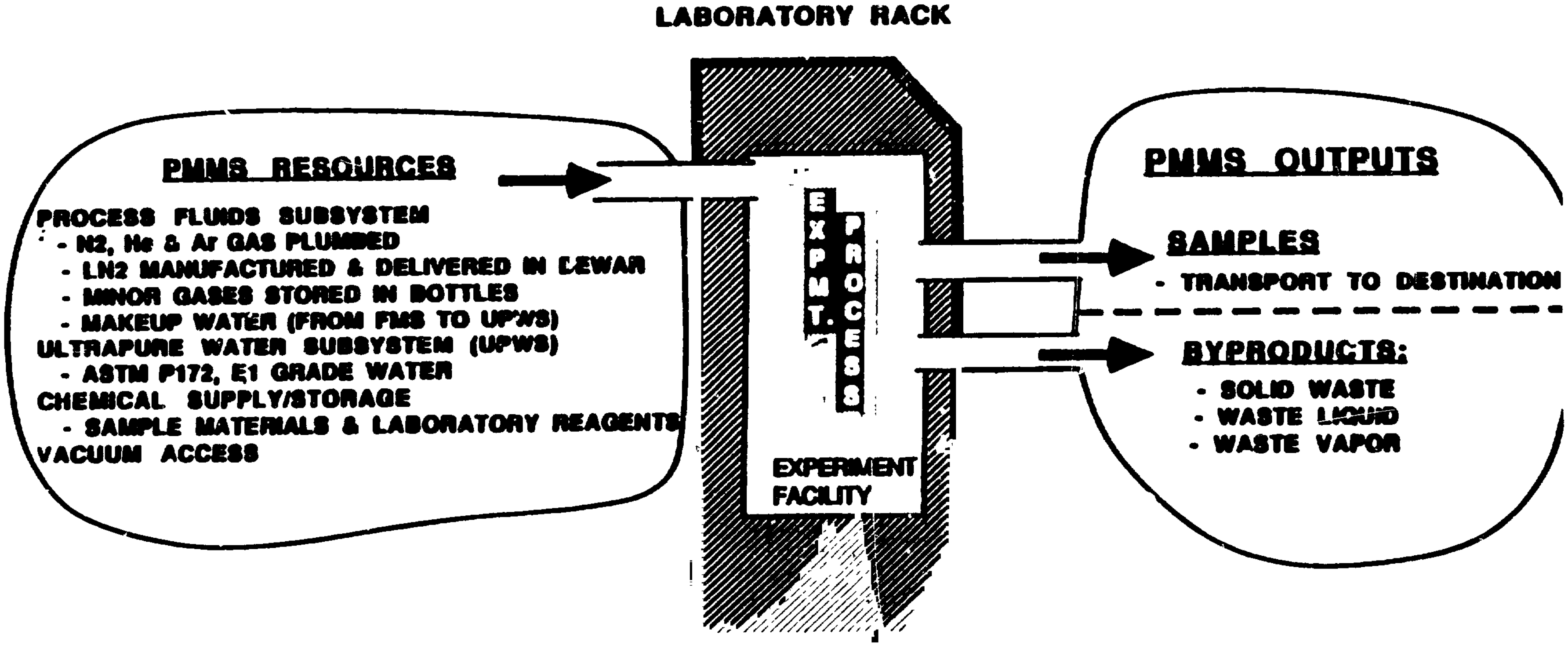
General laboratory support facilities
- Materials processing sciences glovebox
- Life sciences glovebox
- Laboratory sciences work bench

Laboratory support equipment
- 31 items (oscilloscopes to x-rays)

Space Station Freedom

U.S. Laboratory Module
PMMS System

BOEING



THE PMMS PROVIDES A CLOSED SYSTEM FOR ALL MATERIALS ENTERING OR LEAVING LABORATORY EXPERIMENTS AND FACILITIES

SPACE STATION CONTAMINANT CONTROL AND MONITORING

WILLIAM R. HUMPHRIES
EP62

NOVEMBER 1988

LIFE SUPPORT MANAGEMENT WORKING GPOUP BRIEFING

MSFC SPACE STATIO. ECLSS RESPONSIBILITIES

ECLSS

TEMPERATURE & HUMIDITY CONTROL (THC)
- AIR TEMPERATURE CONTROL
- HUMIDITY CONTROL
- VENTILATION
- EQUIPMENT AIR COOLING
- THERMALLY CONDITIONED STORAGE
- PARTICULATE AND MICROBIAL CONTROL

ATMOSPHERE CONTROL & SUPPLY (ACS)
- O_2/N_2 STORAGE & DISTRIBUTION
- VENT & RELIEF
- O_2/N_2 PRESSURE CONTROL

ATMOSPHERE REVITALIZATION (AR)
- CO_2 REMOVAL
- CO_2 REDUCTION
- O_2 GENERATION
- CONTAMINATION CONTROL & MONITORING

WATER RECOVERY & MANAGEMENT (WRM)
- URINE PROCESSING
- HYGIENE WATER PROCESSING
- POTABLE WATER PROCESSING
- WATER STORAGE & DISTRIBUTION
- WATER THERMAL CONDITIONING
- WATER QUALITY MONITORING

WASTE MANAGEMENT (WM)
- RETURN WASTE STORAGE
- FECAL PROCESSING & STORAGE

FIRE DETECTION AND SUPPRESSION (FDS)

5-4519 8-53

CONTAMINANT SOURCES

SOURCE	CONTAMINANT
● MAN	— METABOLIC PRODUCTS: CO_2, NH_3, CO, H_2S, H_2, CH_4, ORGANIC ACIDS, MERCAPTANS — BACTERIOLOGICAL CONTAMINANTS
● SPACECRAFT SUBSYSTEMS, NON-ISOLATED EXPERIMENT EQUIPMENT AND PAYLOADS	— WIDE VARIETY OF ALCOHOLS, ALDEHYDES, AROMATICS, ESTERS, ETHERS, CHLOROCARBONS, FLUOROCARBONS, HALOCARBONS, HYDROCARBONS, KETONES, ACIDS, etc.
● EMERGENCY SITUATIONS: FIRE, SPILLS, EQUIPMENT FAILURES	— CO, CO_2, HYDROCARBONS AROMATICS, ACID GASES. OXIDES OF N_2, SO_2, NH_3, SMOKE, ALCOHOLS, FORMALDEHYDE, etc.
● NONISOLATED ANIMAL AND PLANT EXPERIMENTS	— METABOLIC, BACTERIOLOGICAL

5-507-9-71

ECLSS DESIGN PREMISES

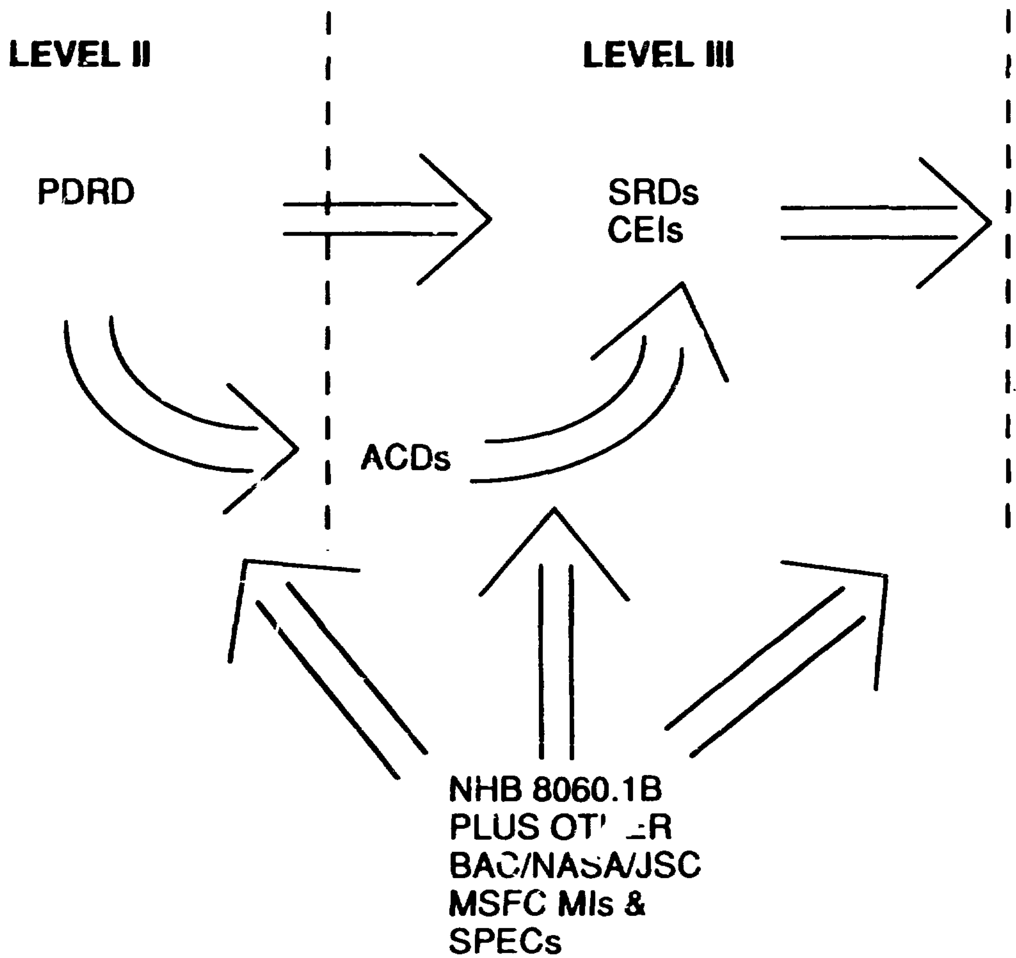
- HAZARDOUS SUBSTANCE USERS WILL BE ISOLATED FROM THE MODULE ENVIRONMENT AND BE TWO FAILURE TOLERANT (i.e., THE PMMS/PAYLOAD SUPPLIER WILL PROVIDE CONTAINMENT AND CONTROL FOR THEIR NON-STANDARD SUBSTANCES - NOT THE ECLSS).

- ANY LIFE SCIENCE OR OTHER PAYLOADS UTILIZING POTENTIALLY HAZARDOUS MICROBIAL MATERIAL IN THEIR OPERATIONS MUST PROVIDE TWO FAILURE TOLERANT MICROBIAL ISOLATION FROM THE MODULE ENVIRONMENT (ANIMALS WILL BE PATHOGEN FREE PER THE HPRRC).

- SUFFICIENT DATA WILL BE MADE AVAILABLE TO THE NASA SO THAT AN INDEPENDENT ASSESSMENT OF CONTAMINANT SAFEGUARDS CAN BE VERIFIED.

5-508-9-71

SPACE STATION PROGRAM
CONTAMINANT CONTROL DOCUMENTATION



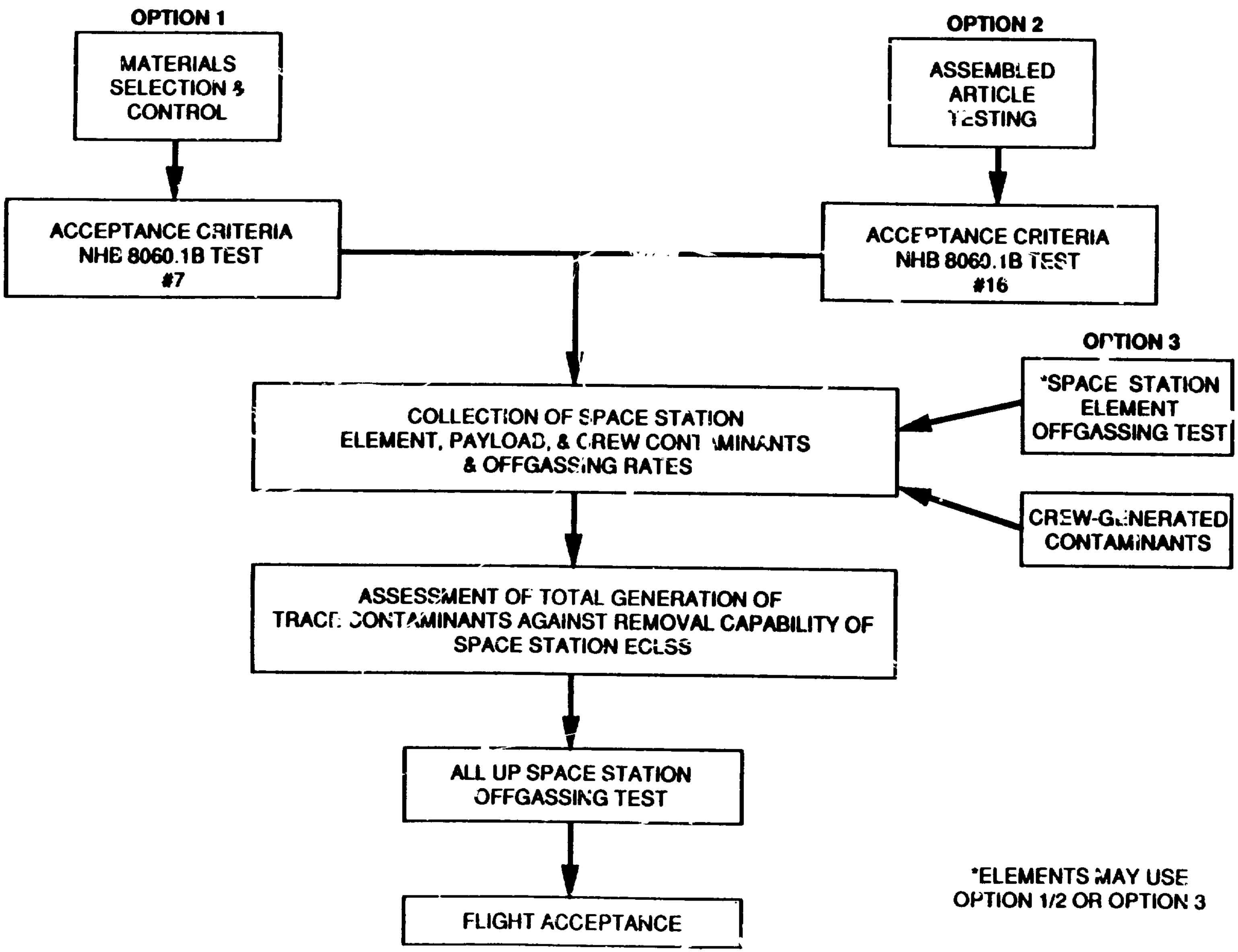
PRIME

PLANS AND REPORTS

– SAFETY PLAN	DR SA01
– SAFETY ANALYSIS AND HAZARDS REPORTS	DR SA03
– CONTAMINATION CONTROL & IMPLE-MENTATION PLAN	DR SE05
– CONTAMINATION CONTROL AND IM-PLEMENTATION REPORT	DR SE06
– SYSTEM & SUBSYS CONTAMINATION ANALYSIS	DR SE27
– CUSTOMER INTE-GRATION	DR SE31

5-510-9-71

SPACE STATION/PAYLOAD TRACE CONTAMINANT CONTROL PROCEDURE



*ELEMENTS MAY USE OPTION 1/2 OR OPTION 3

5-667-9-82

SPECIAL CONCERNS

- LIFE OF SAFETY EQUIPMENT
- HIGH TEMPERATURE CATALYTIC REACTION WITH AIR BORNE CONTAMINANTS
- ISOLATION OF HAZARDOUS SUBSTANCES

  IMPLIES: JEOPARDY OF FLIGHT DUE TO HIGH RISK

  RIGOROUS PAYLOAD DESIGN ISOLATION PROOF

  SLOW TRANSITION TO HAZARDOUS SUBSTANCE USE

- ISOLATION OF AVIONICS COOLING LOOP FROM HAZARDOUS USERS

IMPETUS TO UTILIZE BENIGN MEDIA

5-513-9-71

THE ECLSS WILL:

- CONTROL ALL CONTAMINANTS TO CONCENTRATIONS LESS THAN THE SMAC LEVELS
  - — ANTICIPATED LOADS ARE BASED ON PREVIOUS FLIGHTS AND ANALYSIS UTILIZING EXISTING SMAC LEVELS IN GUIDING EARLY DESIGN OF THE TRACE CONTAMINANT CONTROL AND MONITORING SUBSYSTEM.
  - — AS EQUIPMENT OFF-GASSING DATA AND NEW SPACE STATION SMAC VALUES (DUE TO LONGER EXPOSURE) BECOME AVAILABLE THE DESIGN WILL BE UPDATED.
- INDIVIDUAL EQUIPMENT ITEMS WILL BE OFF GAS TESTED OR MATERIAL EVALUATIONS USED TO DETERMINE THE READINESS TO FLY PER NHB8060.1B FOR EACH EQUIPMENT ITEM BY A JOINT ECLSS/MATERIALS DISCIPLINE TEAM.
- DEVELOP AND UTILIZE AN ANALYTICAL MODEL TO ASSESS TRACE CONTAMINANT LEVELS.
- NEAR REAL-TIME MONITORING WILL BE PROVIDED (INTERACTIVE CONTROLS AND TBD ALARMS).
- SUPPORT ACTIVITIES IN THE PERFORMANCE OF TBD SYSTEM LEVEL OFF-GAS TESTING TO VERIFY THE DESIGN.
- ALERT CREW AND ASSURE CORRECTIVE ACTIONS ARE PLANNED AND IMPLEMENTED IN THE EVENT ANY CONTAMINENT IS APPROACHING AN "OUT-OF-TOLERANCE" CONDITION.
- VERIFY THE PAYLOAD/PMMS CONTAMINANT CONTROL DESIGN.

5 ..9-9-71

MEASURES USED TO CONTROL CONTAMINANTS

TRACE GASES AND ODORS (<SMACs)

- CONTROL OF MATERIALS
- FIXED CHARCOAL (TREATED AND UNTREATED) SORPTION BEDS
- HIGH/LOW TEMPERATURE CATALYTIC CONVERTERS IN CONJUNCTION WITH PRE/POST TREATMENT BEDS
- CONSIDERATION OF CONDENSING HEAT EXCHANGER REMOVAL CAPACITY
- CONSIDERATION OF MOLE SIEVE REMOVAL CAPACITY
- MISCELLANOUS EFFECTS (LEAKAGE MAKEUP, METABOLIC OXYGEN REPLENISHMENT AND LOGISTIC MODULE REVISIT CLEANSING ACTIONS, etc.)

PARTICULATES (< 100k PARTICLES/FT^3)

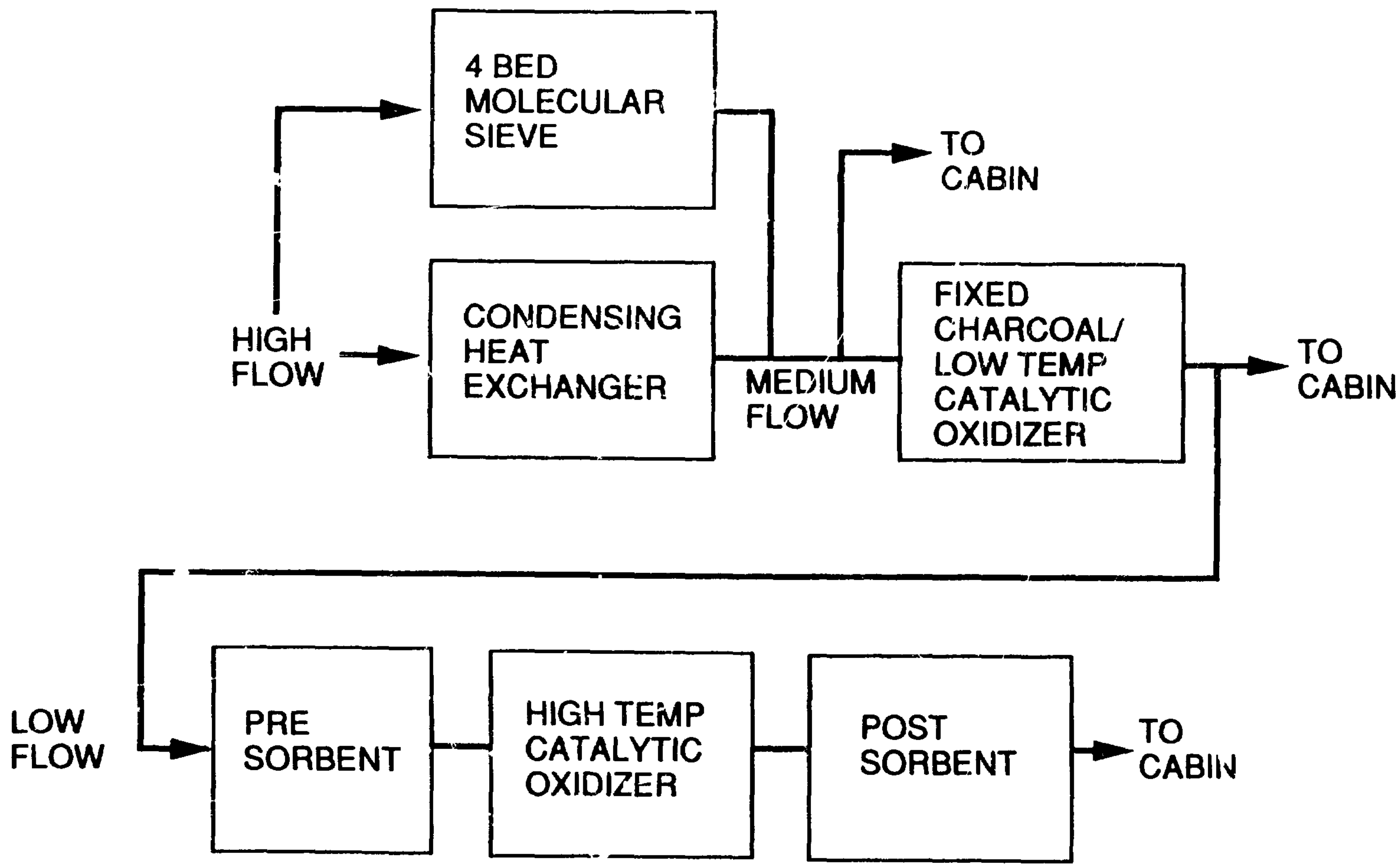
- CONTROL OF MATERIALS
- FILTERATION WITH CIRCULATION
- HEPAFILTRATION

MICROBES

- CONTROL OF FLIGHT MATERIALS
  - AIRBORNE (<1000 CFU/M^3)
    - SAME AS PARTICULATES
  - WATERBORNE
    - BIOCIDE
    - HEAT

5-511-9-71

TYPICAL CONTAMINANT CONTROL SYSTEM CONFIGURATION



5-512-9-71

TRACE CONTAMINANT MONITORING

5-516-9-71

ECLSS CONTAMINATION MONITORING

- AIRBORN/SURFACE MICROBES
  - OFF-LINE

- POTABLE/HYGIENE WATER QUALITY
  - ON-LINE
  - OFF-LINE

- PARTICULATE MONITOR
  - .5 TO 100 MICRON RANGE

- MAJOR CONSTITUENT MONITOR
  - SPECIFIC CONSTITUENTS OF H_2, O_2, N_2, CO, CO_2, H_2O & CH_4
  - ONE UNIT IN EACH MAJOR ELEMENT
  - RAPID SAMPLING

- TRACE GAS MONITOR
  - ONE ATMOSPHERIC CONTAMINANT MONITOR EACH IN THE HAB AND LAB MODULES
  - GAS CHROMATOGRAPH/MASS SPECTROMETER INSTRUMENT USED
  - MULTIPLE SAMPLING LOCATION CAPABILITY – HAB, LAB, NODES, COLUMBUS, JEM & LOG MODULE

5-514-9-71

TRACE GAS MONITORING DESIGN GOALS

- FULLY AUTOMATED WITH POSITIVE SPECIFICATION AND QUANTIFICATION OF ALL COMPOUNDS IN AMU RANGE
- $\leq$ 30 MINUTE CYCLE TIME FOR APROXIMATE AMU RANGE OF 24-250
- SPECIFICATION CONTAINS 222 ACTUAL CONTAMINANT SPECIES RANGING FROM METHANOL (AMU = 32) TO HEXADECAMETYL (AMU =593)
- TARGET SENSITIVITY $\leq$ 50% OF MAC LEVEL
- DATA AVAILABLE ON-BOARD AND GROUND

5-515-9-71

ABSTRACT

THE PROCESS MATERIALS MANAGEMENT SYSTEM OF THE FREEDOM SPACE STATION'S U.S. LABORATORY

The space station user community requirements were defined during the phase B study, 1985 thru 1987, and served to identify common use set of required unique subsystems and facilities. These requirements which resulted in the current design are reviewed and updated. Comparisons are drawn between the Skylab, Spacelab and MIR programs, both as to program goals, methods employed and the facilities provided.

Major system design issues identified are related to the unprecedented space hardware life expectancy of 20 to 30 years, such as reliability and safety, and to the broad spectrum of potentially hazardous chemical substances to be used by the science community, such as materials compatibility, contamination, triple containment and safety.

The PMMS is defined in terms of the currently baselined subsystems and current issues, design options and schedules are reviewed.

PMMS

THE

PROCESS MATERIALS MANAGMENT SUBSYSTEM

(PMMS)

THE HEART OF THE
UNITED STATES LABORATORY

vg 2

PMMS

TOPICS

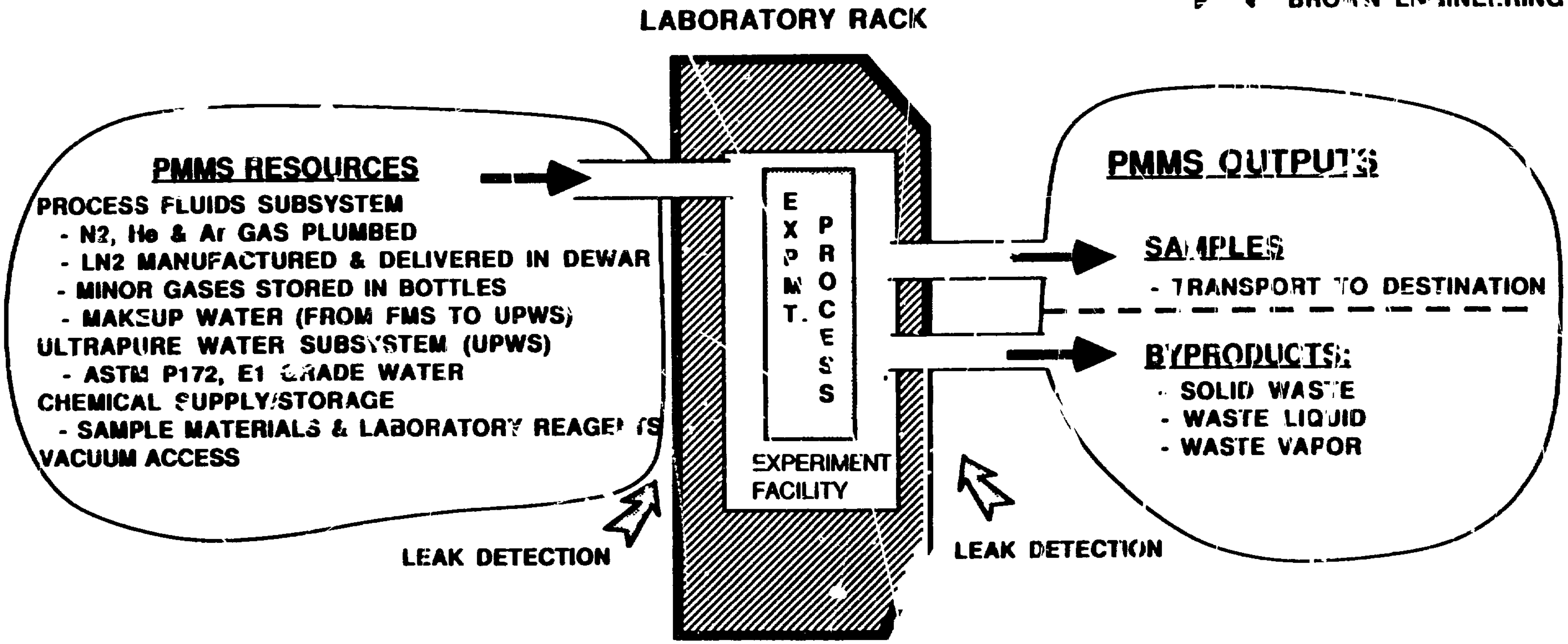
- LABORATORY OUTFITTING
- PMMS SYSTEM DEFINITION
- USER/DESIGN REQUIREMENTS
- PRIOR PROGRAMS INPUTS
- LABORATORY ENVIRONMENT/INTERFACES
- SUBSYSTEM FUNCTIONS & INTERFACES
- DEVELOPMENT TESTING & SCHEDULES

U.S. LABORATORY OUTFITTING

- Accelerometer Mapping System
- PMMS Subsystem
  - Process Fluids Distribution/Storage
  - Ultrapure Water
  - Waste Fluid Management
  - Crew/Hardware Decontamination
  - Chemical Storage
  - Leak Detection
  - Materials Transport
- Vacuum Subsystem
- Materials Science Glovebox
- Laboratory Support Equipment
  - Cutting/Polishing System
  - Microscope System
  - Autoclave
  - X-Ray System
  - Etching Equipment
  - Fluid Handling Tools
  - Digital Multimeter
  - Digital Recording Oscilloscope
  - pH Meter
  - Ultraviolet Sterilization
  - General-Purpose Hand Tools
  - Camera/Camera Locker
  - Electrical Conductivity Probe
  - Cleaning Equipment
  - Digital Thermometers
  - EM Shielded Storage Locker
  - Film Locker

SP88-184

PMMS SYSTEM DEFINITION



THE PMMS PROVIDES CLOSED SYSTEM FOR ALL MATERIALS ENTERING OR LEAVING LABORATORY EXPERIMENTS AND FACILITIES

GOAL: PROVIDE ON-ORBIT CAPABILITIES AND SAFETY ENVIRONMENT EQUIVALENT TO EARTH BASED LABORATORY

vg 4

PROCESS MATERIALS MANAGEMENT SYSTEM

THE CHALLENGE:

- THE PMMS MUST HANDLE ALL INPUTS AND OUTPUTS OF MATERIALS TO THE US LAB EXPERIMENTS AND SUBSYSTEMS
- SOME MATERIALS MAY BE HAZARDOUS IN ONE OR MORE OF THEIR STATES AND DURING EXPERIMENT OPERATIONS
- PARTS OF THE PMMS MUST BE SERVICEABLE AND MAINTAINABLE OVER THE 30 YEAR LIFE OF THE STATION

THE APPROACH:

- USER DATA BASE ANALYSIS PROVIDES THE MATERIAL HANDLING REQUIREMENTS FOR THE PMMS
- BASED ON CURRENT NASA SAFETY GUIDELINES THE PMMS IS DESIGNED FOR TRIPLE CONTAINMENT
- THE PMMS IS DESIGNED WITH ORU DEFINED MODULES FOR MAINTAINABILITY

PMMS DESIGN RATIONALE

TELEDYNE BROWN ENGINEERING

PRIMARY CRITERIA

- MAXIMUM SAFETY
- MAXIMUM USER ACCOMMODATION
- MINIMUM CREW TIME
- MINIMUM WEIGHT & VOLUME
- COST/BENEFIT
- COOPERATIVE FUNCTIONS
- AUTOMATED OPERATION
- MAINTAINABILITY
- RELIABILITY

SPACE STATION

PMMS REQUIREMENTS SUMMARY

TELEDYNE BROWN ENGINEERING

PMMS STATED REQUIREMENTS

REF. SOURCES:		SUBJECT:	REQUIREMENTS
SS-SRD-0001		General	Safety, maintainability, reliability, ground/manual function inhibit, venting limited
SS-IRD-0200		PMMS	Process fluid...distribution...interface. Waste scheduling/identification, customer containment/control at rack level.
JSC-30000	PDRD	FMS	FMS provides storage, transfer, control, conditioning of integrated fluids [nitrogen, water, waste], venting constraints.
JSC-30264	ACD	Integrated: Nitrogen Water Waste	Primary interface: node 1, secondary: node 2. Tank pressurant, ECLSS, PMMS process fluids. Internal storage, separate line to PMMS. Options: fuel, oxidizer, inert, liquid. Waste interfaces are TBD.
SS-SPEC-J002	CEI	PMMS	Physical, functional, PMMS parameters.

DERIVED REQUIREMENTS

REFERENCE MISSION OPERATION ANALYSIS DOCUMENTS (RMOAD) - RED BOOK - GREEN BOOK - BLUE BOOK	MMPF USER STUDY - MSFC - TBE - BAC SYSTEMS OPERATION IMPERITIVES - SPACELAB EXPERIENCE - PHASE B DESIGN DRIVERS

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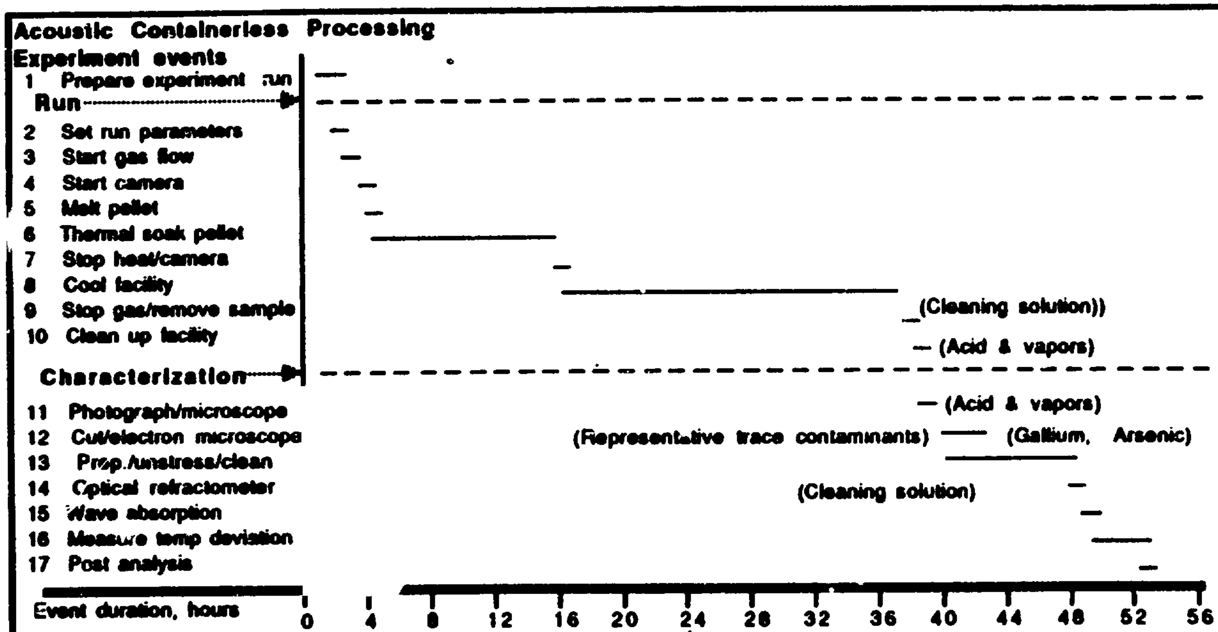
SPACE STATION

PMMS WASTE FLUID ANALYSIS (SAMPLE)

TELEDYNE BROWN ENGINEERING



	Run										Characterization				
Event #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Category total
Time (min)	20	1	1	1	1	1	1	20	10	15	15	30	30	30	178 min.
Waste category	Volume (liters)														
Inert gas (Ar, He)	18	52	52	52	52	52	52	320							650.0 liters
Cabin air	64							18	5	16	8	28	10	10	159.0 liters
Water									0.1					1	1.1 liters
Nitrogen												10	28		38.0 liters
Event total	82	52	52	52	52	52	52	338	5.1	16	8	38	38	11	848.1 liters

Analysis Indicates Predominant Waste Constituents Are Inert Gas and Cabin Air

SPACE STATION

PMMS REQUIREMENTS SAMPLE

TELEDYNE BROWN ENGINEERING

USL PROCESS FLUID REQUIREMENTS*
14 EXPERIMENT SET, CHARACTERIZATION
NO RECYCLING

FLUID	10 HRS/DAY CREW TIME		20 HRS/DAY CREW TIME		30 HRS/DAY CREW TIME	
	MASS	VOL (FT^3)	MASS	VOL (FT^3)	MASS	VOL (FT^3)
LIQ. H_2O	904.4	14.5	2152.5	34.5	2720.3	43.6
GAS Ar	25.8	231.9	49.5	444.9	70.2	630.9
GAS N_2	26.9	344.7	64.2	822.7	96.5	1236.7
LIQ. N_2	75.1	1.5	150.5	3.0	262.0	5.2
GAS O_2	10.4	116.7	18.9	212.1	25.7	288.3
GAS He	1.9	170.4	4.1	367.7	6.1	544.5
GAS CO_2	0.4	3.3	1.1	9.0	1.3	10.6
GAS H_2	0.2	35.6	0.2	35.6	0.3	53.4
TOTAL	1045.[illegible]	918.6	2441.0	1929.5	3182.4	2813.2

*ALL GAS VOLUMES ARE BASED ON STANDARD ATMOSPHERIC TEMPERATURE AND PRESSURE.

LAB SUPPPORT EQUIPMENT INTERFACES
(Excluding Life Sciences Equipment)

NOMENCLATURE	INTERFACES WITH						
	PMMS/GB	FMS	USERS	ECLSS	DMS/C&W	PWR/THERM	STRUCTURE
AUTOCLAVE	√	√	√	√	√	√	√
BATTERY CHARGER			√		√	√	
CAMERA	√		√				
CAMERA LOCKER							√
CLEANING EQUIPMENT	√	√	√	√	√	√	
CUTTING & POLISHING UNIT		√	√		√	√	√
DIGITAL MULTIMETER	√		√		√	√	
DIG RECORDING O-SCOPE			√		√	√	√
DIGITAL THERMOMETER	√		√		√	√	
DOSMETER, PASSIVE				√		√	
ELECT. CONDUCT. PROBE	√		√		√	√	
EM - STORAGE LOCKER			√				√
ETCHING EQUIPMENT	√	√	√				
FILM LOCKER							√
FLUID HANDLING TOOLS	√	√	√				
GEN PURPOSE HAND TOOLS	√		√				
MAINT WS/LS GB (GLSF)			√	√	√	√	√
MASS MEAS DEVICE - μ	√		√		√	√	
" " " - MACRO	√		√		√	√	
MICROSCOPE SYSTEM			√		√	√	√
MP GB (GLSF)	√	√	√		√	√	√
pH METER	√	√	√		√	√	
REFRIGERATOR	√		√	√	√	√	√
SPECIMEN LABELING	√		√				
ULTRAVIOLET STERILIZER	√		√		√	√	√
X-RAY SYSTEM	√		√		√	√	√

OTHER PROGRAMS

SKYLAB:

NOMINAL 90 DAY MISSIONS
LIMITED SET OF EXPERIMENTS
LIMITED FLEXIBILITY

SHUTTLE/SPACELAB:

NOMINAL 8 DAY MISSIONS
DIVERSE EXPERIMENT SETS
FLEXIBLE WITHIN BOUNDS

SALYUT/MIR:

VARIABLE STAY MISSIONS
TEST OF THE MAN
LIMITED EXPERIMENT SET
LIMITED FLEXIBILITY

REMOTE SENSING MODULE
ATMOSPHERIC SCIENCES MODULE
MATERIALS PROCESSING MODULE
ROBOTS ON-ORBIT

SPACE STATION

PMMS *LABORATORY SCIENCE ACCOMMODATION*

TELEDYNE BROWN ENGINEERING

US LAB COMMUNITY REQUIREMENTS

TBE
UNIQUE SYSTEMS

BAC
STANDARD FACILITIES
POWER
THERMAL
DATA
STRUCTURAL
ETC.

USER ENVIRONMENT

PMMS
- GAS DISTRIBUTION
- ULTRAPURE WATER
- WASTE MANAGEMENT

ACCELEROMETER

STANDARD SYSTEMS

LAB SUPPORT EQUIPMENT

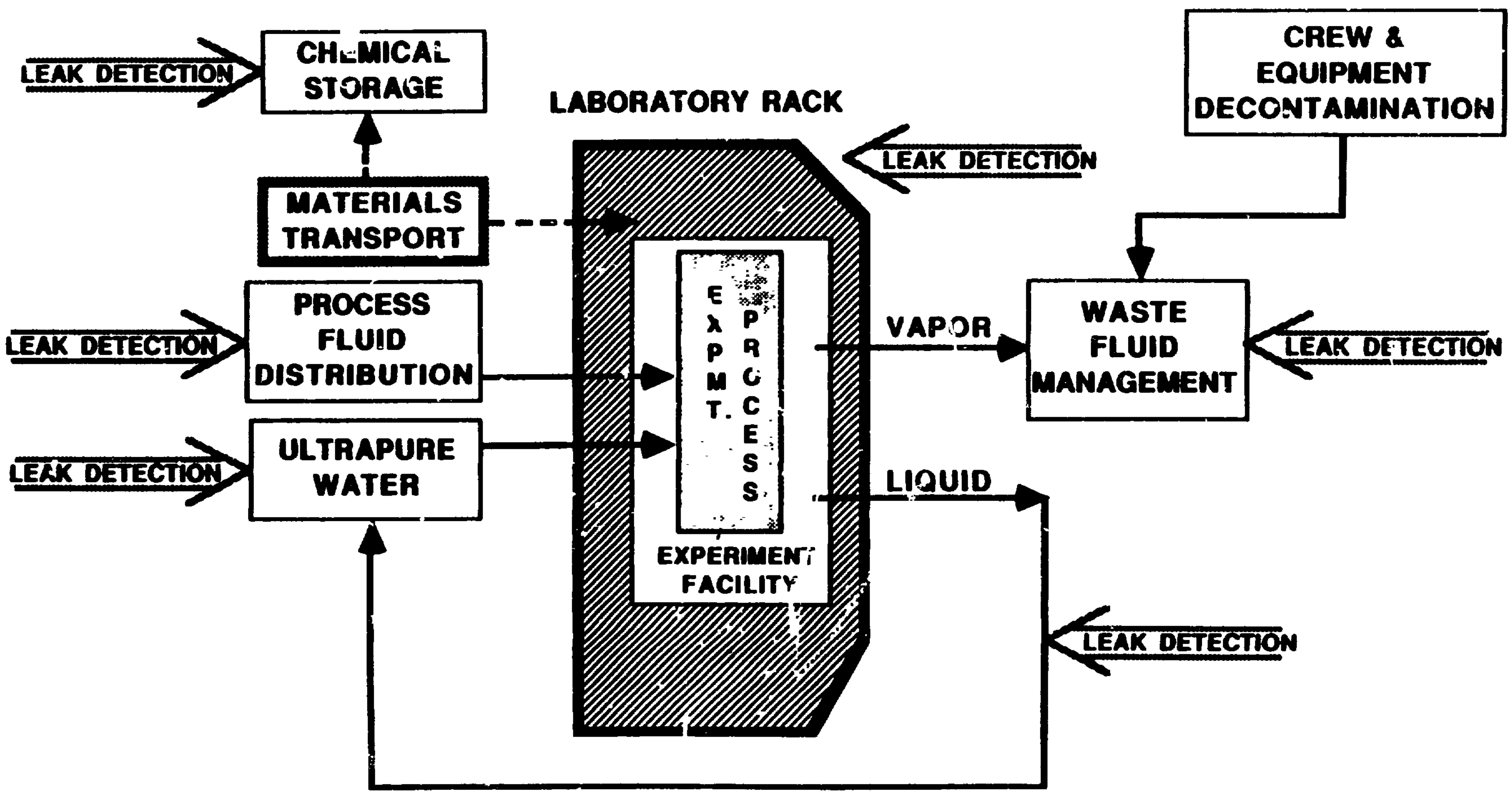
VACUUM VENT

vg-1

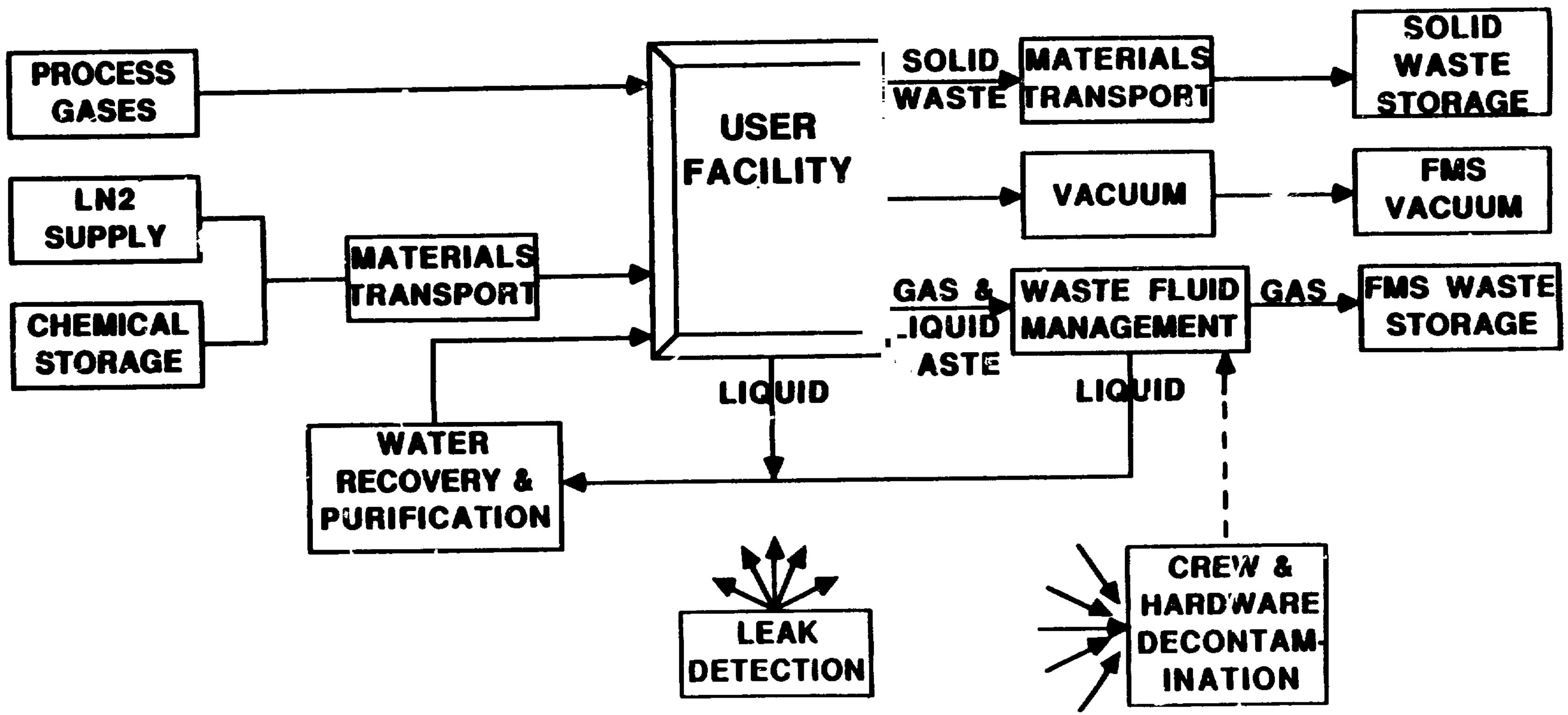
SPACE STATION

PMMS FUNCTIONAL DIAGRAM

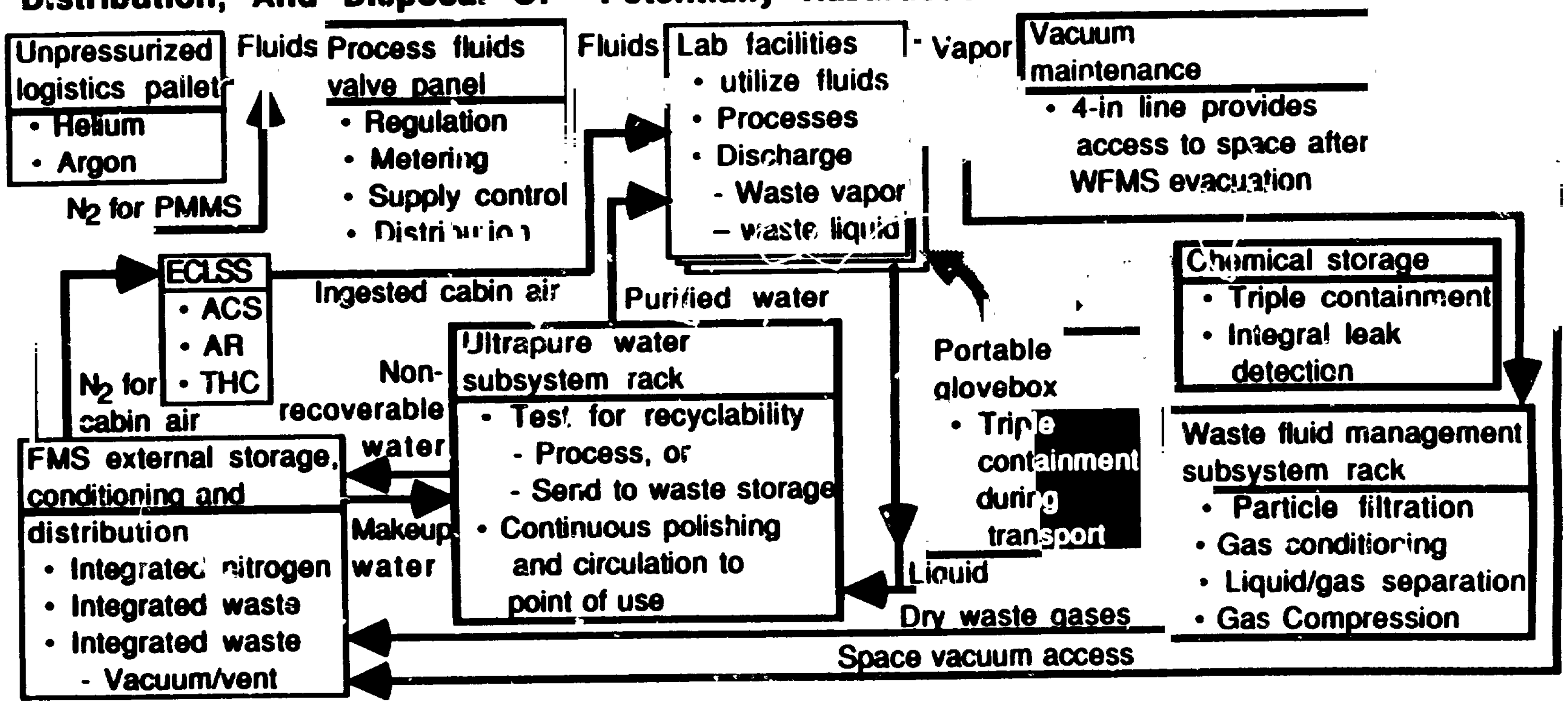
TELEDYNE BROWN ENGINEERING



USER FACILITY INTERFACES
(DIRECT & INDIRECT)



■ b **PMMS provides Safe Containment, Centralized Storage, Distribution, And Disposal Of Potentially Hazardous Materials**



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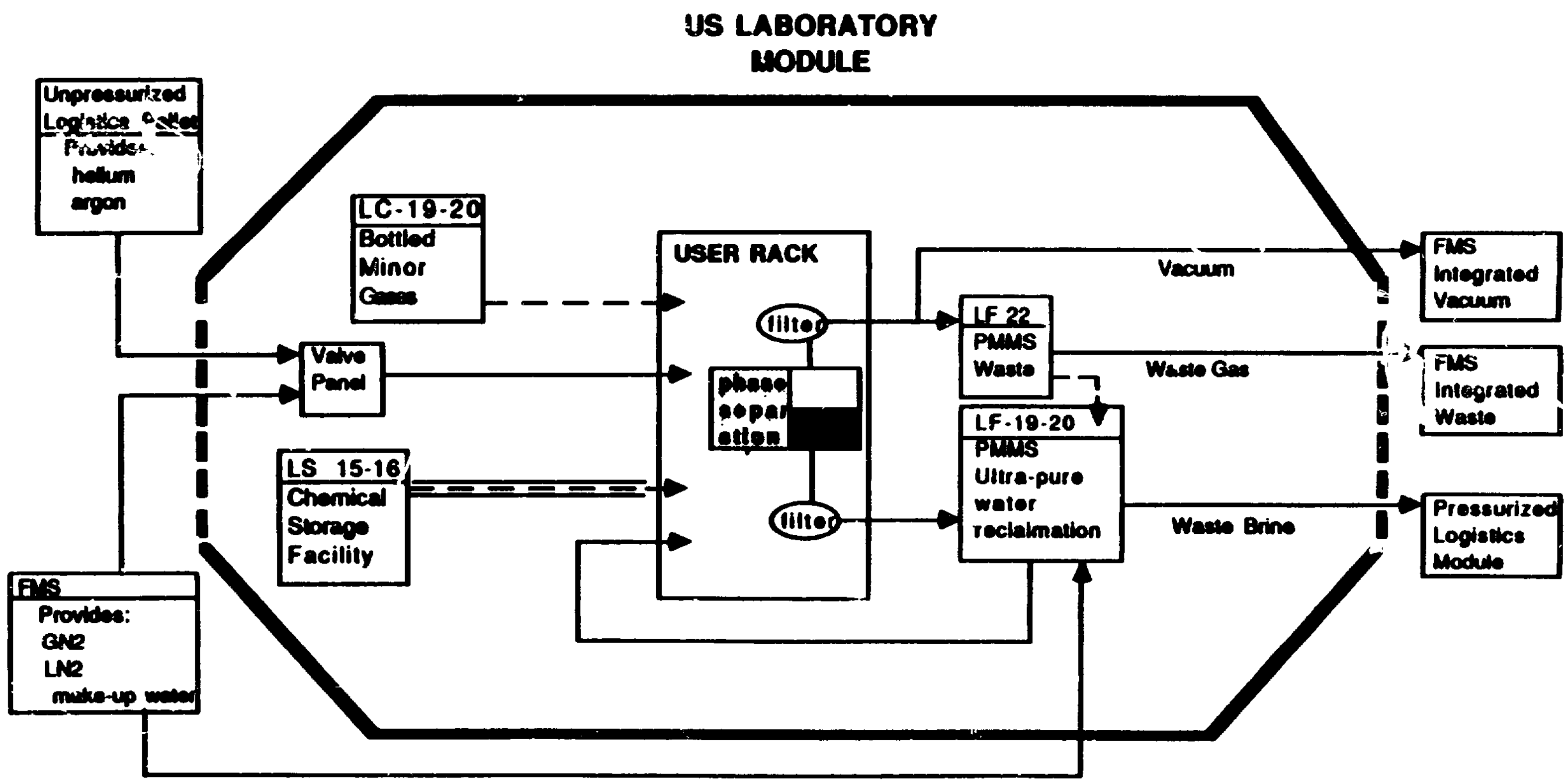
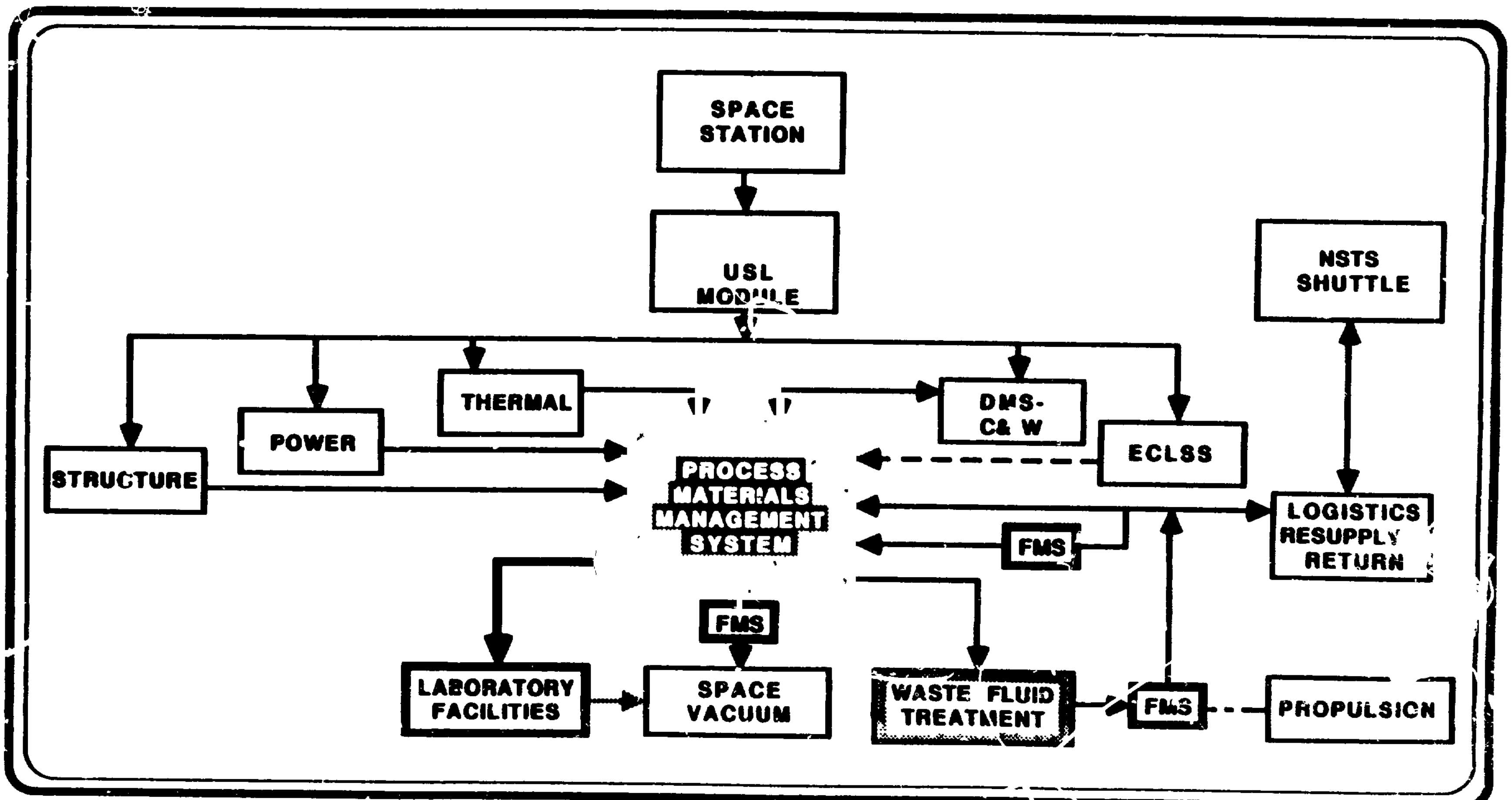
PMMS OPERATION

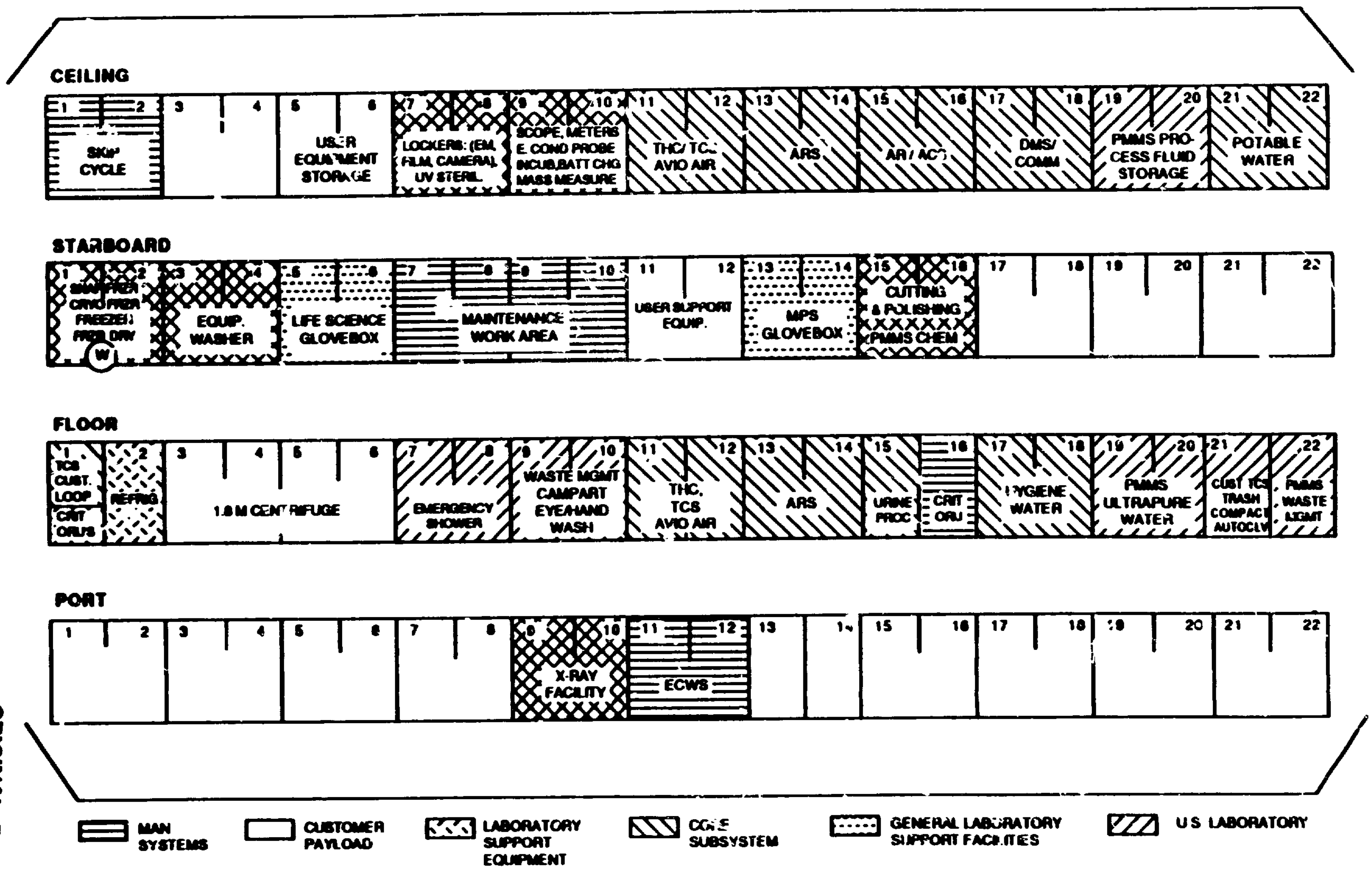
INTERNAL & EXTERNAL PMMS INTERFACES



PMMS INTERFACES



U. S. LABORATORY



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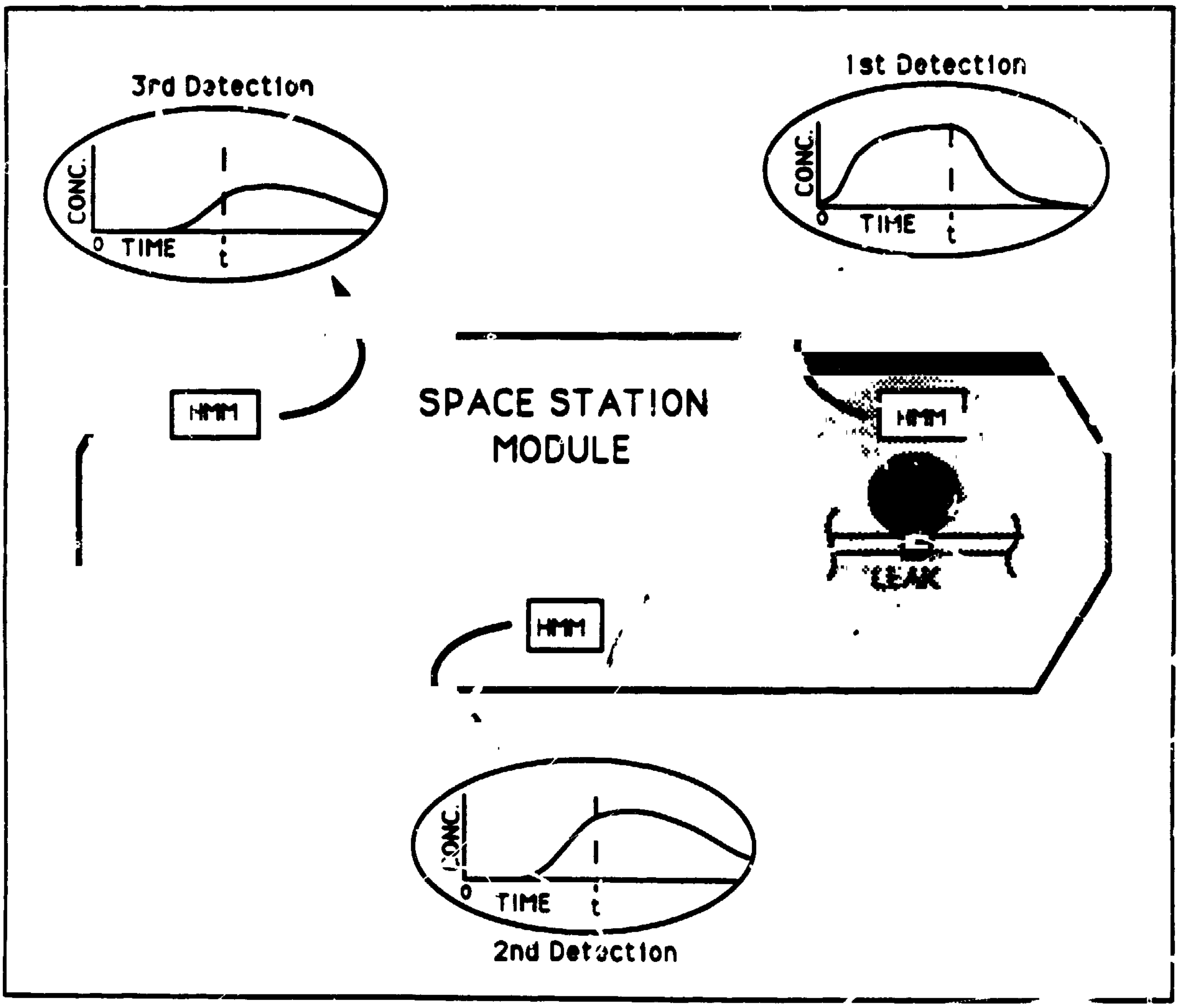
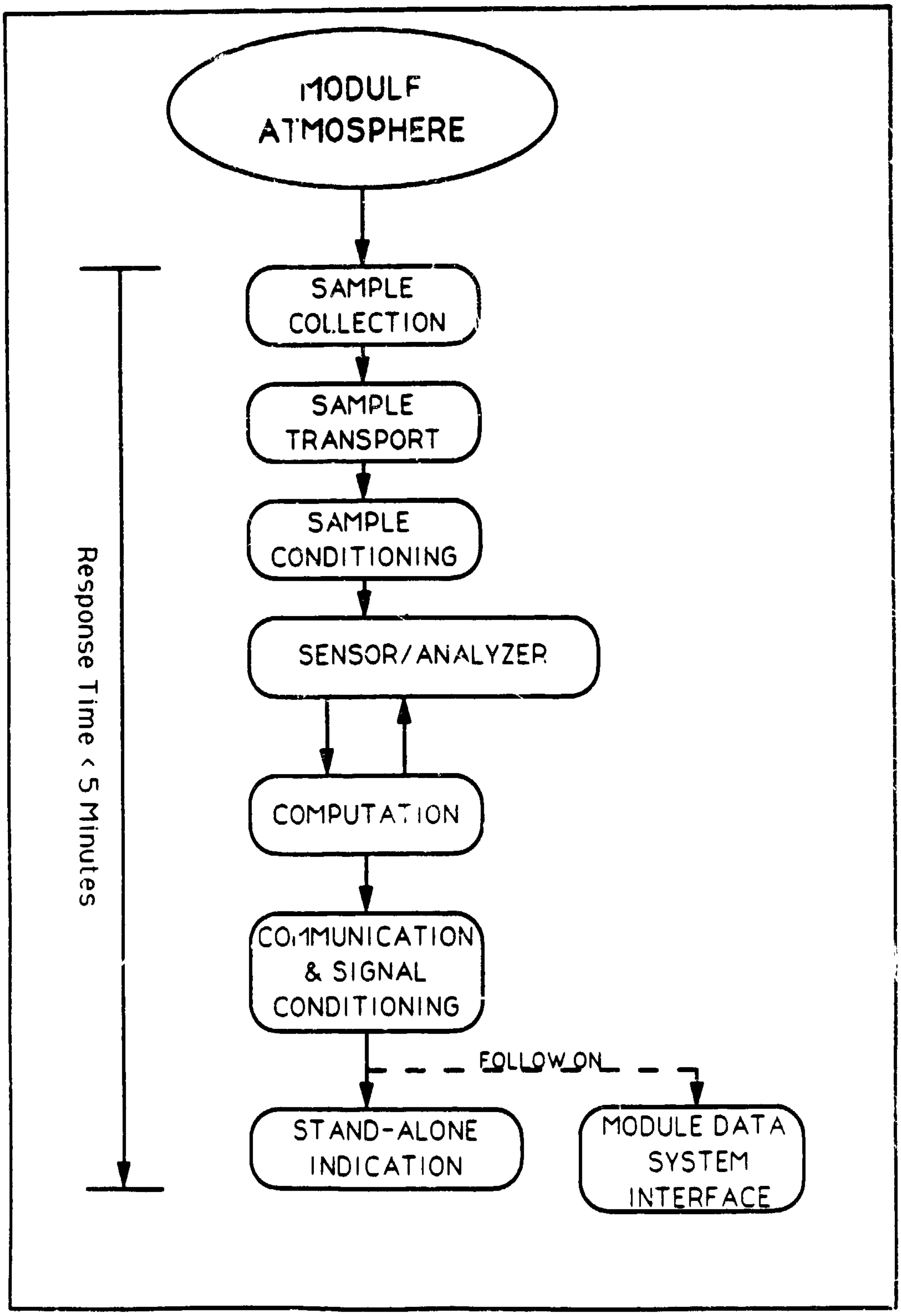
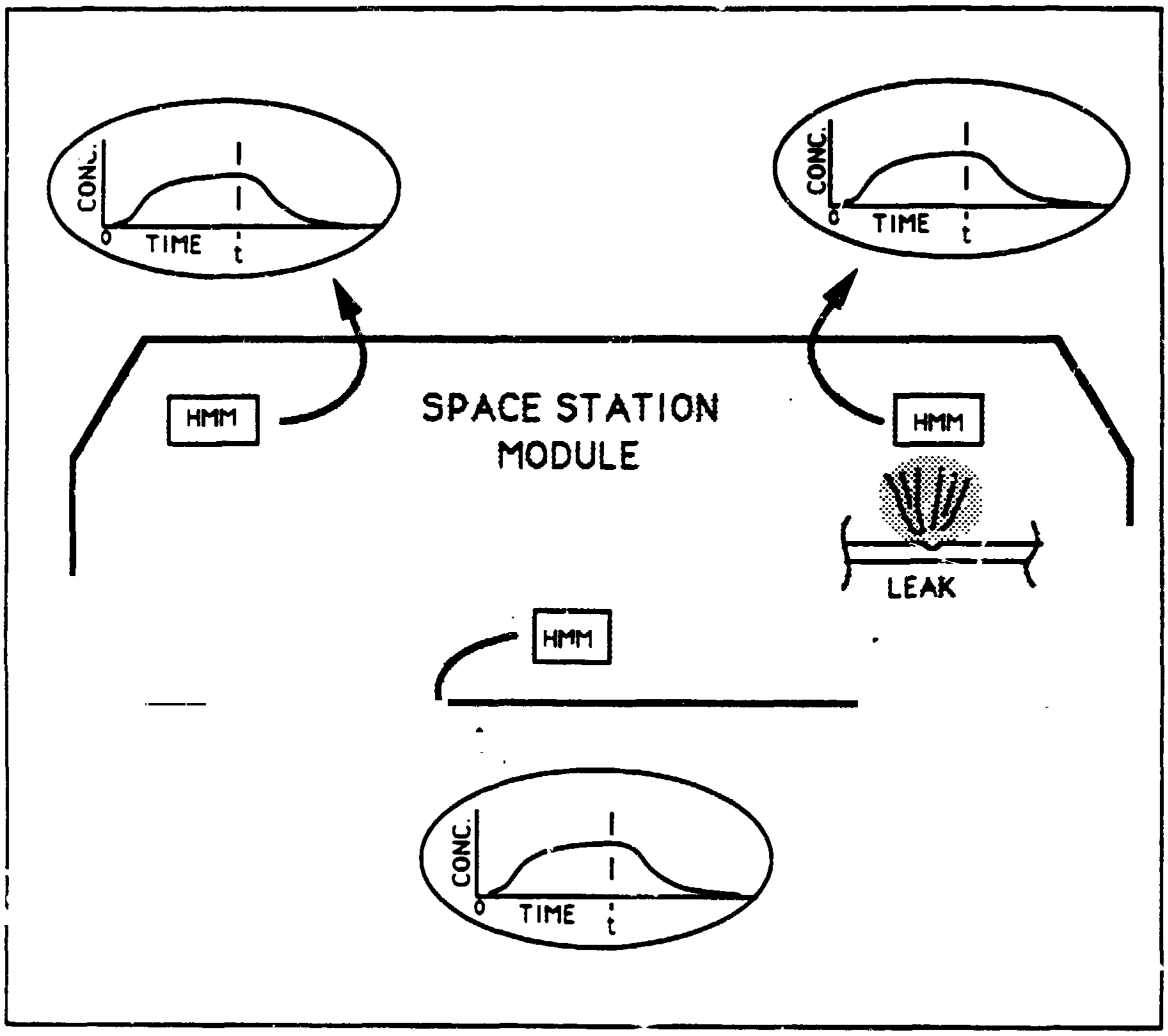
Detection & Quantification Problem (Simplified)



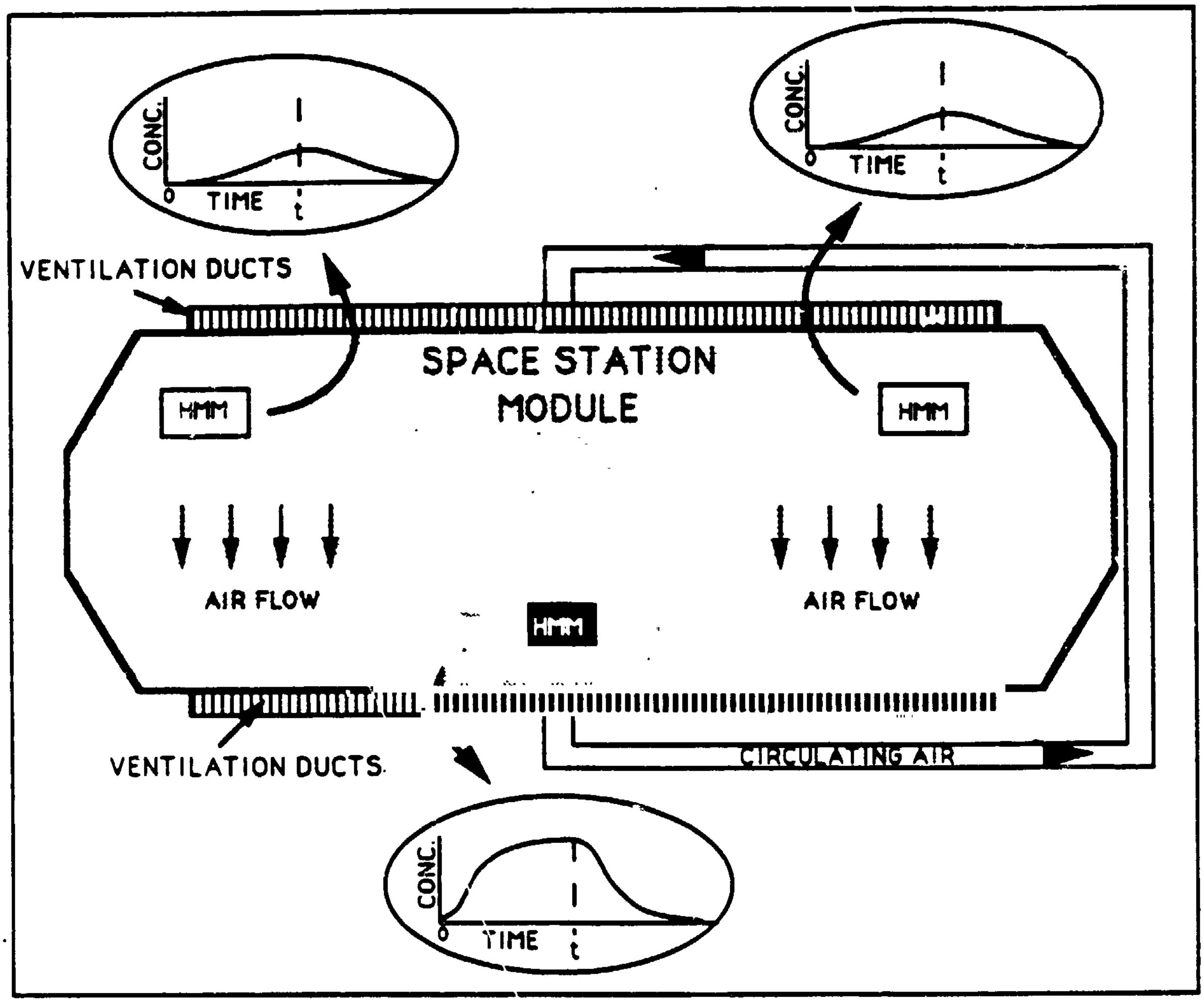
CASE 1: STAGNANT AIR

Response Time Elements



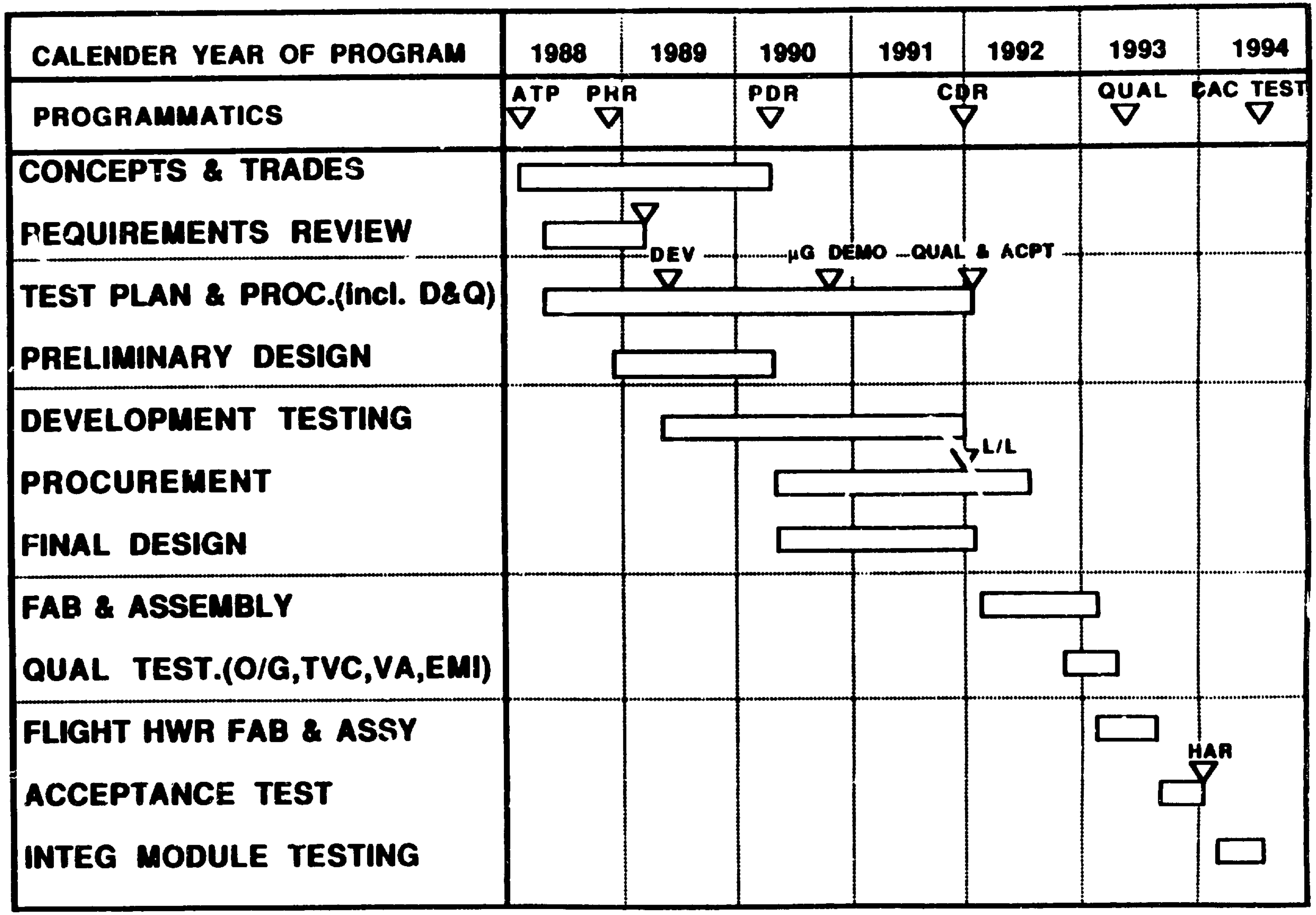


CASE 2: TURBULENT AIR

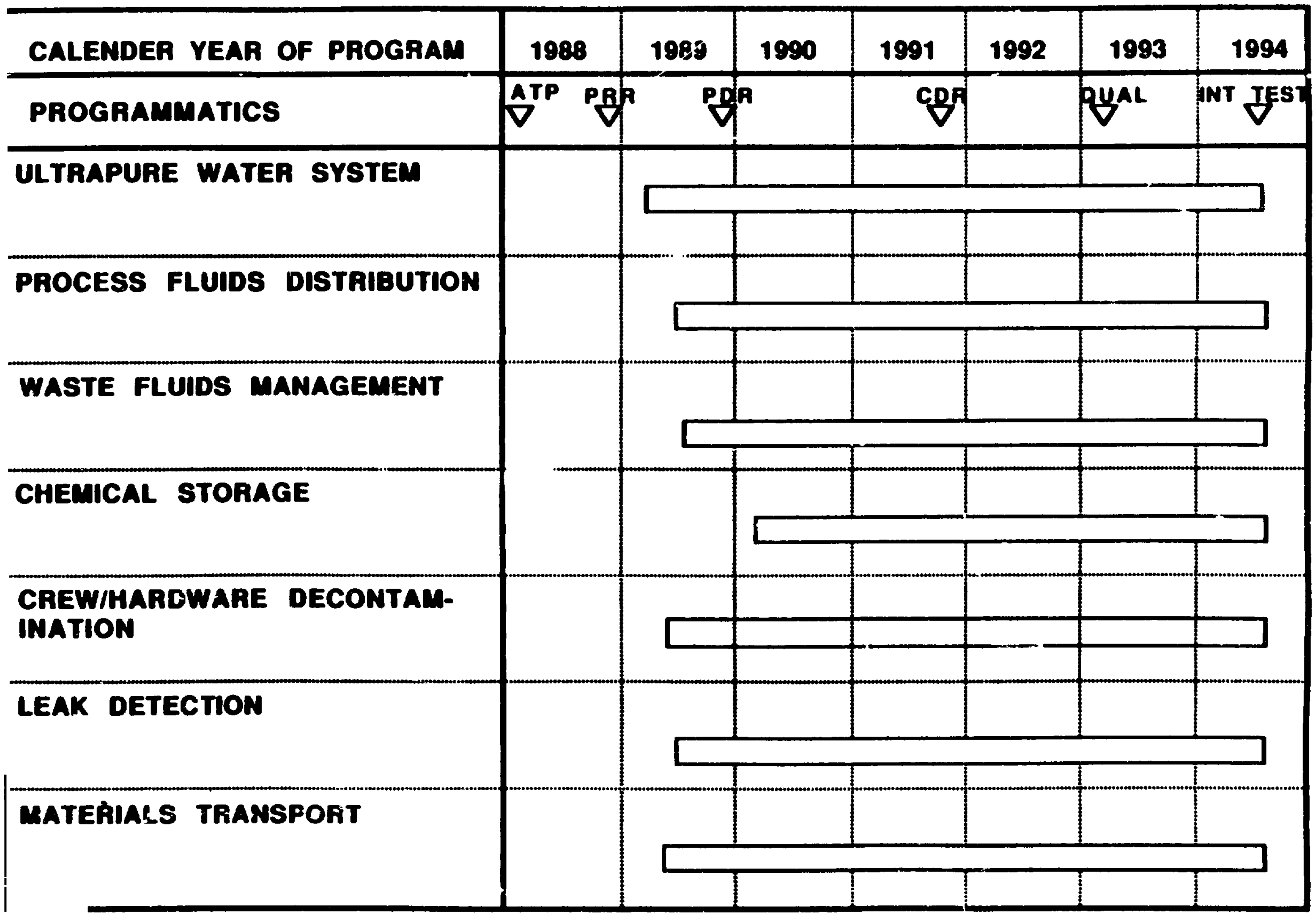


CASE 3: AIR RECYCLE

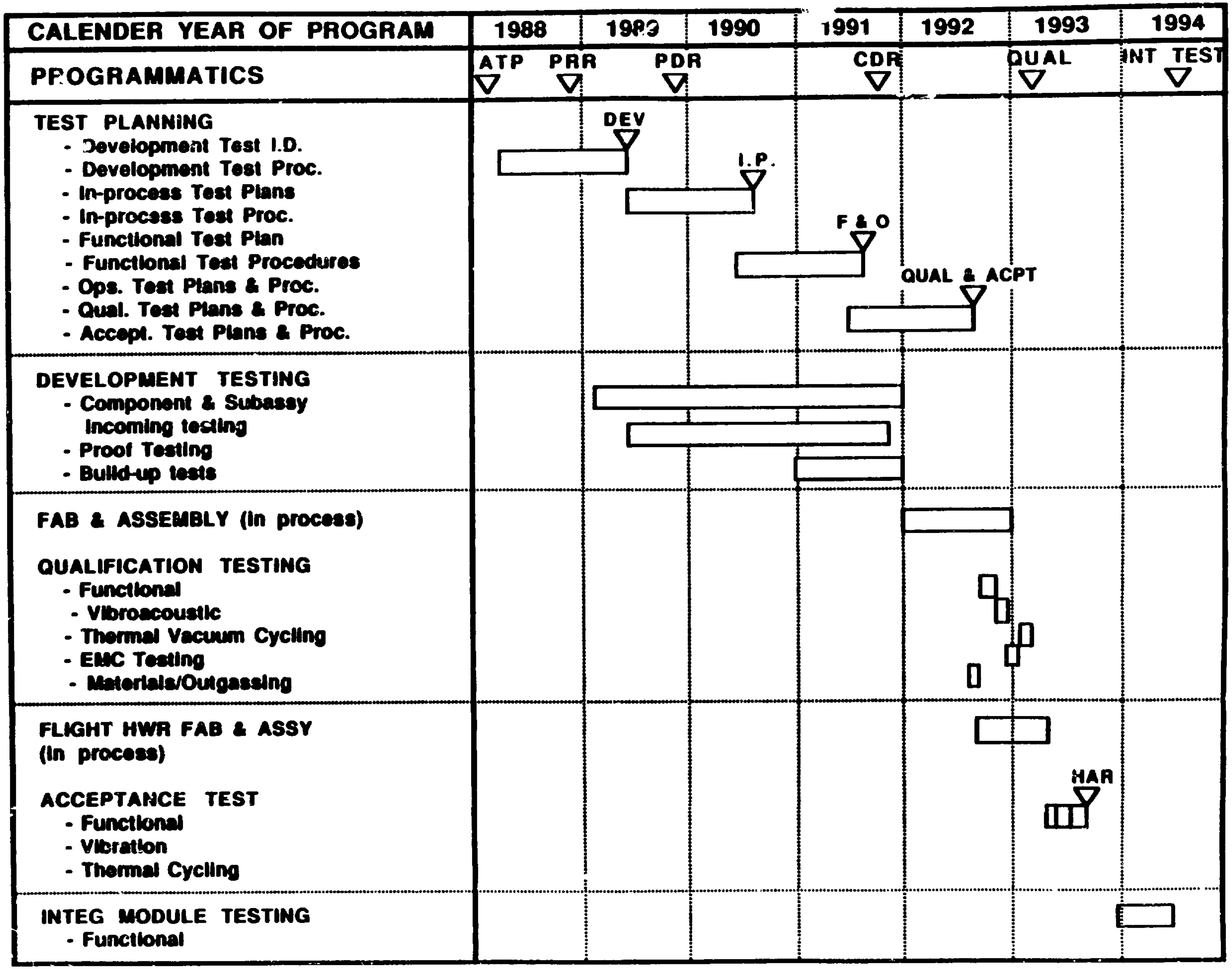
PMMS SCHEDULE
DEVELOPMENT & QUALIFICATION



PMMS DEVELOPMENT TESTING SCHEDULE



ULTRAPURE WATER SYSTEM
TEST ACTIVITIES



TYPES OF TESTING
PRIOR TO PDR

SUPPORT TO GENERIC COMPONENT/SUBASSEMBLY SELECTION
(common PMMS components - Q.D.'s, sensors, tubing...)

SELECTED COMPONENT VERIFICATION TESTS
(performance to specifications for pumps, controls, filters...)

MATERIALS COMPATIBILITY TESTING/EVALUATION
(chemical reactivity tests, samples to MSFC...)

UNIQUE DESIGN PROOF TESTS
(Q.D. & ATMOS bag dual containment, MTS seals, fluid handling tools, etc.)

pH COMPATIBILITY TESTS
(acid treatment & microscopic/SEM evaluation)

WASTE LINE CONTAMINATION AND CLEANING TESTS
(waste materials can be handled & lines cleaned between runs)

ULTRAPURE WATER MONITORING - CONTINUOUS & RELIABLE
(Total Organic Carbon(TOC), Limulus Amebocyte Lysate(LAL)...)

ULTRAPURE WATER PRODUCTION MAINTENANCE
(continuously pure production with maintenance of lines & filters)

LEAK DETECTION CAPABILITIES
(broad spectrum, sensitivity, detection software...)

ACCELEROMETER MEASUREMENTS, CALIBRATION & SOFTWARE
(prove sensitivity, spectrum, ground calibration & mapping S/W concepts)

PMMS POTENTIALLY
HAZARDOUS PROOF TESTING

* TBE PROOF TEST: WHERE COMPONENT OR ASSEMBLY FAILURE MIGHT HAVE AN ADVERSE EFFECT ON CREW SAFETY OR MISSION SUCCESS, THESE WILL BE TESTED WITH QUALIFICATION LEVEL TEMPERATURES, PRESSURES AND MATERIAL COMPATABILITY STRESSES, IN ADDITION TO ANY OTHER TEST PROCEDURES.

TYPES OF PROOF TESTING:

1) NO LEAK UNDER QUAL PRESS & TEMP'S

2) HOT/COLD FLUID TRANSFER

3) pH VARIABLE MATERIALS STABILITY

4) INTERNAL OPERATIONS CLEANLINESS

5) COMBUSTABLE SUBTANCES HANDLING

6) COMBINATIONAL STRESS TEST
   - HOT CORROSIVES & CAUSTICS UNDER PRESSURE
   - SERIAL CLEAN RUNS OF HIGHLY REACTIVE SUBSTANCES

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PMMS

SUBSYSTEM	NECESSARY FUNCTIONS
• Process Fluids Distribution	Storage, Conditioning, Distribution, Monitoring and Storage
• Ultrapure Water	Recovery, Processing, Quality Monitoring, Distribution
• Waste Fluid Management	Recovery, Processing (phase separation, filtration, gas compression, mixing, combustion), Quality Monitoring, Transportation
• Crew/Hardware Decontamination	Handle effluent from crew and hardward decontamination
• Chemical Storage	Containment, leak detection
• Leak Detection	Sample from multiple locations, analyze for anomalous conditions, deliver hazard warning, perform high-resolution analysis to identify substance(s)
• Materials Transport	Mobile Containment Unit (with manipulative access)

PMMS CRITICAL DEVELOPMENT AREAS

DUE TO IT'S NATURE AS A CENTRALIZED SYSTEM WITH DISTRIBUTION LINES, THE PHYSICAL AND FUNCTIONAL PARAMETERS OF THE PMMS WILL LEVEY REQUIREMENTS ON THE MODULE & CORE SYSTEMS, LOGISTICS, USER FACILITIES, AND INTEGRATED FMS. IN ADDITION, RISK WILL MANDATE EARLY PMMS DEVELOPMENT TESTING IN THE INDICATED AREAS:

PROCESS FLUIDS DISTRIBUTION:

THE ON ORBIT DELIVERY OF CRYOGENS IS A NEW AND UNTESTED TECHNOLOGY. THE METHOD OF APPLICATION IS NOT WELL DEFINED.

- POWER DEMANDS FOR CRYOGEN PRODUCTION & STORAGE
- TRANSPORT & DELIVERY FOR TEMPERATURE SENSITIVE, TWO PHASE FLUID IN ZERO-G
- STORAGE BOIL-OFF
- CONVERSION EFFICIENCY

CHEMICAL STORAGE:

A NUMBER OF SAFETY RELATED CONCEPTS GENERATE CONTRADICTOR DESIGN REQUIREMENTS. (e.g.)

- CHEMICAL STORAGE CONTINGENCY VENTING NEGATES SPECIES ISOLATION
- ACCESS & USE BREAKS TRIPLE CONTAINMENT AT SOME POINT
- ACTIVE STORAGE & LEAK DETECTION NEGATES TRIPLE CONTAINMENT BY REQUIRING RACK AVIONICS AIR
- HYPOBARIC STORAGE PROMOTES CONTAINER LEAKAGE
- CHEMICAL SPECTRUM COMPLICATE PASSIVE LEAK DETECTION & CONTAINER COMMONALITY

PMMS CRITICAL DEVELOPMENT AREAS (CONTINUED)

MATERIALS TRANSPORT:

THE MULTIPLICITY OF FUNCTIONS TO ACCOMMODATE AND THE NECESSITY TO INTERFACE WITH MANY FACILITIES COMPLICATES CONFIGURATION AND SIZING.

- MECHANICAL INTERFACE DESIGN TO PREVENT LEAKAGE INTO THE CABIN
- MATERIALS SELECTION TO RESIST MULTIPLE THREAT ENVIRONMENTS
- CLEANING TO PRECLUDE CROSS CONTAMINATION

ULTRAPURE WATER:

RECLAMATION OF WASTE WATER AND PROCESSING TO HIGH PURITY ARE TWO DISTINCT PROCESSES

- BOTH ARE COMPLICATED BY THE UNDEFINED QUALITY OF THE FEED WATER.
- USER INTERFACES MUST BE DEFINED PRIOR TO INITIATION OF FACILITY DESIGN.
- INSTRUMENTATION FOR ONLINE QUALITY MONITORING IS A DEVELOPMENT ISSUE
- POWER CONSUMPTION, THROUGHPUT, QUALITY, AND RECOVERY EFFICIENCY MUST BE SIMULTANEOUSLY OPTIMIZED.

PMMS CRITICAL DEVELOPMENT AREAS (CONTINUED)

WASTE MANAGEMENT:

THE UNCONSTRAINED NATURE OF THE CHEMICALLY AGGRESSIVE AND POTENTIALLY HAZARDOUS WASTE STREAM IMPOSES COMPLEX DESIGN/DEVELOPMENT ISSUES.

- PUMP/COMPRESSOR DESIGN FOR CHEMICALLY AGGRESSIVE ENVIRONMENT
- LOW PROFILE VACUUM RATED VALVES AND QD'S FOR CHEMICALLY AGGRESSIVE ENVIRONMENT
- SEALS (DESIGN & MATERIALS) TO WITHSTAND CHEMICALLY AGGRESSIVE ENVIRONMENT
- ANALYSIS TO REDUCE RISK OF MIXING UNCONSTRAINED WASTE STREAMS
- TEST & EVALUATE CANDIDATE COMBUSTION TECHNOLOGIES TO REDUCE REACTIVE POTENTIAL OF MIXED WASTE STORAGE
- ESTABLISH COMPONENT LIFE EXPECTANCIES & ACCEPTABLE DESIGN MARGINS
- DEVELOP ORU CHANGEOUT PROCEDURES WHICH PROVIDE APPROPRIATE CONTAINMENT
- DEVELOP & VERIFY CLEANING METHODS
- MAJOR INTERFACES WITH THE FMS MUST BE RESOLVED IN PARALLEL WITH FMS DEVELOPMENT

PMMS CRITICAL DEVELOPMENT AREAS (CONTINUED)

LEAK DETECTION:

A SAFETY CRITICAL FUNCTION WITH UNCONSTRAINED CHALLENGE. MUST DEFINE ECLSS, PMMS, AND USER RESPONSIBILITIES WITH AN APPROPRIATE DEGREE OF OVERLAP. ESTABLISH ONE OR MORE TECHNOLOGIES WHICH WILL:

- DETECT A NEAR INFINITE RANGE OF CHEMICAL SUBSTANCES AT EXTREMELY LOW LEVELS
- PROVIDE TIMELY ALERT TO PROTECT CREW & INITIATE CONTINGENCY MEASURES
- AID ECONTINGENCY PLANNING WITH MATERIAL IDENTIFICATION, SOURCE LOCATION, AND THREAT EVALUATION
- VERIFY EFFECTIVENESS OF CONTINGENCY MEASURES PRIOR TO RESUMPTION OF NORMAL LAB OPERATIONS

CREW & HARDWARE DECONTAMINATIO

ANOTHER SAFETY CRITICAL FUNCTION. MAY HAVE TO OPERATE IN A DEGRADED RESOURCE ENVIRONMENT.

- ENVELOPE UNDEFINED CHALLENGES WITH MINIMAL HARDWARE
- DEFINE PROCEDURES AND ESTABLISH CAPABILITY LIMITS

PMMS & USL KEY CHALLANGES

- **PMMS DESIGN FOR TRIPLE CONTAINMENT TO INSURE SAFETY DURING POTENTIALLY HAZARDOUS OPERATIONS**

- **NUMEROUS COMPLEX INTERFACES:**
  - LOGISTICS
  - USER FACILITIES
  - MODULE "CORE" SYSTEMS
  - FLUIDS MANAGEMENT SYSTEM

- **ON-ORBIT INTEGRATION OF LINES AND RACKS WITH POTENTIAL FOR LEAKS FROM SYSTEMS HANDLING HAZARDOUS MATERIALS**

- **NEW TECHNOLOGIES OR NEW ON-ORBIT ACTIVITIES:**
  - CRYOGEN MANUFACTURE, DELIVERY AND USE IN μG ENVIRONMENT
  - BROAD SPECTRUM CHEMICAL STORAGE ISOLATION METHODS
  - CHEMICAL/SAMPLE TRANSPORT MECHANISM WITH MULTIPLE INTERFACES
  - CONTINUOSLY ON-LINE WATER QUALITY MONITORING INSTRUMENTATION
  - SERIAL HANDLING TECHNIQUES & ANALYSES FOR CHEMICAL WASTES
  - COMPONENTS NECESSARY TO OPERATE IN HARSH CHEMICAL ENVIRONMENT
  - RAPID, SENSITIVE & BROAD SPECTRUM LEAK DETECTION IN μG
  - TEST & OPERATIONAL PROCEDURE DEVELOPMENT TO INSURE SAFE OPS OF POTENTIALLY HAZARDOUS MATERIALS

FLUID MANAGEMENT SYSTEMS (FMS) DESCRIPTION AND ISSUES

Presentation to

SPACE STATION FREEDOM
TOXIC AND REACTIVE MATERIALS HANDLING
WORKSHOP

November 30, 1988

G.R. Schmidt
FMS Systems Engineer
Level II/ PSC
Booz•Allen & Hamilton

AGENDA

- INTRODUCTION
  - Overview of FMS
  - Rationale for Integration

- PROCESS FLUID SUPPLY
  - Integrated Nitrogen System (INS)
  - Integrated Water System (IWS)
  - Other Potential Integrated Process Fluid Systems

- WASTE HANDLING
  - Integrated Waste Gas System (IWGS)

- CONCLUSIONS
  - Acronym List

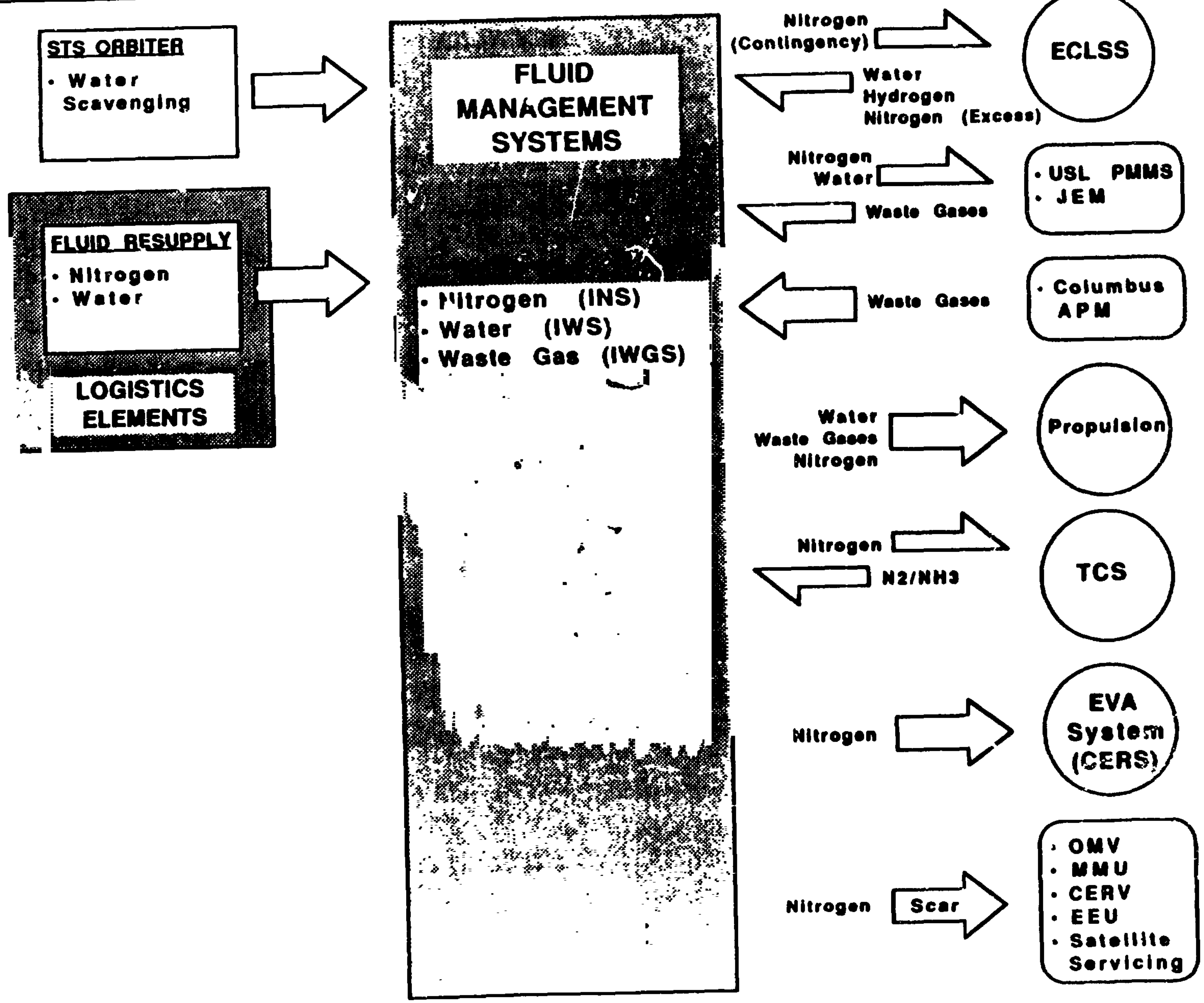
OVERVIEW OF FMS

- FMS PROVIDES INTEGRATED FLUID RESOURCES TO ELEMENTS AND SYSTEMS OF FREEDOM MANNED BASE
  - 1 of 9 Baselined Distributed Systems
  - Responsible for Handling Nitrogen, Water and Waste Gases
  - Potential for Addition of Other Integrated Systems

- FMS DESIGN AND OPERATION SIGNIFICANTLY INFLUENCED BY:
  - Design and Operational Characteristics of Interfacing Elements and Systems
  - Fluid Resupply and Disposal Requirements of Users

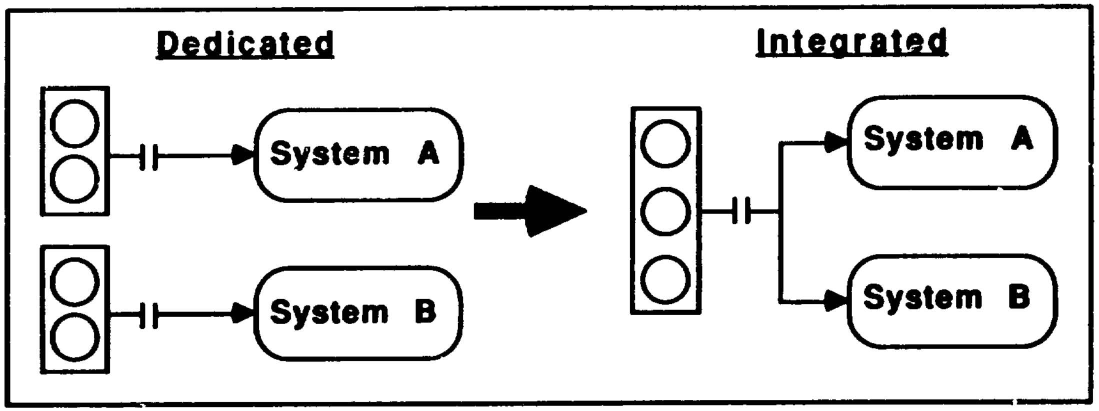
- RECENT FMS WORKING GROUP PROPOSED MANY CHANGES IN ARCHITECTURE
  - Addition of More Functional and Design Detail
  - Resolution of Many Overlap Issues with Other Systems
  - Changes in Partitioning of Responsibilities Between FMS, ECLSS and Labs

PRINCIPAL FMS INTERFACES



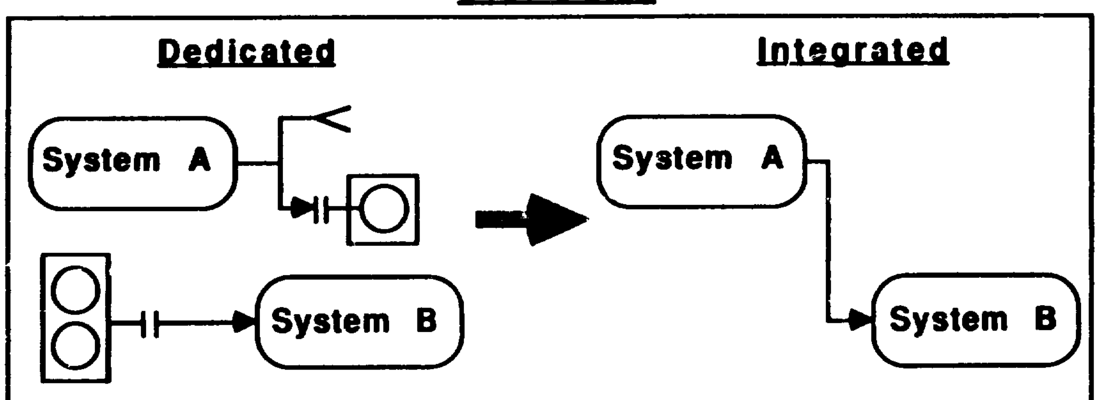
RATIONALE FOR FLUIDS INTEGRATION

RESUPPLY



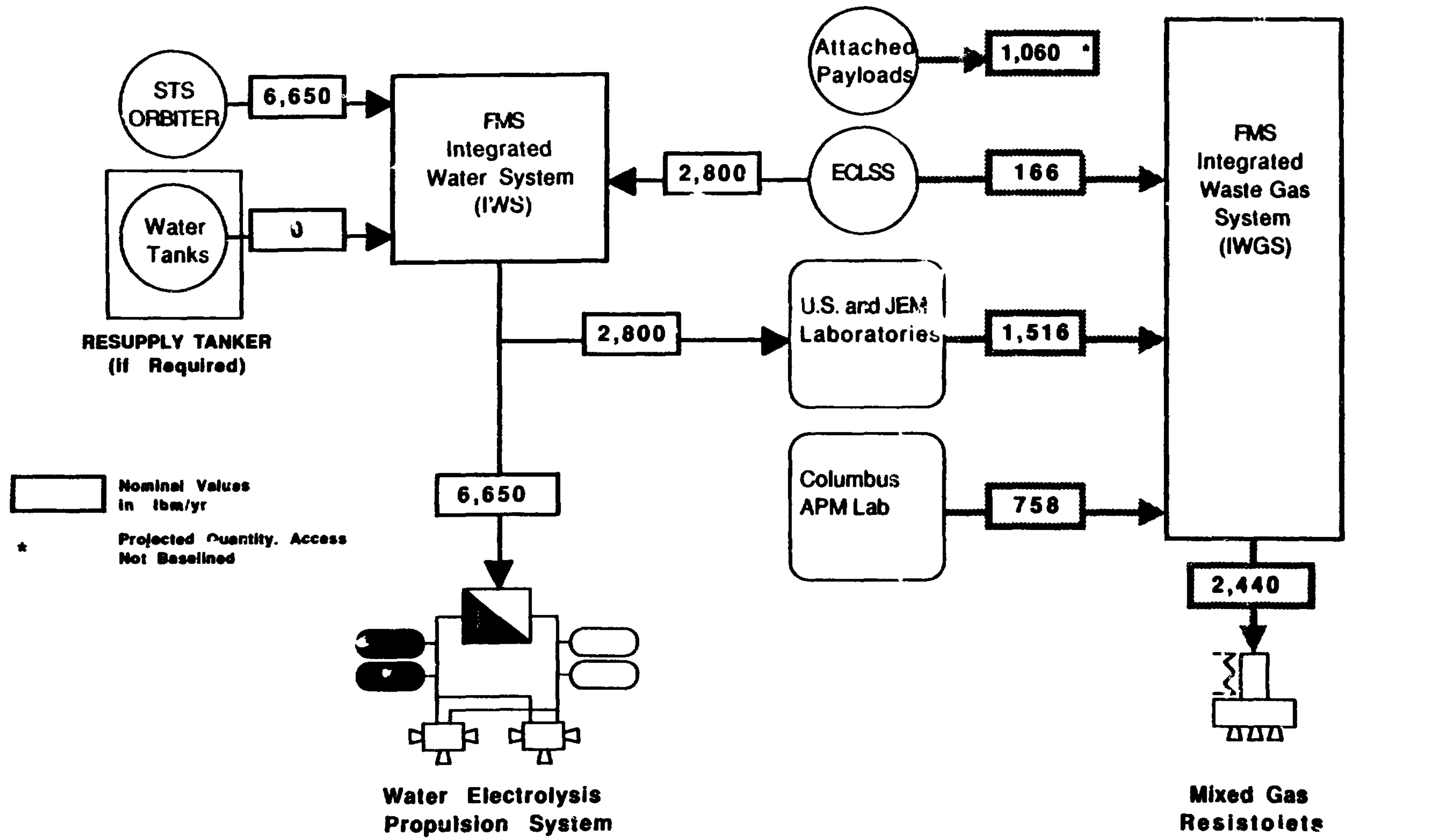
- REDUCTION IN OVERALL DISTRIBUTION HARDWARE
- INCREASE IN RESUPPLY HARDWARE MASS EFFICIENCY
- REDUCTION IN ON-ORBIT TANK CHANGEOUT AND OPERATIONS

DISPOSAL



- REDUCTION IN OVERALL DISTRIBUTION AND DISPOSAL HARDWARE
- REDUCTION IN SYSTEM B RESUPPLY COSTS
- REDUCTION IN ON-ORBIT S/S SUPPORT OPERATIONS AND DOWNSUPPLY DEMAND

EXAMPLE OF INTEGRATED FLUIDS USAGE



INTEGRATION OF WATER AND WASTE GAS HANDLING SIGNIFICANTLY REDUCES RESUPPLY COSTS

AGENDA

- INTRODUCTION
  - Overview of FMS
  - Rationale for Integration

- PROCESS FLUID SUPPLY
  - Integrated Nitrogen System (INS)
  - Integrated Water System (IWS)
  - Other Potential Integrated Process Fluid Systems

- WASTE HANDLING
  - Potential Additional Systems

- CONCLUSIONS
  - Acronym List

INTEGRATED NITROGEN SYSTEM (INS) DESCRIPTION

FUNCTIONAL REQUIREMENTS

- PROVIDES NITROGEN GAS TO THE FOLLOWING:
  - USL and JEM Fluid Systems for Experiments
  - ECLSS for Emergency Storage Makeup and Extra Contingency
  - IWS for Node Water Tank Pressurant Control
  - External TCS for Ammonia Loop Purge
  - EVA System Crew Equipment Retrieval System (CERS) for Propellant
  - Propulsion for Electrolysis Unit Pressurization
  - IWGS for Disposal Access

- PROVIDES SCAR INTERFACES FOR FUTURE HIGH PRESSURE USERS
  - Manned Maneuvering Unit (MMU) Propellant
  - Extravehicular Excursion Unit (EEU) Propellant
  - Crew Emergency Rescue Vehicle (CERV) Propellant
  - Orbital Maneuvering Vehicle (OMV) and Satellite Servicing Pressurant

KEY FEATURES

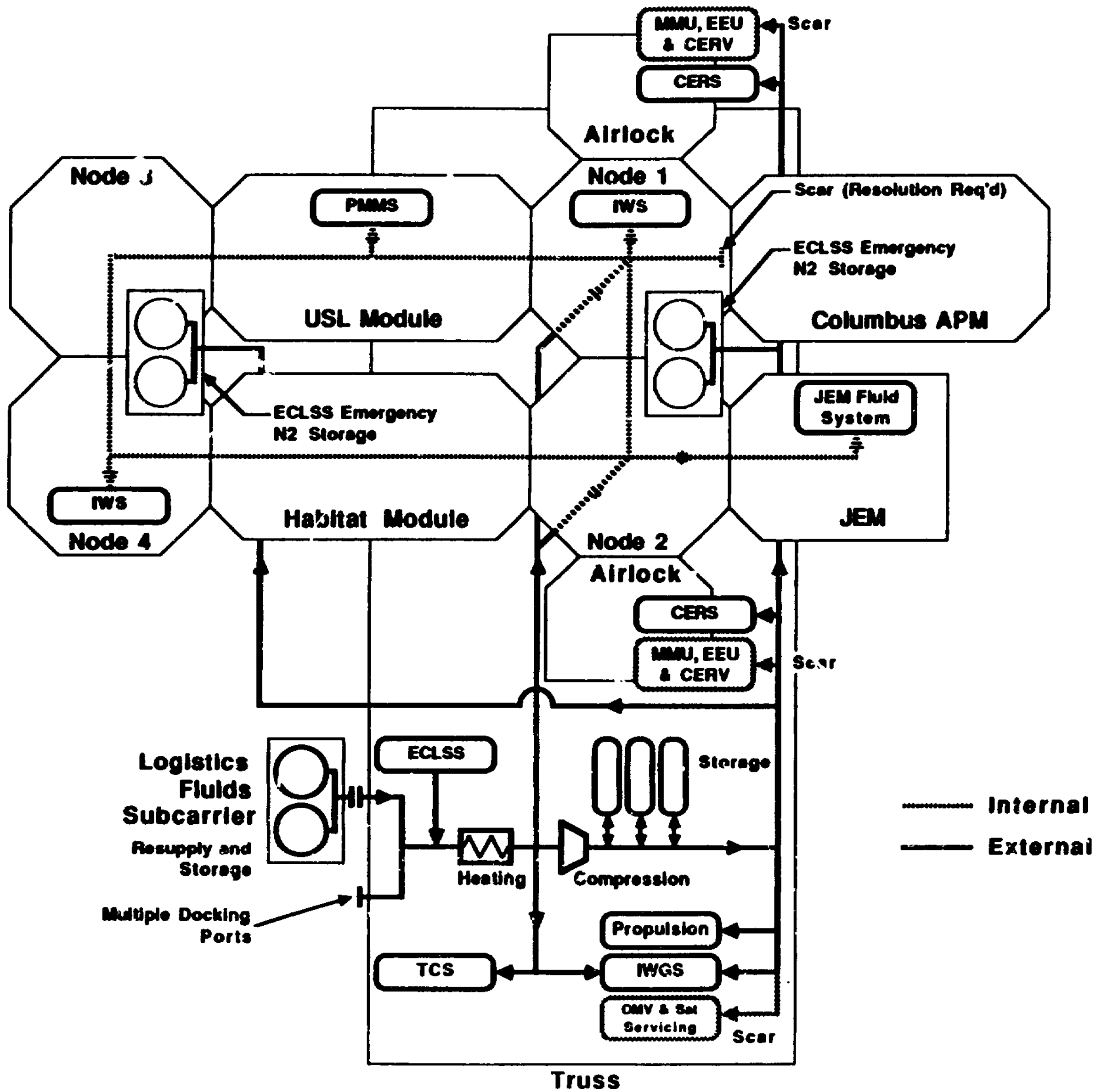
- RESUPPLY OF N_2 VIA SUPERCRITICAL CRYOGENIC STORAGE TANKS IN UNPRESSURIZED LOGISTICS CARRIER (Fluids Subcarrier)

- THERMAL EXPANSION, HEATING AND TRANSFER TO INTERNAL AND LOW PRESSURE USERS

- COMPRESSION AND HIGH PRESSURE STORAGE ON TRUSS FOR HIGH PRESSURE USERS

- INTERNAL AND EXTERNAL DISTRIBUTION LINES

INS ARCHITECTURE



INS SUMMARY

FEATURES THAT MITIGATE SAFETY, CONTAMINATION AND COST IMPACTS

- SEPARATE ECLSS NITROGEN SUPPLY
  - Eliminate Possibility of Lab/ECLSS Cross-Contamination
  - Establish ECLSS End-to-End Control of Nitrogen Supply
  - Add ECLSS Access to INS Nitrogen in Event of Emergency

- HIGH PRESSURE NITROGEN STORAGE ON TRUSS
  - 6,000 psi Required for Baseline and Growth Users
  - External Location to Minimize Impact of Catastrophic Failure

- ALL INS DISPOSAL ROUTED THROUGH WASTE GAS SYSTEM (IWGS)

CURRENT ISSUES

- NO PROVISION FOR TRANSFER OF CRYOGENIC LIQUID OR GAS TO LABORATORIES
  - No Clear Requirement
  - Responsibility of Laboratory Element or User

- GROUND HANDLING OF RESUPPLY SUBSYSTEM SUPERCRITICAL NITROGEN
  - Ground Hold Requirement Major Design Driver on Tanks

- REMOVAL OF NITROGEN SUPPLY TO COLUMBUS APM PAYLOADS
  - No PMMS-type Process Fluid Supply in Columbus APM
  - Raises Issues With Standardization of Payload Interfaces

INTEGRATED WATER SYSTEM (IWS) DESCRIPTION

FUNCTIONAL REQUIREMENTS

- COLLECTS EXCESS WATER PRODUCED BY ON-ORBIT SYSTEMS (ELIMINATES POTENTIAL VENTING, DUMPING OR RETURN)
  - Water Product from NSTS Orbiter Fuel Cells
  - Discarded ECLSS Hygiene Water

- PROVIDES WATER TO ON-ORBIT CONSUMERS
  - USL PMMS and JEM
  - Propulsion Electrolysis Units

- RECEIVES MAKEUP WATER FROM LOGISTICS IN EVENT OF NET WATER DEFICIT
  - Unpressurized Logistics Carrier (ULC) Fluids Subcarrier
  - Pressurized Logistics Carrier

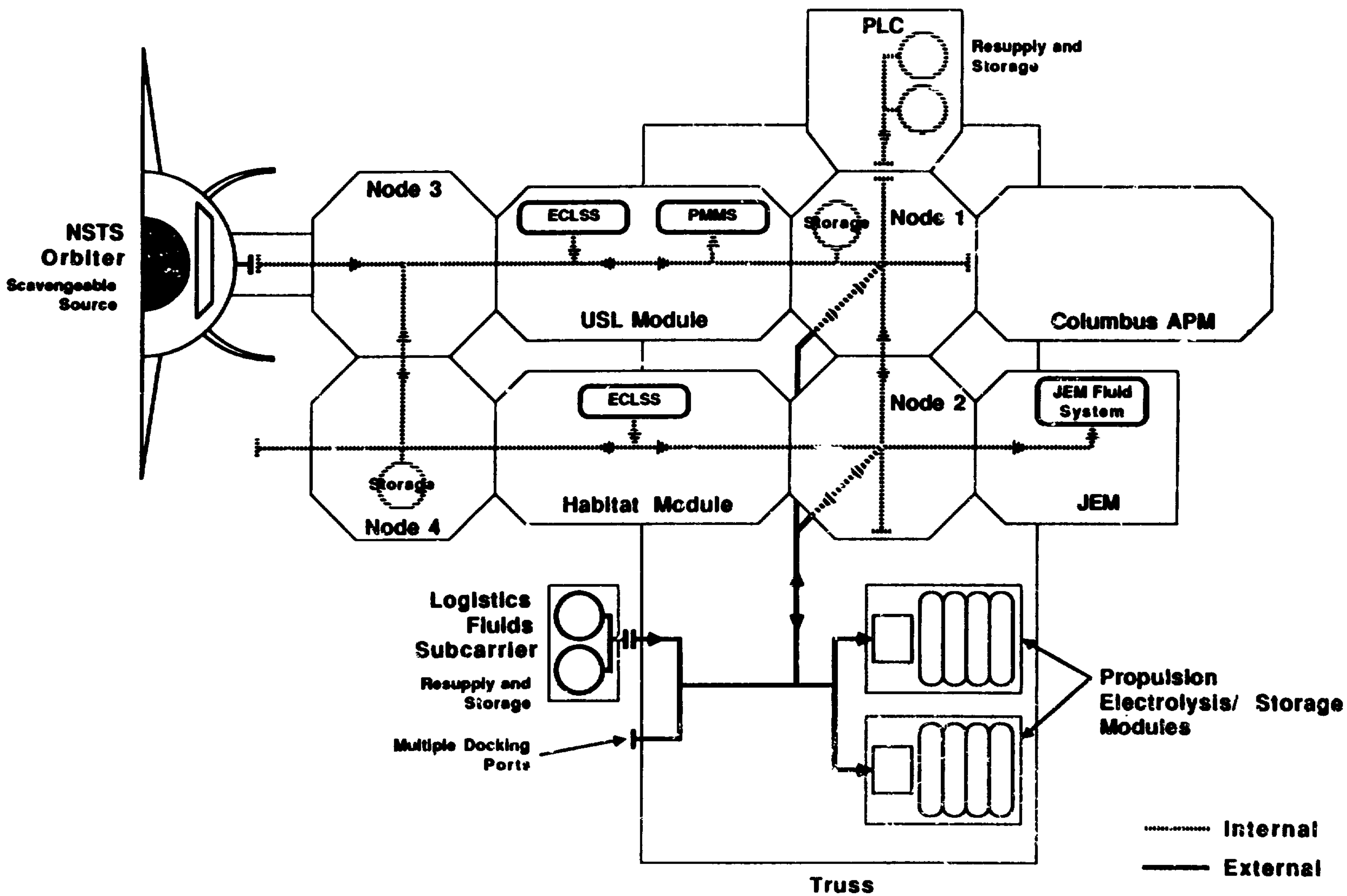
KEY FEATURES

- ORBITER WATER SCAVENGING EQUIPMENT IN NODES 3 AND 4

- INTERNAL WATER LOOP AND EXTERNAL DISTRIBUTION THROUGH NODES 1 AND 2

- WATER STORAGE IN NODES 1 AND 4

IWS ARCHITECTURE



IWS SUMMARY

FEATURES THAT MITIGATE SAFETY, CONTAMINATION AND COST IMPACTS

- SEPARATE FMS AND ECLSS WATER LOOPS
  - Autonomous IWS Storage in Nodes
  - Design Features to Prevent Backflow of Contaminants Across ECLSS/FMS Interface
- DIRECT ACCESS TO ORBITER WATER BY ECLSS
  - Separate ECLSS Scavenging Equipment
  - Allows Flushing of ECLSS Water Loops

CURRENT ISSUES

- REMOVAL OF WATER SUPPLY TO COLUMBUS APM PAYLOADS
  - No PMMS-type Process Fluid Supply in Columbus APM
  - Raises Issues With Standardization of Payload Interfaces

ADDITIONAL POTENTIAL INTEGRATED FLUID SYSTEMS

- **INTEGRATED LABORATORY SUPPLY**
  - Argon
  - Helium

  Favorable Reductions in Resupply and On-Orbit Hardware Costs

  - CO_2
  - Krypton
  - Oxygen

  Small Quantities May Not Justify Integration

- **ECLSS BACKUP OXYGEN**
  - Implement Access to Propulsion High Pressure Oxygen by ECLSS (Emergency Backup Only)
  - Similar to ECLSS/INS High Pressure Interface

AGENDA

- **INTRODUCTION**
  - Overview of FMS
  - Rationale for Integration

- **PROCESS FLUID SUPPLY**
  - Integrated Nitrogen System (INS)
  - Integrated Water System (IWS)
  - Other Potential Integrated Process Fluid Systems

- **WASTE HANDLING**
  - Potential Additional Systems

- **CONCLUSIONS**
  - Acronym List

INTEGRATED WASTE GAS SYSTEM (IWGS) DESCRIPTION

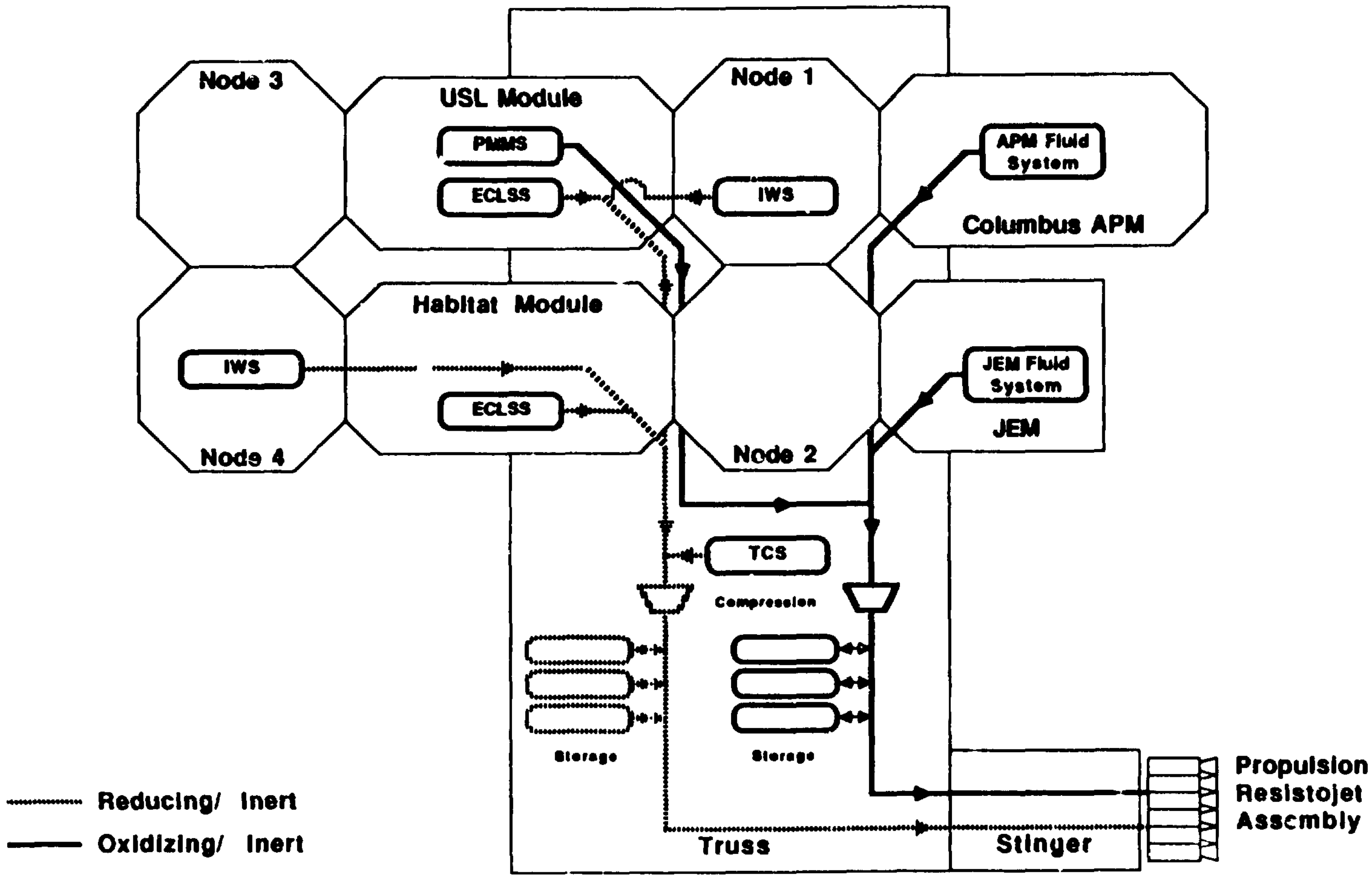
FUNCTIONAL REQUIREMENTS

- COLLECTS DISCARDED REDUCING GAS MIXTURES
  - Excess Hydrogen from ECLSS O_2 Generation and Bosch CO_2 Reduction
  - Ammonia/Nitrogen Mixtures from External TCS Purge
- COLLECTS DISCARDED INERT/ OXIDIZING GAS MIXTURES
  - USL PMMS, JEM and Columbus APM
  - IWS Water Tanks
  - INS Dump
- PROVIDES GAS MIXTURES TO RESISTOJETS FOR AUGMENTATION OF REBOOST

KEY FEATURES

- 2 TYPES OF WASTE GAS COLLECTION AND STORAGE
  - Reducing/Inert Mixtures
  - Oxidizing/ Inert Mixtures
- COMPRESSION AND STORAGE ON TRUSS
- NO PROCESSING OR REACTIVE STABILIZATION
  - All Safing Performed by Labs and/or Users

IWGS ARCHITECTURE



IWGS SUMMARY

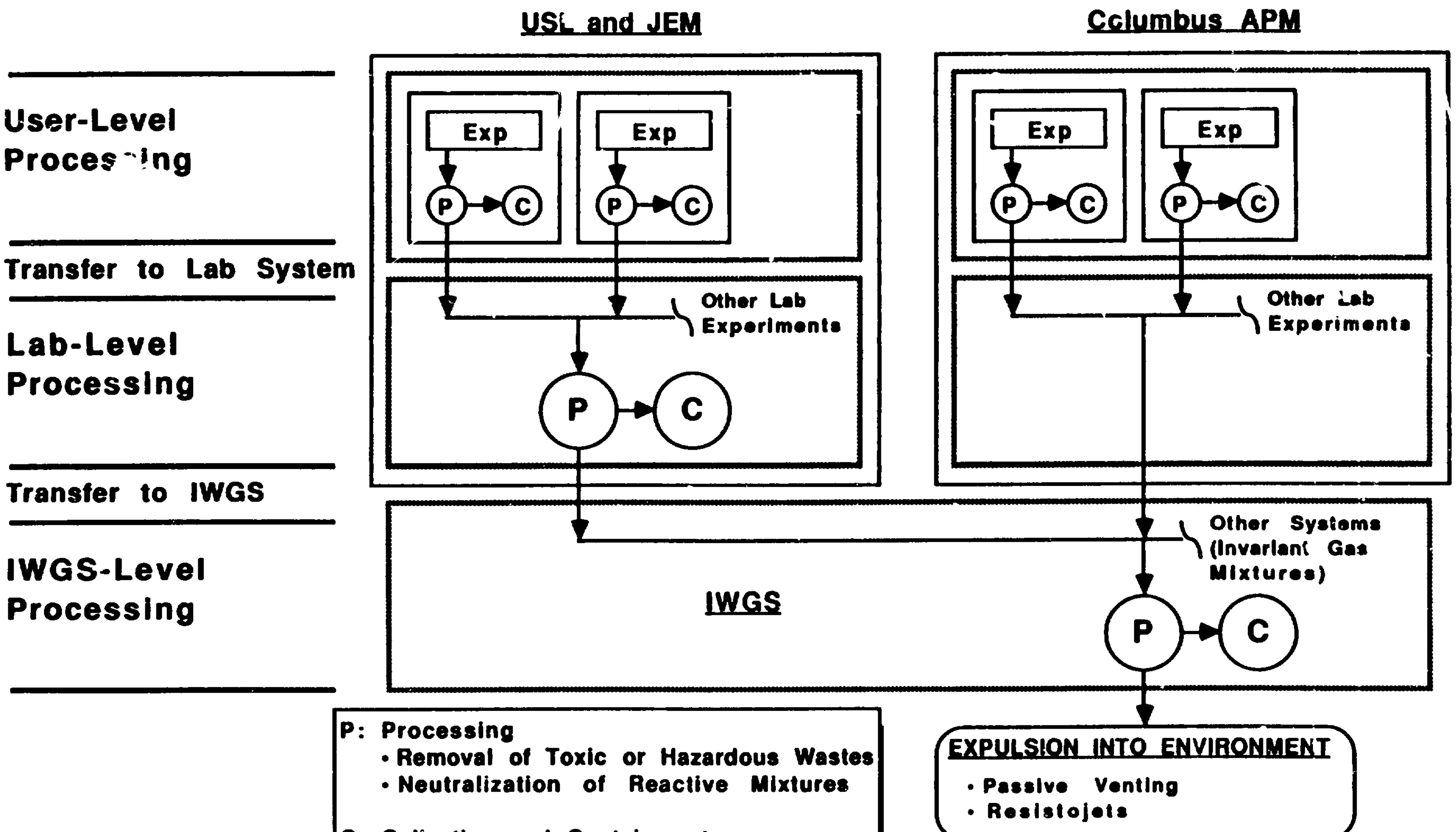
FEATURES THAT MITIGATE SAFETY, CONTAMINATION AND COST IMPACTS

- STORAGE AND HANDLING IN 2 SEPARATE GAS COLLECTION STREAMS
  - Sufficient for Safe Transfer and Storage on Truss
  - Elim ates Complex and Potentially Hazardous Processing Equipment

CURRENT ISSUES

- DELETION OF FMS PROVIDED WASTE GAS PROCESSING
  - Removal or Neutralization of Toxic and Hazardous Compounds Performed by User Payloads and/or Lab System
- ELIMINATION OF INTEGRATED VACUUM VENT SYSTEM
  - Feasibility of Extensive Vacuum Network Questionable
  - Venting of Very Low Pressure Products Performed at Lab/ Element Level
  - Requires Station Provided Integrated Control (e.g., OMA)
- REMOVAL OF FMS PROVIDED WASTE WATER DISPOSAL
  - Lab Reclamation Reduces Amount of Discarded Water
  - Handling Performed by Lab or Users

S.S. FREEDOM WASTE GAS HANDLING HIERARCHY



P: Processing
- Removal of Toxic or Hazardous Wastes
- Neutralization of Reactive Mixtures

C: Collection and Containment
- Storage of Removed Waste Products
- Return to Earth or
- Dispose In-Orbit

WASTE PROCESSING REQUIREMENTS BETWEEN EACH LEVEL ARE INFLUENCED BY:

- TYPES AND COMMONALITY OF DISCARDED WASTES
  - Toxicity and Handling Hazards
  - Commonality of Products from Different Sources

- EXTERNAL CONTAMINATION RESTRICTIONS
  - Column Densities of Respective Constituents
  - Deposition Limits
  - Disposal Locations and Viewing Angle Requirements
  - Definition of Quiessence and Non-quiessance

- TRANSFER, STORAGE AND DISPOSAL HARDWARE COMPATIBILITY
  - Resistojet Materials
  - Storage Tank Liners
  - Compressors

- VOLUME AND MASS LIMITATIONS
  - Internal Volume Requirements for Storage
  - Downsupply Demand and Capability

- PARTITIONING BETWEEN USER AND STATION COSTS

LEVEL II STUDY INITIATED TO DETERMINE DEGREE OF PROCESSING FOR USERS, LABS AND IWGS

STUDY SOURCES

- MICROGRAVITY AND MATERIALS PROCESSING FACILITY DATA RELEASE-2/2/87
- WASTE PROCESSING INDUSTRY
  - Technology, Methods and Hardware
- FMS WORKING GROUP

GENERAL GUIDELINES

- SIMPLIFY PROCESSING REQUIREMENTS
  - Isolate Unique Hazardous Products at Source
  - Transfer Common Gases to Integrated System (i.e., PMMS, FMS)
- MINIMIZE OVERALL HARDWARE
- ASSURE THAT EXPERIMENT DESIGNS MINIMIZE POTENTIALLY DANGEROUS FAILURES

WASTE PROCESSING REQUIREMENTS - STUDY RESULTS

- USL PAYLOAD LEVEL
  - Removal of Hazardous and User Unique Products
  - Removal of Particulates

- PMMS LEVEL
  - Removal of Cleaning Fluids and Water Vapors

- COLUMBUS APM AND JEM FLUID SYSTEM LEVEL
  - Removal of Hazardous Gases

- FMS LEVEL
  - None for Gases Collected from Labs (All Oxidizing/Inert Mixtures)
  - Dedicated Collection, Storage and Disposal of ECLSS and TCS Waste Gases

AGENDA

- INTRODUCTION
  - Overview of FMS
  - Rationale for Integration

- PROCESS FLUID SUPPLY
  - Integrated Nitrogen System (INS)
  - Integrated Water System (IWS)
  - Other Potential Integrated Process Fluid Systems

- WASTE HANDLING
  - Potential Additional Systems

- CONCLUSIONS
  - Acronym List

CONCLUSIONS

- MOST SIGNIFICANT HAZARDOUS MATERIALS HANDLING ISSUES FOR FMS PERTAIN TO WASTE HANDLING
  - Requires End-to-End Consideration from User Production to Final Disposal
  - May Significantly Impact User and Station Costs

- INITIATION OF IWGS AND LAB MODULE PRELIMINARY DESIGN REQUIRES COMMON SET OF REFERENCE REQUIREMENTS
  - Results of Level II Waste Processing Study

- FMS WORKING GROUP SERVES AS FORUM FOR DEFINING END-TO-END ARCHITECTURE FOR WASTE GAS HANDLING ON S.S. FREEDOM
  - User Accomodation Panel
  - External Contamination Working Group
  - Resource Allocation Panel

ACRONYM LIST

ACD	Architectural Control Document
CERS	Crew Equipment Retrieval System
CERV	Crew Emergency Rescue Vehicle
ECLSS	Environmental Control and Life Support System
EEU	Extravehicular Excursion Unit
EVA	Extravehicular Activity
FMS	Fluid Management System
HBC	Hyperbaric Chamber (Airlock)
INS	Integrated Nitrogen System
IWFS	Integrated Waste Fluid System (Current Baseline)
IWGS	Integrated Waste Gas System (Proposed Baseline)
IWS	Integrated Water System
JEM	Japanese Experiment Module
Lab	Laboratory
MMU	Manned Maneuvering Unit
OMV	Orbital Maneuvering Vehicle
NSTS	National Space Transportation System
PLC	Pressurized Logistics Carrier
ULC	Unpressurized Logistics Carrier

Transport of Hazardous Materials

Presented by
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Work phone: (205/461-2468
FAX No.: (205/461-3070

Logistics Elements - Transport of Hazardous Materials

- Outline
  - Logistics Elements Background
    - Requirements
    - Resources
    - Design Drivers
    - Design Goals
    - Baseline Elements
  - Operations
    - Phase (ø) Definitions
    - Cargo Delivery Modes
    - Cargo Handling Methods
    - On Station Parking Positions
  - Hazard Identification
    - Definition
    - Classification
  - Hazardous Cargo Transportation
    - Transportation Method Criteria
    - Hazardous Cargo Identification - PLM
    - Hazardous Cargo Delivery Methods - PLM
    - Hazardous Cargo Identification - FSC, HSC, BSC, ASTS
    - Hazardous Cargo Delivery Methods - FSC, HSC, BSC, ASTS
  - Future Development

Logistics Elements - Transport of Hazardous Materials

- **Background**

  - **Baseline cargo requirements**

Category	Type	Annual Quantity (lbs) Resupply	Return
Crew, Station, Customer	Pressurized	80,672	72,800
	Unpressurized	41,140	41,140
	Fluids	6,400	1,532
	Propellants	14,832	0
		143,044	115,472

- **Baseline launch and landing resource**

  Transportation Vehicle - Orbiter

  Dedicated logistics flights/year - 8

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Logistics Elements – Transport of Hazardous Materials

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- Background
  - Logistics Transportation System
    - —Major design requirements
      - Weight
      - Power
      - Heat rejection
      - Safety
    - —Major design goals
      - Lightweight
      - Efficient
      - Flexibility

Log El #1/Haz Materials/D/lt/11-21-88

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LOGISTICS ELEMENTS
TRANSPORT OF HAZARDOUS MATERIALS

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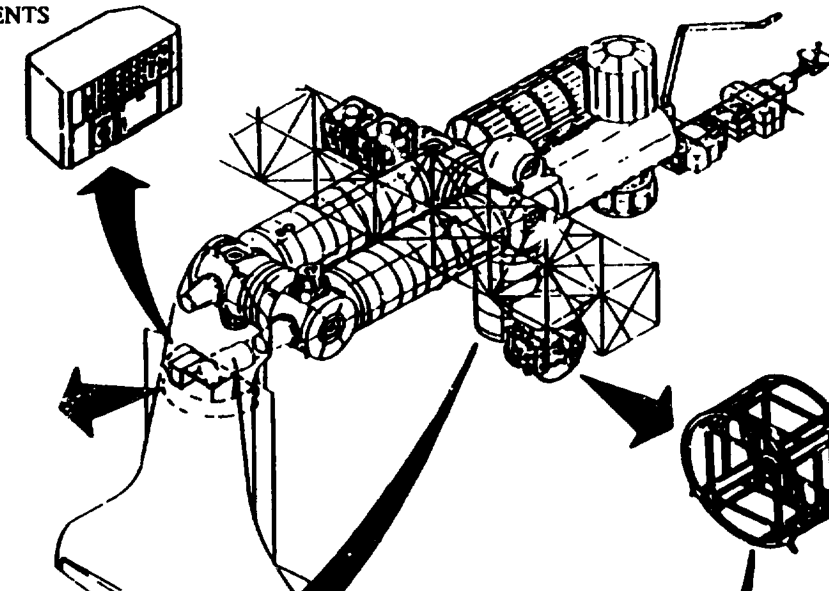
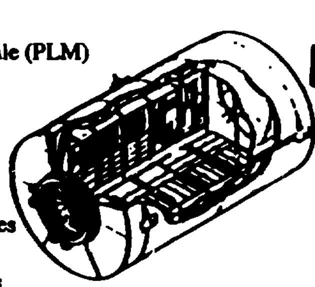
- **BACKGROUND**

BASELINE LOGISTICS ELEMENTS



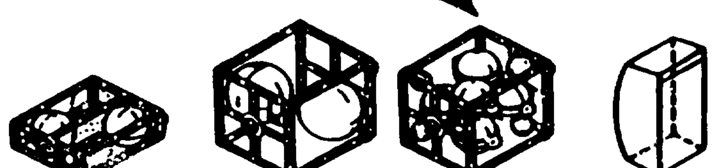
■ Animal/Specimen Transport System (ASTS) (2 required)
- Specimen delivery and return.
- Outfitted to carry -
  - Rats
  - Plants
  - Specimens (Incubated, refrigerated, frozen, and cryogenic)

■ Docking module
- Outfitted to carry ASTS (1)
- Satisifies stringent late/early access requirements
- Interfaces with station docking systems



■ Pressurized Logistics Module (PLM) (3 required)
- Cargo:
- Crew Support:
  - Food
  - Personnel supplies
  - Housekeeping supplies
- Station Support
  - Maintenance supplies
  - Spares
  - EVA support
- Customer Support
  - USL Equipment & supplies
  - JEM Equipment & supplies
  - Columbus equipment & supplies
- GSE Roller Floor

■ Unpressurized Logistics Carrier (ULC) (4 required)
- Carriers
  - Station spares
  - Platform and satellite supplies (resupply and ORU's)
  - Attached payloads
- Modular Interchangeable fluid/propellant subcarriers



Hydrazine subcarrier (HSC) (2 required)	Bipropellant subcarrier (BSC) (2 required)	Fluids subcarrier (FSC) (2 required)	Dry Cargo subcarrier (DCSC) (8 required)

■ Subcarriers
- Provides multiple combinations of subcarriers with the ULC
- Efficient manifesting
- Direct mounting to a variety of non-containerized cargo configurations
- Subcarriers are attached by automated attachments and umbilical mechanisms

LOGISTICS ELEMENTS
TRANSPORT OF HAZARDOUS MATERIALS

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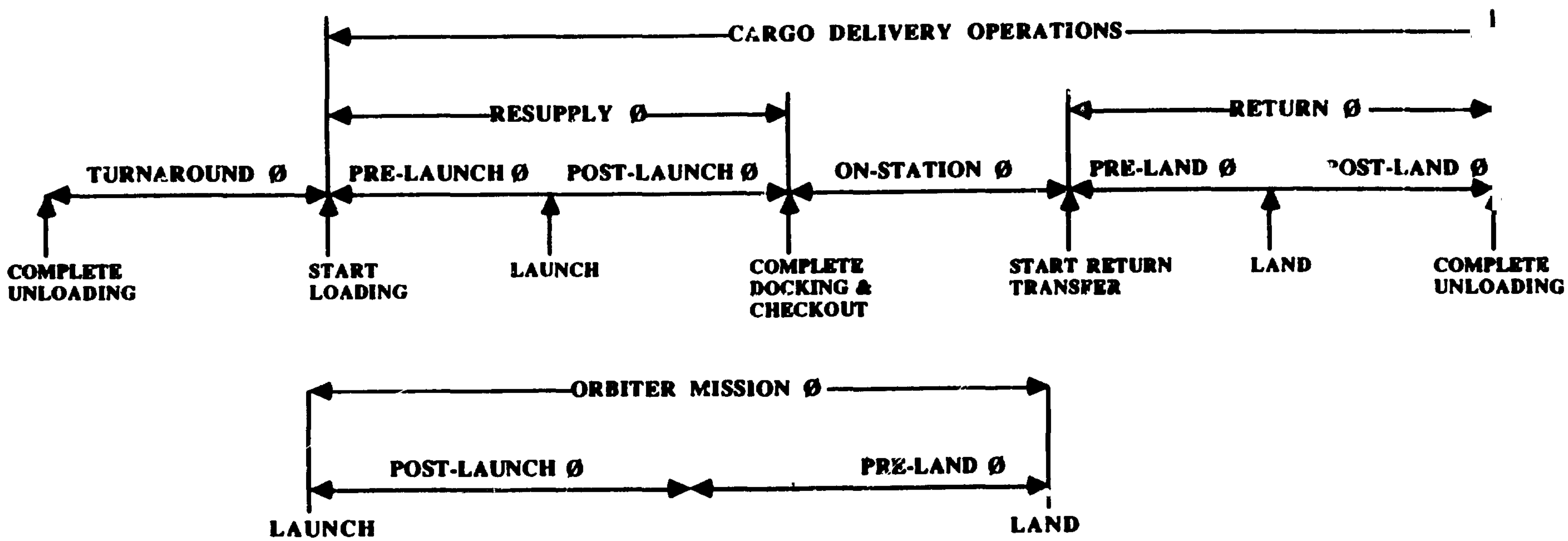
- **OPERATIONS**
  - **OPERATIONS CYCLE Ø DEFINITIONS**



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Logistics Elements – Transport of Hazardous Materials

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- **Operations**
  - Cargo delivery modes

    Transfer – Movement of the cargo to and from the Logistics Elements by manual or systems operations

    Transport – Movement of the cargo from origin to destination after it has been emplaced in/on the Logistics Elements

    Storage – Containment of the cargo after it has been emplaced in the Logistics Element Cargo Accommodations

Logistics Elements - Transport of Hazardous Materials

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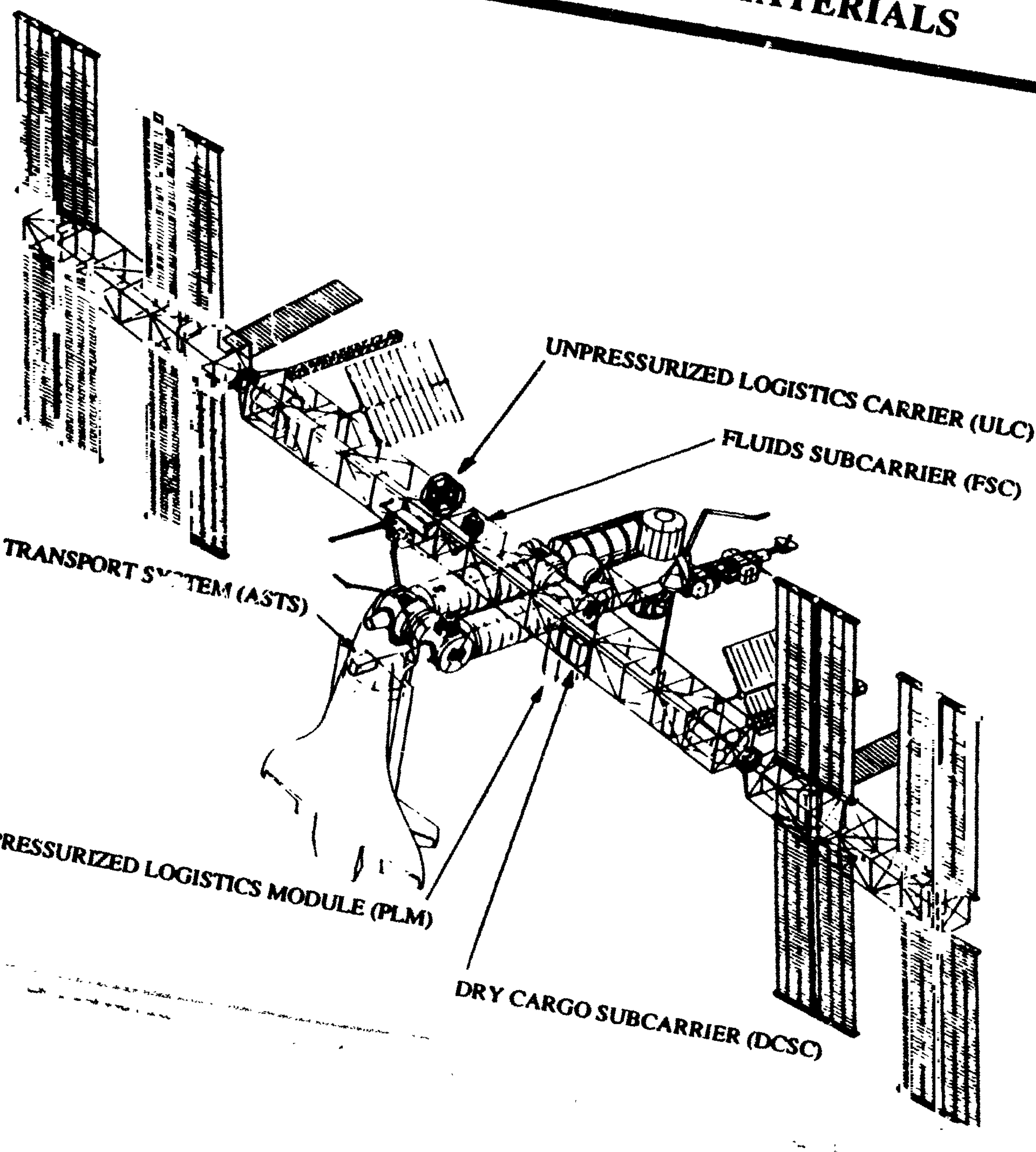
- **Operations**
  - **Cargo handling method**

Operations Phase	Cargo Handling Method		
	Transfer Method	Transport Vehicle	Storage Location
Prelaunch	Manual and System	GSE	PLM, ASTS, FSC, DCSC
Postlaunch	Manual	Orbiter	PLM, ASTS, FSC, DCSC
On Station	Manual and System	NA	PLM, FSC, DCSC
Preland	Manual	Orbiter	PLM, ASTS, FSC, DCSC
Postland	Manual	GSE and 747	PLM, ASTS, DCSC
Turnaround	NA	NA	NA

Log #6/Haz Materials/Handling/lt/11-22-88

LOGISTICS ELEMENTS - TRANSPORT OF HAZARDOUS MATERIALS

• OPERATIONS



Logistics Elements - Transport of Hazardous Materials

- **Hazard Identification**

  Definition

  - **Hazardous cargo is defined as any cargo that poses a threat to the**
    - **Personnel**
    - **Ground facilities**
    - **Flight systems - Orbiter, Space Station, 747**
    - **Mission**
    - **Environment**

  - **The degree of the threat is measured by the effect on the**
    - **Personnel's ability to function**
    - **Operational capabilities of the facilities or flight systems**
    - **Successful completion of mission plans**
    - **Level of environmental contaminants**

Logistics Elements - Transport of Hazardous Materials

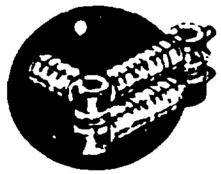
- Hazard Identification

  <u>Classification</u>

  - Cargo is classified as hazardous if -
    - The cargo material has properties which pose a hazard
    - The delivery state of the cargo poses a hazard
  - The three types of hazards are
    1) Explosive release of potential energy
       - Explosion
       - Combustion
    2) Contamination
       - Toxins
       - Harmful Biotic Forms
       - Corrosive
       - Asphyxiants
       - Irritants
    3) Chemical spills
    4) Any combination of 1), 2), and 3)

Logistics Elements - Transport of Hazardous Materials

- Hazardous cargo transportation
  - Criteria will be defined to govern the method of hazardous cargo transportation by establishing standards for
    - Safe distance
    - Energy containment
    - Energy release confinement
    - Contaminant containment
    - Acceptable contaminant levels
    - Operating procedures



Logistics Elements - Transport of Hazardous Materials

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- **Hazardous cargo identification**
  - Transported in PLM

Cargo	Transportation Phase	Destination /Orgin	Hazard						
			Explosive	Flammable	Toxic	Biological	Corr	Asphyx	Irritants
AMMONIUM BIFLOUIDE	RESUPPLY	USL					√		
BROMINE	RESUPPLY	USL					√		
CHROMIC ACID	RESUPPLY	USL					√		
HYDROCHLORIC ACID	RESUPPLY	USL					√		
HYDROFLUORIC ACID	RESUPPLY	USL					√		
HYDROGEN PEROXIDE	RESUPPLY	USL					√		
LITHIUM	RESUPPLY	USL					√		
LITHIUM NIOBIUM	RESUPPLY	USL					√		
NITERIC ACID	RESUPPLY	USL					√		
POTASSIUM	RESUPPLY	USL					√		
POTASSIUM HYDROXIDE	RESUPPLY	USL					√		
PERCHLORIC ACID	RESUPPLY	USL					√		
SILVER NITRATE	RESUPPLY	USL					√		
SODIUM ALUMINATE	RESUPPLY	USL					√		
SODIUM HYDROXIDE	RESUPPLY	USL					√		
SODIUM HYPOCHLORITE	RESUPPLY	USL					√		
SULFURIC ACID	RESUPPLY	USL					√		
ACETONE	RESUPPLY	USL		√					
ACETONITRILE	RESUPPLY	USL		√					
BENZENE	RESUPPLY	USL		√					
DIMETHYL SULFIDE	RESUPPLY	USL		√					
ETHANOL	RESUPPLY	USL		√					
FRUAN	RESUPPLY	USL		√					
GLYCEROL	RESUPPLY	USL		√					
ISOPROPYL ALCOHOL	RESUPPLY	USL		√					
KEROSENE	RESUPPLY	USL		√					
LATEX SOLUTION	RESUPPLY	USL		√					
METHANOL	RESUPPLY	USL		√					
METHYL ETHYL KETONE	RESUPPLY	USL		√					
TOLUENE	RESUPPLY	USL		√					
XYLENE	RESUPPLY	USL		√					

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Logistics Elements - Transport of Hazardous Materials

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- Hazardous cargo identification
  - Transported in PLM

Cargo	Transportation Phase	Destination /Orgin	Hazard: Explosive	Flammable	Toxic	Biological	Corr	Asphyx	Irritants
AC[illegible]	RESUPPLY	USL		√					
N-BUTANE	RESUPPLY	USL		√					
HEPTANE	RESUPPLY	USL		√					
HYDROGEN	RESUPPLY	USL		√					
METHANE	RESUPPLY	USL		√					
OXYGEN	RESUPPLY	USL		√					
PROPANE	RESUPPLY	USL		√					
TRICHLOROETHANE	RESUPPLY	USL		√					
LITHIUM	RESUPPLY	USL		√					
POTASSIUM	RESUPPLY	USL		√					
POTASSIUM FERRICYA	RESUPPLY	USL		√					
POTASSIUM HYPOPHOS	RESUPPLY	USL		√					
ACETIC ACID	RESUPPLY	USL							√
ACROLEIN	RESUPPLY	USL							√
ALLYL ALCOHOL	RESUPPLY	USL							√
AMMONIUM HYDROXIDE	RESUPPLY	USL							√
BENZENE	RESUPPLY	USL							√
CARBON TETRACHLORIE	RESUPPLY	USL							√
CHLORINE	RESUPPLY	USL							√
CHLOROBENZENE	RESUPPLY	USL							√
CHLORODIFLOUROMETN	RESUPPLY	USL							√
COPPER CULFATE PENT	RESUPPLY	USL							√
DICHLOROMETHANE	RESUPPLY	USL							√
FLUORINE	RESUPPLY	USL							√
HYDROFLUORIC ACID	RESUPPLY	USL							√
IODINE	RESUPPLY	USL							√
IRON	RESUPPLY	USL							√
ISOPROPYL ALCOHOL	RESUPPLY	USL							√
METHANOL	RESUPPLY	USL							√
METHYL ETHYL KETONE	RESUPPLY	USL							√
OXALIC ACID	RESUPPLY	USL							√

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Logistics Elements - Transport of Hazardous Materials

- Hazardous cargo identification
  - Transported in PLM

Cargo	Transportation Phase	Destination /Orgin	Hazard						
			Explosive	Flammable	Toxic	Biological	Corr	Asphyx	Irritants
PHENOL	RESUPPLY	USL							√
ORTHOPHOSPHORIC ACID	RESUPPLY	USL							√
SODIUM HYPOCHLORITE	RESU*PLY	USL							√
SULFURIC ACID	RESUPPLY	USL							√
TRICHLOROTRIFLUOROE	RESUPPLY	USL							√
TRICGHLOROTTHYLENE	RESUPPLY	USL							√
TRIMETHYLBENZENE	RESUPPLY	USL							√
XYLENE O-M-P-	RESUPPLY	USL							√
ZINC CHLORIDE	RESUPPLY	USL							√
ARGON	RESUPPLY	USL						√	
CARBON DIOXIDE	RESUPPLY	USL						√	
CARBON MONOXIDE	RESUPPLY	USL						√	
NITROGEN	RESUPPLY	USL						√	
XENON	RESUPPLY	USL						√	
ACETONITRILE	RESUPPLY	USL						√	
ACROLEIN	RESUPPLY	USL						√	
ALLYL ALCOHOL	RESUPPLY	USL							
AMMONIA	RESUPPLY	USL			√				
AMMONIUM CHLORIDE	RESUPPLY	USL			√				
ARSENIC	RESUPPLY	USL			√				
ATROPINE	RESUPPLY	USL			√				
BENZALKONIUM CHLO	RESUPPLY	USL			√				
BERYLLIUM	RESUPPLY	USL			√				
BROMINE	RESUPPLY	USL			√				
2-BUTOXYETHANOL	RESUPPLY	USL			√				
N-BUTYL ALCOHOL	RESUPPLY	USL			√				
CADIUM	RESUPPLY	USL			√				
CADIUM IODIDE	RESUPPLY	USL			√				
CADIUM SULFIDE	RESUPPLY	USL			√				
CADIUM SELENIDE	RESUPPLY	USL			√				
CADIUM TELLURIDE	RESUPPLY	USL			√				

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Logistics Elements - Transport of Hazardous Materials

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Hazardous cargo identification

- Transported in PLM

Cargo	Transportation Phase	Destination /Orgin	Hazard: Explosive	Flammable	Toxic	Biological	Corr	Asphyx	Irritants
CARBON MONOXIDE	RESUPPLY	USL			√				
CARBON TETRACYHLOR	RESUPPLY	USL			√				
COPPER CHLORDIE	RESUPPLY	USL			√				
COPPER NITRATE	RESUPPLY	USL			√				
CYCLOHEXANOL	RESUPPLY	USL			√				
DIHYDROXYDIETHYL ET	RESUPPLY	USL			√				
DIISOBUTYL KETONE	RESUPPLY	USL			√				
2,6-DIMETHYL-4-HEPTAN	RESUPPLY	USL			√				
FLUORINE	RESUPPLY	USL			√				
GALLIUM ARSENIDE	RESUPPLY	USL			√				
GALLIUN PHOSPHIDE	RESUPPLY	USL			√				
GERMANIUM	RESUPPLY	USL			√				
GLUTARALDEHYDE	RESUPPLY	USL			√				
HYDROGEN BROMIDE	RESUPPLY	USL			√				
HYDROGEN PEROXIDE	RESUPPLY	USL			√				
HYDROGEN IODIDE	RESUPPLY	USL			√				
IODINE	RESUPPLY	USL			√				
INDENE	RESUPPLY	USL			√				
INDIUM	RESUPPLY	USL			√				
INDIUM PHOSPHIDE	RESUPPLY	USL							
LEAD	RESUPPLY	USL			√				
MAGNESIUM CHLORIDE	RESUPPLY	USL			√				
MAGNESIUM OXIDE	RESUPPLY	USL			√				
MERCURY	RESUPPLY	USL			√				
MERCURIC BROMIDE	RESUPPLY	USL			√				
MERCURIC CHLORIDE	RESUPPLY	USL			√				
MERCURIC OIODIDE	RESUPPLY	USL			√				
MERCURY CADMIUM TEL	RESUPPLY	USL			√				
OZONE	RESUPPLY	USL			√				
POTASSIUM DICHROMA	RESUPPLY	USL			√				
POTASSIUM FERRICY	RESUPPLY	USL			√				

dk/jenle-g#2/transport of haz mat pg4/jms/11/22/88

Logistics Elements - Transport of Hazardous Materials

- Hazardous cargo identification
  - Transported in PLM

Cargo	Transportation Phase	Destination /Orgin	Hazard						
			Explosive	Flammable	Toxic	Biological	Corr	Asphyx	Irritants
POTASSIUM ORTHOHOS	RESUPPLY	USL			√				
POTASSIUM PERMANGA	RESUPPLY	USL			√				
PHENOL	RESUPPLY	USL			√				
STYRENE	RESUPPLY	USL			√				
SODIUM ALUMINATE	RESUPPLY	USL			√				
SODIUM AZIDE	RESUPPLY	USL			√				
SODIUM CHLORATE	RESUPPLY	USL			√				
SODIUM NITRATE	RESUPPLY	USL			√				
SODIUM THICUANATE	RESUPPLY	USL			√				
SILVER NITRATE	RESUPPLY	USL			√				
SULFAMIC ACID	RESUPPLY	USL			√				
TELLURIUM	RESUPPLY	USL			√				
TANTALUM	RESUPPLY	USL			√				
TRICHLOROOETHANE	RESUPPLY	USL			√				
TRICHLORETHYLENE	RESUPPLY	USL			√				
TRINITROPHENOL	RESUPPLY	USL			√				
HEMIMELLITINE	RESUPPLY	USL			√				
PSEUDOCUMENE	RESUPPLY	USL			√				
MESITYLENE	RESUPPLY	USL			√				
MESITYLENE	RESUPPLY	USL			√				
ZINC CHLORIDE	RESUPPLY	USL			√				
ZINC TELLURIDE	RESUPPLY	USL			√				
LAB WASTE	RETURN	USL	√	√	√	√	√	√	√
HUMAN WASTE	RETURN	USL/HAB				√	√		√
TRASH	RETURN	USL/HAB				√			√
ECLSS - HYDROGEN	RESUPPLY	TBD	√	√					

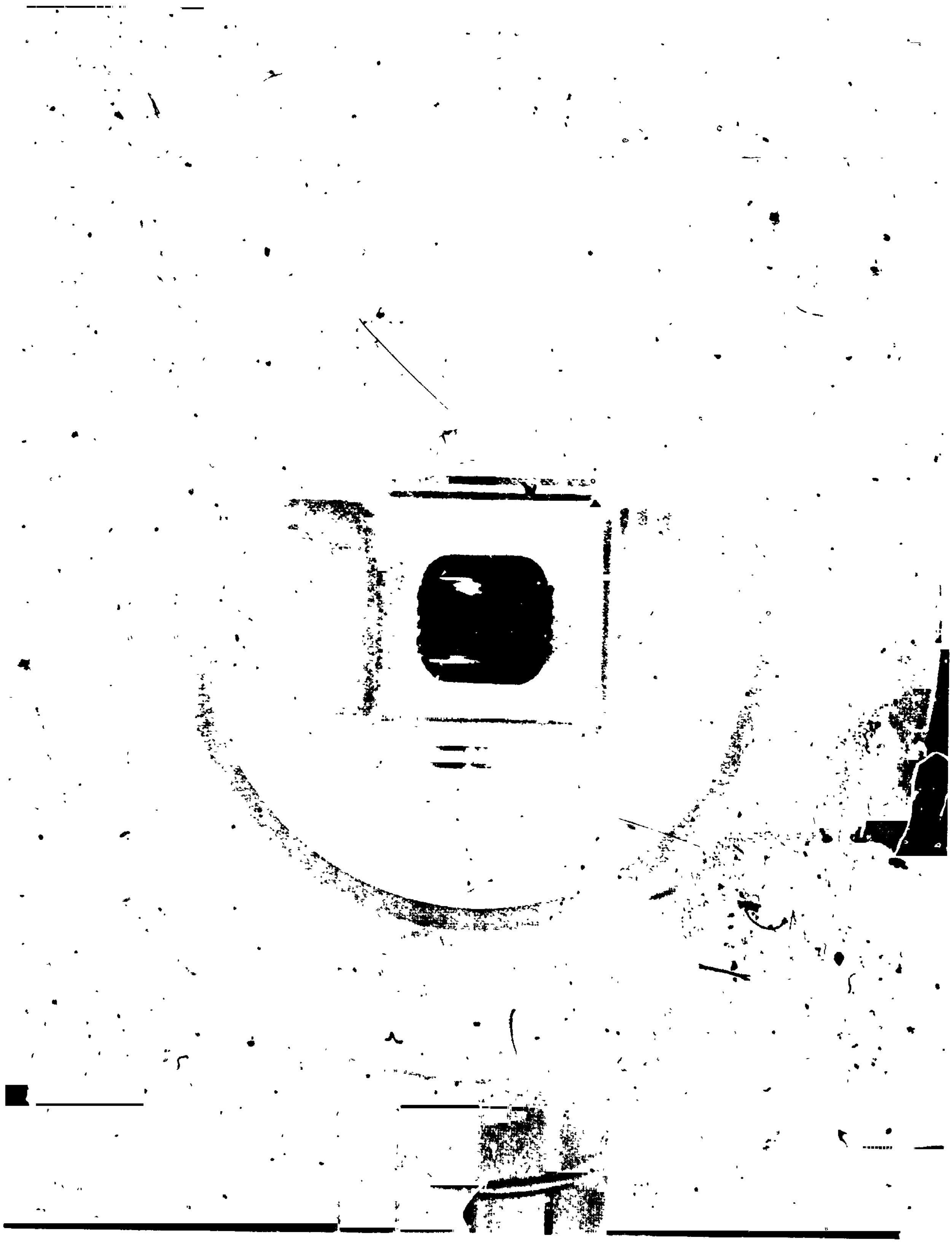
dk/jpnlog#2/transport of haz mat pg5/jms/11/22/88

Logistics Elements - Transport of Hazardous Materials

11/29/88

- Hazardous cargo transportation
  - Baseline hazardous cargo delivery methods - PLM

Cargo	Transfer Method	Cargo Accommodations
Lab supplies	Manual	User supplied containers providing triple containment
Experiment products	Manual	User supplied containers providing triple containment
Lab waste	Manual	User supplied containers providing triple containment
Human waste	Manual	User supplied containers providing triple containment
Trash	Manual	User supplied containers providing triple containment



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Space Station Freedom

Logistics Elements - Transport of Hazardous Materials

BOEING
11/29/88

- **Hazardous cargo identification**
  - Transported in FSC, HSC, BSC, ASTS

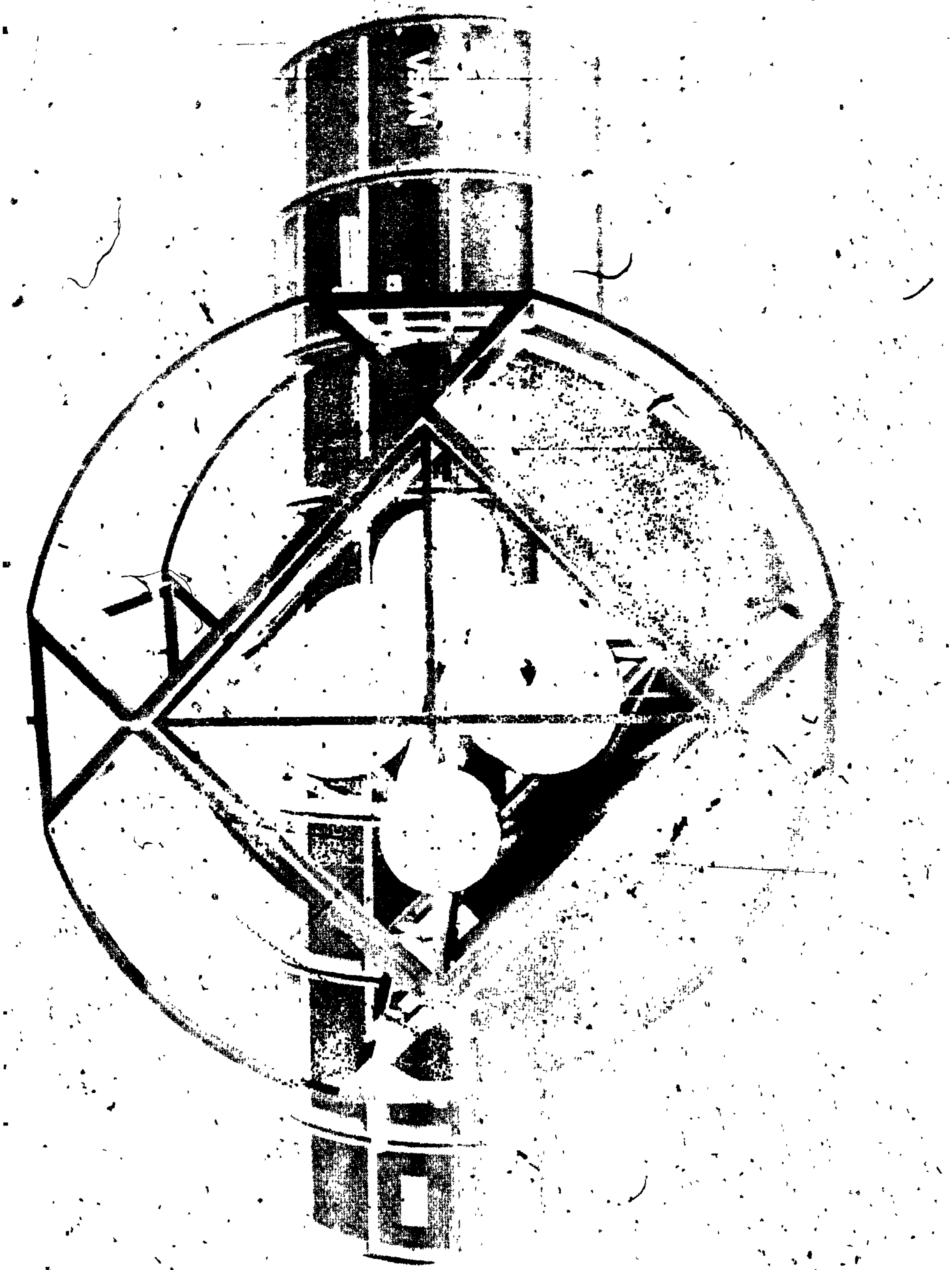
Cargo	Transportation Phase	Destination /Orgin	Hazard						
			Explosive	Flammable	Toxic	Biological	Corr	Asphyx	Irritants
[illegible]									
NITROGEN	RESUPPLY	USL, ECLSS, JEM, OMV						√	
OXYGEN	RESUPPLY	USL	√		√				
HELIUM	RESUPPLY	USL	√					√	
ARGON	RESUPPLY	USL	√					√	
HSC									
HYDRAZINE (N2H2)	RESUPPLY	SATELLITE SERVICE		√	√			√	
BSC									
MONOMETHYL HYDRAZINE (MMH)	RESUPPLY	COP	√	√	√			√	
TETROXIDE (N204)	RESUPPLY	COP	√	√	√			√	
ASTS									
LIVING ANIMALS	RESUPPLY/RETURN	USL				TBD			
SPECIMENS	RESUPPLY/RETURN	USL				TBD			

Logistics Elements - Transport of Hazardous Materials

11/29/88

- Hazardous cargo transportation
  - Baseline hazardous cargo delivery methods - FSC, HSC, BSC, ASTS

Cargo	Transfer Method	Logistics Element	Cargo Accommodations
High pressure gas	Plumbing	FSC	Leak before burst tanks
Cryogenic fluid	Plumbing	FSC	Dewar
Propellants	Plumbing	HSC/BSC	Leak before burst tanks
Special access specimens	Manual	ASTS	Cages and conditioned storage satisfying specified bio isolation requirements



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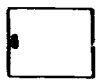
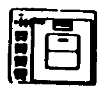
SPACE STATION

Animal Specimen Transport Facility Description

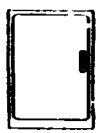
BOEING
7/16/86

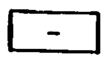
Components

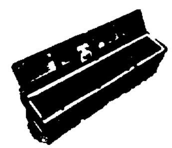

+ 4°C refigerator

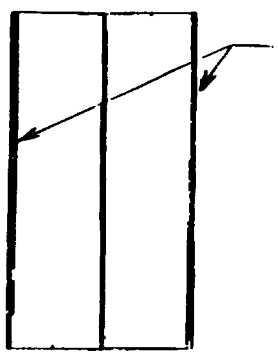

37°C incubator


-196°C cryogenic storage freezer

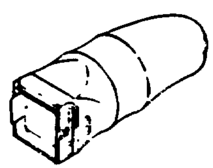

-70°C freezer


Ambient storage

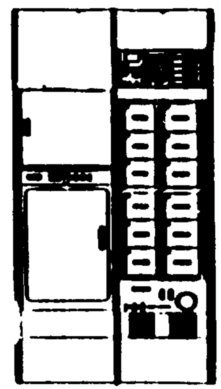

Animal cages

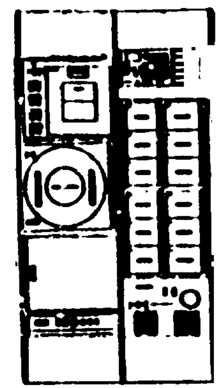

Seat track provisions

Level 2 double rack


Cage OSE

Flight Configuration


Rodents, ambient storage, -70°C freezer


Plants, incubator, -196°C freezer, 4°C refrigerator

Log Elements/Disk 2/J/078 8

Logistics Elements - Transport of Hazardous Materials

- Future Development

  - Continued hazardous cargo identification
    Evolving cargo requirements
    On going optimum fluids delivery state analyses

  - Finalize transportation method criteria

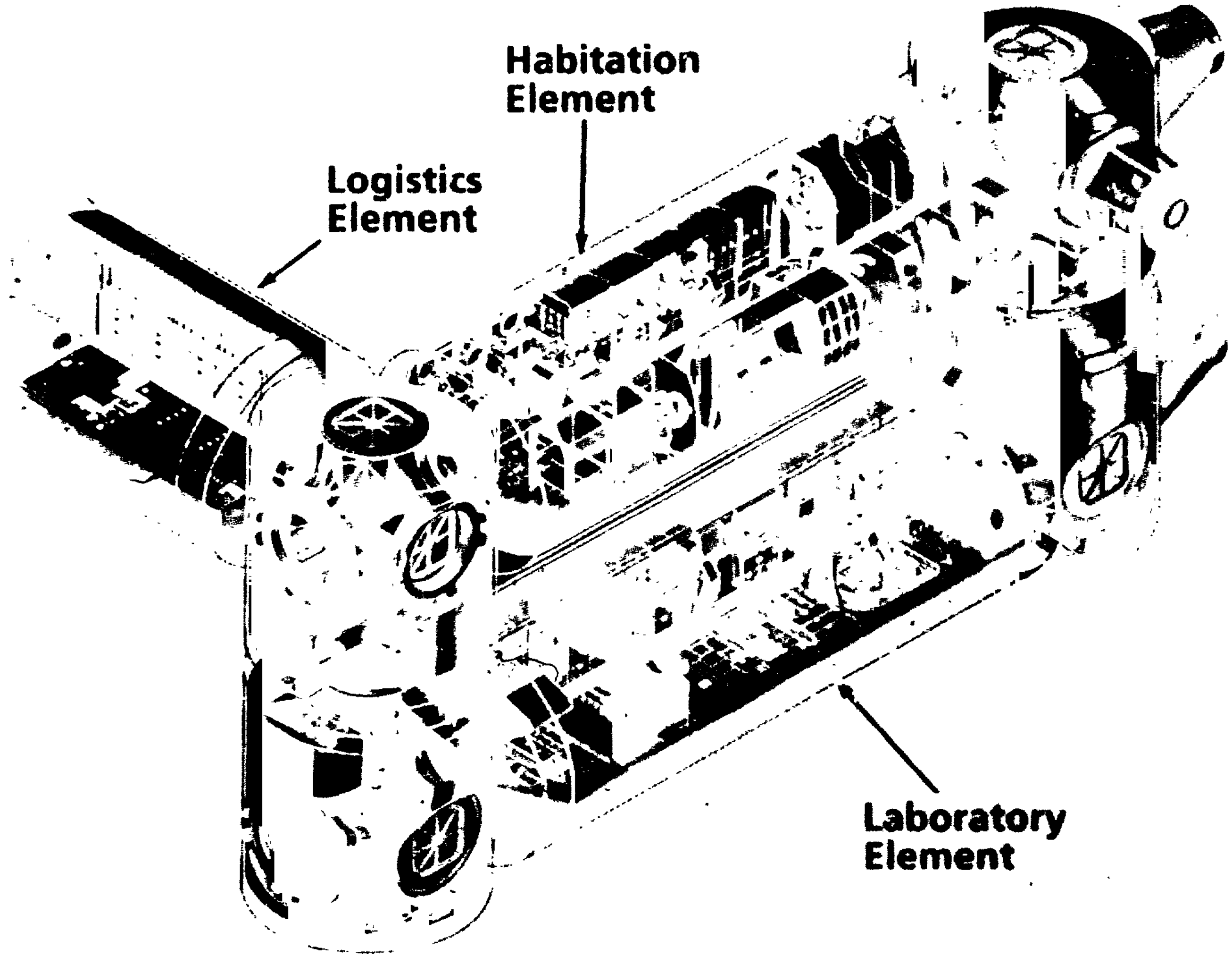
  - Continued design and development of Logistics Elements and cargo accommodations

  - Continued design and development of user supplied hazardous cargo containers

Space Station Freedom

Space Station Freedom
Pressurized Element Arrangement

BOEING



N91-15937

SPACE STATION PRESSURIZED LABORATORY SAFETY GUIDELINES

LES McGONIGAL

NASA/MSFC

WPO1 SAFETY

SPACE STATION TOXIC AND REACTIVE MATERIALS HANDLING WORKSHOP

NOVEMBER 30, 1988

SPACE STATION PRESSURIZED LABORATORY SAFETY GUIDELINES

The development of space based laboratory guidelines is a mixture of consideration of past experience, contemplation of present operations and conjecture regarding proposed endeavors. This is not to say that we must grope for answers but that we must understand the limits of our experience and factor those limits in as we step forward cautiously. Underlying the development of laboratory safety guidelines for Space Station Freedom must be the recognition of the uniqueness of this resource. While safety requirements for ground-based laboratories have come about literally by accident (and the loss of many laboratories and a few researchers as well), we can ill afford to generate safety requirements for space laboratories in the same manner.

Before we begin to establish technical safety guidelines and requirements a common understanding of their origin and importance must be shared between Space Station Program Management, the User Community, and the safety organizations involved. This is done through organization and communication, of course, but there must also be an appreciation of each others' interests. A space-based laboratory in which the experiments are received and returned in unopened containers, while useful and safe, does not take full advantage of the facilities' potential for more interesting experiments. Safety can be built into the facility to allow more interesting experiments but at a cost to the program manager. Safety guidelines and requirements will be driven by the nature of the experiments and degree of crew interaction. The greater and more complex the potential risk the more stringent and complex the safety requirements. Once a programmatic decision has been made regarding the level of acceptable potential risk, safety guidelines are then applied to generate safety requirements to prevent the potential risk from becoming a reality.

IDENTIFY THE HAZARDS

The first guideline to be applied is that of hazard identification. Ground-based laboratory and previous flight experience are combined to yield generic requirements such as those for safety showers and containerization of experiments. For as much experience as we have, however, there are still significant gaps left when it is applied to the Space Station laboratory. SKYLAB, SPACELAB, and shuttle mid-deck experiments allowed limited crew interaction or manipulation and a high degree of training specific to each experiment was given to assigned crewmembers. The new and different work proposed for the Space Station laboratory, i.e. material transfer and characterization, increases the probability of material spills to the point that serious consideration must be given to hazardous material spill response capability. We have no significant experience with micro gravity spill propagation, control or cleanup of toxic and reactive materials.

The primary tools for identifying hazards are the various hazard analyses that can be applied to experiment proposals. SSP 30309, "Safety Analysis and Safety Risk Assessment Requirements and Processes Document for the Space Station Program", provides the detailed instruction relative to the application of specific hazard analysis techniques. Safety Engineers are generally well-versed in the techniques of hazard analysis but they may or may not have a background in the area that a given experiment is designed to investigate. It will be necessary to have experimenters involved in the hazard analysis process in order to more accurately characterize the associated hazards and controls. As hazards are identified, methods of controlling them are developed and requirements are established to implement the controls. The hazard elimination and control precedence sequence is found in SSP 30000, Section 9. In the design of the laboratory, eliminating the hazard source or hazardous operation is the foremost consideration. For laboratory usage, introduction of many experiments also introduces a hazard source or hazardous operation. To perform meaningful experiments a certain amount of risk has to be accepted, however, the level of risk acceptance needs to be established by informed management to screen out those experiments that pose too great a threat to the Space Station. This level need not be fixed but may change as the capabilities of the laboratory and of space-based laboratory experience mature. Other actions for control of hazards incorporate safety devices, special procedures and personnel protective clothing or equipment.

LOP TECHNICAL SAFETY REQUIREMENTS

Technical safety requirements fall into two categories; those imposed upon the Program Manager and those imposed upon the User. These are found in SSP 30000, section 3; SS-SPEC-0002; SS-IRD-0200 and other Space Station documents.

IMPOSED ON SPACE STATION

SSP 30000, SECTION 3

Emergency decontamination of crew members in the event a crew member becomes contaminated by a toxic substance used within the lab. (2.1.2 2.1.1.F)

Containment, transfer and management of both general and toxic trash, materials, and waste used within this laboratory to support payloads. (2.1.2.2.1.2.B)

Stowage of ... emergency equipment. (2.1.2.2.1.1.E)

Accommodation of safe general storage for payloads in the laboratory. (2.1.2.2.1.1.G)

Capability shall be provided for detecting and extinguishing any fire in Space Station habitable volumes. (2.1.11.2.12)

Contaminant Sampling (2.1.11.2.16)

Safety interlocks, hardware and/or software implemented, shall be provided wherever practical to prevent unsafe operations from being executed. (2.1.11.2.1.D)*

A caution and warning system shall provide warning to the Space Station on-board crew and ground personnel (as required) of impending or existing dangerous conditions that pose a threat to station personnel and/or safety critical equipment. (2.1.11.2.2.3)*

Potentially explosive containers shall be located outside habitable areas, shall be isolated and protected so that the failure of one will not cause the failure of the others, and shall be designed to leak before rupture. (2.1.11.2.4.1)*

Triple containment of hazardous materials. The use of chemicals which would create a toxicity problem or cause a hazard to SSP hardware if released shall be avoided where practical. If use of such chemicals can not be avoided, they shall be triple contained. (2.1.11.2.4.5)*

Hazardous accumulation of fluids. Provisions shall be made to prevent uncontrolled hazardous accumulations of gases or liquids within the space station. Detection, monitoring, and control of hazardous gases or vapors shall be required in critical areas and closed compartments. (2.1.11.2.5)*

Exposed surface temperatures. Exposed surfaces within pressurized elements shall not exceed a high temperature of 45 degrees Centigrade or be protected from crew interaction with the surface, and a low temperature less than 4 degrees Centigrade. (2.1.11.2.8)*

Hazardous materials. The space station materials requirements for hazardous materials, flammability, and off gassing are specified in SSP 30233. (2.1.11.3)*

SS-SPEC-0002 CEI SPECIFICATION FOR LABORATORY MODULE

Atmosphere Revitalization. The atmospheric revitalization (AR) subsystem will regenerate the module atmosphere, as necessary, to provide a safe and habitable environment for the crew. The basic elements of the AR subsystem will include... atmosphere contamination control and monitoring. The atmospheric contaminants include trace gases, odors, microbial load, particulate and debris loads of the module atmosphere. (3.7.9.3.1)

The Process Material Management Subsystem (PMMS) shall provide... compatible waste disposal, ...transporting process inputs or outputs while maintaining isolation from the general USL atmosphere, ...decontamination equipment, ...safe storage of chemicals and materials (includes user provided materials and fluids), ...support (for) routine laboratory cleanup, ...decontamination equipment. (3.7.16)

The PMMS shall provide decontamination services for the crew, laboratory equipment, and payload equipment as follows:
1. PMMS shall accommodate contaminated effluent generated in the process of crew or equipment decontamination.
2. The PMMS shall provide the capability to support routine internal cleanup of US Lab facilities.

3. The PMMS shall have the capability to support non-standard cleanup of leaks and spills in contained volumes.
4. The standard PMMS hardware shall assist in cleanup/decontamination of non-hazardous leaks/spills of solids and liquids into the open cabin environment. **The PMMS shall not be designed for cleanup of hazardous open cabin spills.** (3.7.16.2)

General Laboratory Support Facilities. The general laboratory support facilities provide standard work areas with subsystem utility support for USL payload operations These facilities consist of a laboratory sciences workbench, a materials processing glovebox, and a life sciences glovebox. (3.7.18)

IMPOSED ON USERS

SSP 30000, SECTION 3

Several requirements imposed on the space station contain an element of User responsibility. In some cases (2.1.11.2.2.3) a sensor interface with the Caution and Warning system may be needed. In other cases (2.1.11.2.8) design of the experiment equipment will be required to incorporate the standard. Applicable requirements are 2.1.11.2.1.D, 2.1.11.2.2.3, 2.1.11.2.4.1, 2.1.11.2.4.5, 2.1.11.2.5, 2.1.11.2.8, & 2.1.11.3. These are marked with an * in the section above.

SS-IRD-0200 CUSTOMER TO USL INTERFACE REQUIREMENTS

EQUIPMENT INTEGRITY / SAFETY FACTORS (3.3.18.1)

All customer equipment shall be designed to withstand the launch, on-orbit, and landing environments as defined in SS-SRD 0001, Section 3, Paragraph 2.2.1. These environments shall be withstood without the following events occurring: failures; leaking of hazardous fluids; or the releasing of equipment, loose debris, or particles which could damage the USL or cause injury to the crew. USL customer equipment shall be designed such that the equipment integrity and load-carrying capability of structural mounting provisions fulfill the following requirements:

a. Factors of Safety: The minimum factors of safety to be used against load limit conditions to establish design loads shall be as defined in SS-SRD-0001, Section 3, Paragraph 2.2.1.2.4.

b. Fatigue Life: Customer equipment shall have a fatigue life consistent with the requirements specified in SS-SRD-0001, Section 3, Paragraph 2.2.1.2.7.

c. Fracture Control: Customer equipment shall be designed to meet the fracture control requirements specified in SS-SRD-0001, Section 3, Paragraph 2.2.1.2.6.

d. Depressurization: During normal operations, pressure within the USL shall be maintained at 760 + 10 torr. Under some emergency conditions, evacuation of the module will be required and depressurization of the module will occur. Customer facilities shall withstand the environment created by the depressurization/repressurization without creating an uncontrollable hazard.

FIRE (3.3.18.2)

a. In addition to the fire detection and suppression capabilities of the ECLSS, customer equipment which pose a potential fire hazard shall be instrumented by the customer to provide for early detection and warning through the Caution and Warning Subsystem (CWS) of the USL.

b. In the event a fire is detected in the customer equipment, appropriate fire suppression techniques will be implemented. Airflow and utilities shall be disconnected by the USL.

OVERTEMPERATURE (3.3.18.3)

a. Equipment which has failure modes which can produce dangerously heated surfaces in crew areas shall provide an interface to the CWS to alert the crew to the hazard and allow them to take corrective and avoidance action.

b. Customer loads shall be configured such that in the event of power disconnect or failure, the load will cool down and/or cease operation in a safe manner.

ALERT (3.3.18.4)

The USL DMS and CWS will provide an equipment malfunction alerting system that will be available to all customers. This system will notify the USL crew members of any abnormal or hazardous conditions and allow them to take timely corrective action.

LEAKAGE (3.3.18.5)

a. Hazardous materials shall be contained within the customer equipment or the hazardous materials work area. All materials representing life-threatening hazards shall be so contained that any predictable sequence of failures will not result in releasing them into the USL atmosphere. Appropriate customer equipment shall be instrumented to detect any leakage which would present a hazard to crew or equipment. Such instrumentation shall be connected to the USL CWS and shall initiate both an audible and visual alarm at the site of the offending condition.

b. No release of particulate matter, liquids, vapors or fumes into the habitable volume shall be permitted unless it can be shown that the contaminant can be handled by the ECLSS. All potentially contaminating substances associated with payloads and processes shall be identified by type, toxicity, quantity, hazard level, use, and location by the customer. Customer contamination control is to be performed at the assembly and rack levels.

SURFACE TEMPERATURE (3.3.18.6)

Under normal operations, the mean radiant temperature of the habitable interior volume shall not exceed 30°C. Exposed surfaces within the USL (both USL and customer equipment) shall remain within the high and low limits of 45°C to 4°C, respectively. Surface temperatures exceeding 45°C shall require specific interfacing agreements. No external equipment surfaces within the USL, whether reachable or not, shall be cooler than the dewpoint temperature of the module atmosphere.

MATERIALS (3.3.18.7)

Customer equipment materials requirements are provided in SS-SRD-0001, Section 3, Paragraph 2.2.1.3.

DEVELOP OPERATING PROCEDURES AND CONSTRAINTS

SSP 30000, Section 4, Paragraph 2.2.H states that "all hazardous operations shall be designed to minimize exposure of the crew to the hazardous condition." This requirement is supported by the hazard analyses performed to identify hazards. Part of the process is to develop controls to counter the identified hazards. At this point in the Space Station Program, a useful project would be the development of a Space Station Laboratory User's Manual wherein user requirements could be consolidated and laboratory procedures could be codified.

PROVIDE TRAINING AND EDUCATION

SSP 30000, Section 4, Paragraph 3.12.B requires that "crew and designated ground support personnel shall be certified to perform their assigned duties." This would certainly include those duties performed in the laboratory. A major resource in the development of the training would be a laboratory procedures guide such as discussed in the previous section.

SSP 30000, Section 4, Paragraph 3.12.D requires that "all crewmembers shall be trained in space systems associated with... safety, and emergency procedures."

CONDUCT REVIEWS AND EVALUATIONS

From time to time it will be necessary to conduct reviews and evaluations to determine if the requirements imposed on the laboratory and on the users are adequate and whether or not they are having the desired effect. Safety is also concerned with whether or not the approved operating procedures are being followed. The mechanics of such a review and evaluation would have to be developed with the view that on-site inspections would be difficult but not necessarily impossible. Membership of a review committee is anticipated to include both the safety and user community. This committee could also be tasked with development and maintenance of the proposed Laboratory User's Manual.

PREPLAN FOR EMERGENCIES

In spite of our best efforts to design against hazards, emergencies will arise which will require timely response. The history of man's endeavors verifies this statement. Preplanning is the only way to have the response capability available when necessary. Included in a good preplan will be equipment, such as hazardous material spill response, control and clear) equipment and rehearsals in the use of the equipment.

AREAS FOR FURTHER DEVELOPMENT

1. TRANSACTION MANAGEMENT. A goal of the Space Station Program is to allow the users maximum autonomy in manipulating their experiments from the ground. Safety has concerns regarding conflicts between operations requested from the ground and conditions on-orbit which could result in hazards to the crew. This problem is currently being worked at Level II and satisfactory resolution is anticipated.

2. OPEN CABIN HAZARDOUS MATERIAL SPILLS. Current no system or subsystem has been identified to handle open cabin spills of hazardous materials. Candidate systems are PMMS, Man Systems, and ECLSS. Work needs to be done first in the characterization of the problem in terms of required responses to a number of different types of materials.

3. SPACE STATION LABORATORY PROCEDURES MANUAL. This type of manual is necessary for the consolidation of requirements imposed upon the user and the codification of procedures (including emergency procedures). This document would also be used in review and evaluation of the laboratory and its operat'on.

Martin E. Coleman, Ph.D.
JSC Medical Sciences Division

AGENDA FOR PRESENTATION

ROLE OF JSC TOXICOLOGY GROUP

GENERAL REQUIREMENTS FOR TOXIC CONTAMINATION CONTROL AND MONITORING

PAYLOAD CHEMICALS THAT MAY BE TOXIC CONTAMINANTS

RECYCLED WATER CONCERNS

POTENTIAL SOURCES OF ENVIRONMENTAL CONTAMINATION

ESCAPE OF PAYLOAD AND GENERAL USAGE CHEMICALS
- STYRENE
- MERCURIC IODIDE

CREW METABOLISM
- CARBON DIOXIDE
- CARBON MONOXIDE
- SKATOLE

THERMODEGRADATION AND COMBUSTION OF MATERIALS
- CARBON MONOXIDE
- HYDROGEN FLUORIDE
- HYDROGEN CYANIDE

OFFGASSING
- ACETALDEHYDE
- CARBON DISULFIDE
- METHY ETHYL KETONE

WHY TOXICOLOGICAL SAFEGUARDS WILL BE ESPECIALLY IMPORTANT IN THE SPACE STATION

A. VERY LITTLE AIR EXCHANGE

B. LONG TIME FOR TOXINS TO ACCUMULATE

C. WIDE DIVERSITY OF OPERATIONS

D. LARGE SCALE OF OPERATIONS

E. GREAT COST IMPACT OF CREW IMPAIRMENT OR EVACUATING MODULE

F. LIMITED MEDICAL CARE AVAILABLE

NSTS MISSION SUPPORT BY THE JSC TOXICOLOGY GROUP

PREFLIGHT

A. ESTABLISH SMAC LIMITS FOR POTENTIAL ATMOSPHERIC CONTAMINANTS

B. CONDUCT AND INTERPRET OFFGAS TESTS
   1. INDIVIDUAL FLIGHT ARTICLES
   2. FLIGHT CONFIGURED ORBITER AND SPACELAB

C. TOXICOLOGICAL SUPPORT FOR PAYLOADS
   1. PAYLOAD SAFETY REVIEWS
   2. TOXICOLOGICAL ASSESSMENTS AND CONTINGENCY PROCEDURES

D. ADDRESS OTHER TOXICOLOGICAL ISSUES
   1. SPECIAL PROBLEMS RELATED TO SPACE FLIGHT
   2. SPECIAL PROBLEMS RELATED TO GROUND OPERATIONS

INFLIGHT

PROVIDE CREW WITH MEANS TO COLLECT AIR SAMPLES
- STAINLESS STEEL AIR CYLINDERS
- SOLID SORBENT AIR SAMPLER (TENAX RESIN)

POSTFLIGHT

GC/MS ANALYSIS OF INFLIGHT ATMOSPHERIC SAMPLES

REPRESENTATIVE PAYLOAD CHEMICALS THAT HAVE FLOWN OR ARE SCHEDULED FOR FLIGHT

CHEMICALS	MISSIONS
SOLVENTS	
DODECANE	SL-1, D-1
TETRADECANE	" "
DISINFECTANTS	
HClO4	SEVERAL SHUTTLE MISSIONS
SALTS (CRYSTAL GROWTH)	
HgI, GaAs, AgNO3	SL-1, SL D-1
METAL ALLOY	
Cd, Cr, Pb, Bi, Co, AG	SL-1, SL-J, SL D-1
	" " "

PROBABLE SPACE STATION PAYLOADS CHEMICALS FROM PROCESS MATERIALS MANAGEMENT SYSTEM (PMMS) LIST

CORROSIVES AND IRRITANTS - AQUEOUS SOLUTIONS OF:

HCl	$NaOH$	ACETIC ACID
H_2O_2	H_2SO_4	FORMALDEHYDE
KOH	NH_4OH	GLUTARALDEHYDE

A. ADVERSE EFFECTS: EYE, SKIN AND MUCOUS MEMBRANE IRRITATION AND INJURY.

B. RECOMMENDED CLEAN-UP IN EVENT OF MAJOR SPILL

SOLUTIONS: USE ADSORBENT MATERIAL; WEAR GLOVES, EYE PROTECTION, AND MASKS.

PARTICULATES: USE HAND HELD VAC OR VAC HOSE

CHEMICALS FROM PMMS LIST - CONTINUED

B. VOLATILE ORGANIC LIQUIDS

ACETONE	ACETONITRILE
METHANOL	DIMETHYL SULFOXIDE (DMSO)
XYLENES	TOLUENE

TOXICOLOGICAL CHARACTERISTICS

1. ALL ARE MILDLY TO MODERATELY IRRITATING

2. ALL HAVE SOME DEGREE OF SYSTEMIC TOXICITY

ACETONITRILE: INTERFERES WITH OXIDATIVE METABOLISM, CAUSING ANOXIA

XYLENES: TOXIC INJURY TO LIVER, KIDNEY AND CENTRAL NERVOUS SYSTEM

TOLUENE: REDUCED RBC COUNTS, MENTAL IMPAIRMENT, MUSCLE INCOORDINATION

METHANOL: NEUROTOXIN (ESP. OPTIC NERVE)

REMOVAL OF VAPORS:

CHARCOAL: ACETONE, ACETONITRILE, XYLENES, TOLUENE

DEHUMIDIFIER: METHANOL

CURRENT MEANS OF ENVIRONMENTAL CONTAMINATION CONTROL IN THE SPACE SHUTTLE

CABIN AIR FAN AND PARTICULATE FILTER MAINTAINS AIR MOVEMENT AND REMOVES PARTICULATES

LITHIUM HYDROXIDE/CHARCOAL AIR SCRUBBER
- LiOH: REMOVES CO_2 AND ACID GASES
- CHARCOAL: REMOVES VOLATILE CHEMICALS

DEHUMIDIFIER
- REMOVES WATER SOLUBLE CONTAMINANTS

WASTE MANAGEMENT SYSTEM (WMS)
- H_3PO_4 TREATED CHARCOAL: REMOVES NH_3, OTHER ALKALINE GASES

AMBIENT TEMPERATURE CATALYTIC OXIDIZER
- PLATINUM ON CHARCOAL: CATALYTIC OXIDATION OF CO AND H_2

GENERAL REQUIREMENTS FOR TOXIC CONTAMINATION CONTROL IN HABITABLE MODULES

A. SAFEGUARDS AGAINST CHEMICAL ESCAPE FROM CONTAINMENT
   - LEAK AND MATERIALS COMPATIBILITY TESTING
   - REVIEW DESIGN AND OPERATION BY PAYLOAD SAFTEY GROUP

B. MATERIALS CERTIFICATION
   - OFFGASSING AND FLAMMABILITY

C. PREVENT EXCESSIVE TEMPERATURE AND PRESSURIZATION
   - ADEQUATE FUSES AND THERMOSTATS

GENERAL REQUIREMENTS FOR TOXIC CONTAMINATION CONTROL IN HABITABLE MODULES CONTINUED

D. MINIMIZE RISK OF TOXIC EXPOSURES DURING CONDUCT OF EXPERIMENTS AND CLEANING, REPAIR AND MAINTENANCE PROCEDURES.
   - WORK IN FUME HOOD OR GLOVE BOX IF POSSIBLE.
   - WEAR PROTECTIVE GEAR AND RESPIRATOR
   - USE ADDITIONAL SCRUBBERS & VENTILATION IF NEEDED DURING PROCEDURES.

E. BRIEF CREW, SUPPORT PERSONNEL AS TO TOXIC HAZARD POTENTIAL OF MATERIALS AND OPERATIONS.

F. LABEL CONTAINERS OF ALL HAZARDOUS CHEMICALS.

NASA Lyndon B. Johnson Space Center

Internal Contamination Requirements and Guidelines	Martin E. Coleman, Ph.D.
	JSC Medical Sciences Division

REQUIREMENTS FOR CONTINGENCY PLANS AND EQUIPMENT FOR RESPONDING TO TOXICOLOGICAL ACCIDENT

- FLIGHT CREW AND GROUND SUPPORT PERSONNEL TRAINING
- EMERGENCY CARE FACILITIES AND ANTIDOTES
- RESPIRATORS, PROTECTIVE CLOTHING AND GOGGLES IN EACH MODULE
- ADEQUATE DECONTAMINATION SYSTEMS AVAILABLE
- MEANS OF ISOLATING CONTAMINATED MODULE FROM OTHERS
- CREW, FLIGHT SURGEON AND GROUND SUPPORT TEAM ACCESS TO TOXICOLOGY DATA BASES
- A SAFE HAVEN CONTAINING LIFE SUPPORT PROVISIONS AND DECONTAMINATION EQUIPMENT

C5

Martin E. Coleman, Ph.D.

JSC Medical Sciences Division

GUIDELINES FOR ENVIRONMENTAL DECONTAMINATION SYSTEMS

ADEQUATE TO REMOVE MAXIMUM CHEMICAL SPILL

EFFECTIVE AGAINST ALL POTENTIAL TOXINS

DO NOT RELEASE SIGNIFICANT AMOUNTS OF TOXIC BY-PRODUCTS

MAJOR ADSORBENT MATERIALS SHOULD BE REGENERABLE.

ADEQUATE VACUUM HOSES, ADSORBENTS, AND/OR FILTERS TO REMOVE MAXIMUM AMOUNT OF SOLIDS AND LIQUIDS WITHIN A REASONABLE TIME.

THE REAL-TIME ANALYZER

A. GENERAL RECOMMENDATIONS

1. CAPABLE OF ANALYZING A WIDE RANGE OF CONTAMINANTS AT LOW LEVELS
2. CAPABLE OF ANALYZING AIR IN ALL HABITABLE MODULES AT INTERVALS OF ONE DAY OR LESS
3. REQUIRES A MINIMUM OF CREW TIME AND TRINING
4. HAS BACK-UP OR MODULAR PARTS AVAILABLE IN EVENT OF MALFUNCTION

B. ANALYZERS UNDER CONSIDERATION

1. BROAD SPECTRUM, MULTICOMPONENT ANALYZER AS GAS CHROMATOGRAPH/ MASS SPECTOMETER
2. PORTABLE ANALYZER AS GAS CHROMATOGRAPH
3. NONSPECIFIC ANALYZER FOR QUICK DETECTION AS TOTAL HYDROCARBON ANALYZER
4. COMPOUND SPECIFIC ANALYZER AS ELECTRO-CHEMICAL DETECTORS
5. PARTICULATE ANALYZER AS X-RAY SURVEY METERS AND AERODYNAMIC PARTICLE SIZERS

ENVIRONEMTAL CONTAMINANTS IN RECYLCED WATER

A. DEHUMIDIFIER IS PROBABLY A MAJOR AIR DECONTAMINATION SYSTEM

1. TYPE CONTAMINANTS REMOVED:

VAPORS - MOST EFFECTIVE FOR WATER SOLUBLE, LOW VAPOR PRESSURE COMPOUNDS

SOME LOW SOLUBILITY COMPOUNDS SEEN IN CONDENSATES

PARTICULATES - MAY COME DOWN WITH WATER CONDENSATES

2. RESULTS OF SPACELAB WATER CONDENSATE ANALYSES

COMPOUND	CONCENTRATION (MG/L)		
	SL-1	SL-3	SL D-1
CAPROLACTAM	0.07	4.30	8.80
DECANOIC ACID	1.60		0.07
ETHANOL	0.52	1.10	0.15
ISOPROPANOL	13.0	0.32	0.04
TOLUENE	0.24	0.01	
PHENOL	0.24		0.66
ACETONE	3.31	2.00	1.80

NORMAL WATER LOSS INTO AIR: 1.6 L/PERSON/DAY

B. MEANS OF CONTAMINANT REMOVAL FROM WATER: ACTIVATED CARBON, ION EXCHANGE RESINS

PROBABLY HARDER TO SCRUB CONTAMINANTS FROM WATER THAN FROM AIR

C. TOXICITY CONCERNS:
INGESTION
ADSORPION THROUGH SKIN

N91-15938

INTERDEPENDENCE OF SCIENCE REQUIREMENTS AND SAFETY LIMITATIONS ON THE SPACE STATION

Patrick G. Barber
Professor and Director of Chemistry
Longwood College, Farmville, Virginia 23901

NASA-Teledyne Brown Engineering
Huntsville, Alabama

30 November 1988

Interdependence of Science Requirements and Safety Limitations on the Space Station

Patrick G. Barber
Professor and Director of Chemistry
Longwood College, Farmville, Virginia 23901

One of the compelling reasons for using a facility such as the Space Station for scientific research is the ability to carry out experiments in an interactive mode. The increased time in space coupled with the increased availability of equipment and supplies enables scientists to perform experiments, to observe results, and quickly to repeat the experiments using the previous results as a basis to improve the parameters. In past space experiments this interaction between experimenter and experiment was often severely limited and often necessitated return flights at much later dates. Science conducted with years between experiments proceeds too slowly to be of benefit to either science or the economy. Crystal growth experiments provide a case in point. A sample of lead-tin-telluride semiconductor was flown in October 1985. One run was possible and no on-site analysis was available. The sample was analyzed only upon return to earth. The results although interesting raise questions that require further experimentation. No repeat has been possible and will not likely occur before several more years. In a second example the high school student proposing the growth of lead iodide in space finally had his experiment run on the recent Discovery (STS-26) flight, but he is now in medical school. This mode of operation was a fine beginning, but science in the western world will not progress very far if this continues as the only mode of experimentation. It is too slow and inefficiently utilizes time, equipment, and personnel. So, one of the benefits of experimentation on the space station will be the ability to carry out the experiment, to immediately analyze the result, to calculate improved experimental parameters, and to quickly repeat the experiment. In this improved mode of operation there are new safety considerations that must be addressed in the design stages of both the station and the experiments. I shall share with you some of the chemical and procedural requirements, and I shall discuss some of the earth-bound storage, dispensing, and disposal techniques that may assist in the development of analogous procedures for the space station.

Each scientific discipline has its own specific lists of requirements for on-board analyses in the space station. In the area of crystal growth the manifest of materials will make an industrial hygienist on earth tremble. The exciting crystals of military and industrial importance are not restricted to benign aqueous solutions of proteins and harmless simple electrolytes. High temperature superconductors have barium, yttrium, copper, and oxygen; but some also contain thallium and other toxic, heavy metals. Semiconductors contain mercury, cadmium, tellurium, gallium, arsenic, lead, tin, indium, and antimony. Further, these materials are grown not at ambient temperatures but at temperatures that are 900° C to 1400° C or higher. Furnace designs are being developed that safely allow crystals of even these materials to be grown in space. After the growth has been completed and cooled to room temperature, the samples must be analyzed. This involves non-destructive testing if the equipment is available on the space station. X-ray diffraction, ultrasonic evaluation, optical absorption, and electronic probes are examples of these analyses. Often, however, such methods do not enable scientists to ascertain the needed information. The crystals must be cut and polished. The cutting operation can involve the use of corrosive chemicals and dust-producing saws, and the polishing and etching procedures use solutions that are often highly hazardous. Such reagents as liquid bromine, hydrofluoric acid, and concentrated alkaline solutions are common. A more detailed list of reagents and procedures is given on the <u>viewgraph</u> handouts. Proper labeling, storage, handling, and disposal of reagents will be essential to the successful, safe use of space station for significant science.

The interdependence between the needs of science and the dictates of safety should serve as a spur to the development of new techniques that will allow safe operation on the space station. The science requirements can be clearly defined using current earth-based techniques and needs. The safety limitations will determine which of these techniques and chemicals can be used in the environment of the space station. For those techniques and chemicals for which safe procedures have not yet been developed, encouragement ought to be given to develop new procedures. As an example of such safer procedures that can be developed, consider the development of an electrochemical etching technique for lead tin telluride, which replaced the highly corrosive Norr etch. Also consider the development of a gel based procedure to deliver chemicals in space. The storage, dispensing, spill clean-up, and waste disposal procedures to be used on the space station need to be developed early in the design stages so that scientists can begin looking for acceptable alternative procedures and reagents that can be used on the space station.

A later design feature may also be beneficial. Perhaps not as an initial part of the space station, but certainly as part of future designs, consideration should be given to the use of small, limited mission, detachable experiment and analysis modules [EAM]. The more hazardous reagents and procedures for which safer alternatives cannot be found may still be performed in space. In the event of an accident, the modules can be sealed off from the rest of the station. They can be detached, retrieved, and returned to earth for clean-up. In this way a spill or accident on one such module will not endanger the station or interfere with other on-going experiments.

In designing equipment and procedures to be used on the space station, some of the techniques used in earth-based laboratories can be used as starting points. The problems faced by small, college laboratories are in many ways analogous to those to be encountered on the space station. In both facilities there is the need to store a variety of reagents safely. Often these are incompatible. The volumes of chemicals in both laboratory environments are small and the variety large. This poses problems slightly different from those presented by bulk chemicals, but some guidance is still available from the U.S. Coast Guard's list of incompatible substances and the DOT mandates. Shipping labels and container label information are also helpful. Finally the information available in the MSDS should not be ignored. Storage by hazard category is the general rule in laboratory stockrooms, and should be used on space station as well. Incompatible reagents in close proximity are intolerable on earth, and they are likely to be in space as well. Storage space is at a premium in both earth-based and space-based laboratories. Many questions need to be answered. How can provision be made for the storage of flammables? Do the same flammability figures apply in space? How many separate storage cabinets will be needed? Must their design be modified for the way in which flames propagate in space? Should they be vented, and if so what is to be done with the fumes? The procedures used on earth will be outlined in the <u>viewgraph</u> handouts.

In dispensing chemical reagents on earth, positive and negative air pressures need to be considered. Important as this principle of laboratory design is for earth-based laboratories, it may take on added importance in the space station, for this may be the major source of hazardous substances that move from one part of the station to another. In the event of a spill on earth, the procedure is to dyke with a neutralizing solid, and bag for disposal as illustrated in the <u>viewgraph</u> handouts. What analogous procedures will be developed for use in space? How many different neutralizing clean-up kits will be needed? How many will be needed and in what locations? If an error is made on earth, adequate ventilation can be obtained by opening a window and turning on a hood; the same simple solutions are not possible in space. Or are they? In disposing of reagents the problems faced by earth and space laboratories are likewise analogous. The toxicity and reactivity must be reduced, the volumes reduced, and procedures for the safe storage of a mixture of wastes developed. Chemists have been working on such storage and handling problems, and the recent environmental protection laws have spurred even further developments. A list of references for such procedures will be given in the viewgraph handouts. Finally, in earth-based laboratories accidents often occur in the most unsuspected places; and the same is likely in space. The drain traps can often be sources of trouble, since a variety of reagents are often mixed in them.

Although it is true that the college and space laboratory environments are similar in many respects, there are still some significant differences. Liquids will not pour in a preferred direction in space unless provision is made to force them to do so. They may not coat the samples or adequately mix. The absence of gravity driven convection will make mixing reagents and the removal of heats of reaction more difficult. This may allow for the unanticipated build-up of hazardous local concentrations of heat. The analogous problem faced in polymer synthesis will be reviewed.

Just as the problems faced in small laboratories on earth can provide guidance and insight to experimental procedures that can be adapted for use in space, the procedures and reagent handling systems developed for safe use on board space station, will be useful here on earth. One of the greatest future expenses to be faced by these small facilities is the ever increasing cost and difficulty of safely and legally disposing of spent and surplus chemicals. Techniques that work for space station have an immediate application right here, right now in schools, colleges, and small laboratories.
Further commercial possibilities of this spin off exist. Procedures developed for space station will likely not require continuous human intervention. The automatic and robotic procedures developed for space station will have application in improving the safety and productivity of industrial processes. Finally, as space station and its technology begin to be applied, further experimentation in the schools of this nation will be possible. This can only encourage the preparation of the scientifically literate population needed in the next century.

Safety and science requirements are interdependent spurring the development of new procedures and modified engineering designs. These developments will not merely be useful on space station, for they have far reaching applications on earth.

THE SCIENTIFIC UTILIZATION OF THE SPACE STATION DEPENDS UPON:

- **a. Experimenter Interaction with Experiments**
- **b. Rapid Repetition of Experiments**
- **c. On-Station Analyses of Results**

SIMILARITIES OF ENVIRONMENTAL PROBLEMS BETWEEN COLLEGES AND THE SPACE STATION:

a. **Size** -- limited space which impinges on other functions

b. **Large Variety of Reactions Requiring Pr paration** -- not specialized, must have flexibility.

c. **Large Variety of Reagents Needed** -- cannot wait for stores to be ordered and delivered

d. **Safe Reagent Storage** -- variety must be stored safely for long periods of time

e. **Waste Mitigation, Storage, and Disposal** -- a relatively new problem requiring new solutions

f. **Spill Control Preparation and Procedures** -- equip facility to handle all possible accidents

g. **Air Flow and Quality** -- regulate unexpected movement of liquid and gassous reagents

h. **Extensive Training of Supervisors** -- expect the unexpected.

AN EXAMPLE: REAGENTS AND EXPERIMENTS FOR CRYSTAL GROWTH --

a. **Solution Growth** -- water and/or non-aqueous fluid solvents for
   - proteins -- benign case
   - organic compounds -- flammable and/or toxic solvents and solutes

b. **Melt Growth** --

Temperatures:	ambient → 400°C, lead halides and model compounds
	400-1200°C, LTT, GaAs
	>1200°C, GaAs, ceramics
Procedures:	Czochralski
	Bridgman

c. **Chemical Vapor Decomposition** --
gaseous flow systems such as organometallic tin in gaseous hydrogen, silane in hydrogen, and gallium arsenide from trimethyl gallium and arsine

INSTRUMENTAL TECHNIQUES OFTEN REQUIRE REAGENT FLUIDS:

1. **HPLC -- requires solvents which are often organic**

2. **TLC -- requires solvents which are often organic mixtures**

3. **Electrophoresis -- requires solutions including organic ones**

4. **GC -- requires carrier gases. FID requires hydrogen**

5. **AA -- requires flames and nitrous oxide, acetylene, and oxygen or graphite furnaces. Both burners generate metal vapors**

6. **Optical Microscopy -- require sample preparation including cutting, polishing, and etching**

REAGENTS AND EXPERIMENTS FOR ON-SITE ANALYSES:

a. **Cut and Polish**
   1. water
   2. organic liquids
   3. acids/bases, dilute to 18M H_2SO_4 and 50% KOH
   4. special corrosives, e.g., HF, Br_2, and mixtures such as Norr etch

b. **Etch**
   1. less concentrated than for cutting and polishing but still corrosive and/or toxic
   2. many developed some specific for particular faces and dislocations

AIR AND FLUIDS MANAGEMENT:

a. **Storage**
by categories
guidance from USCG, chemical suppliers, MSDS, DOT shipping labels

b. **Dispensing**
microgravity creates the need for new solutions but similar to movement of reagents in vacuum lines.

c. **Mixing**
microgravity creates the need for new solutions but similar to polymer solutions and gels.

d. **Spent Reagent Management**
traditional methods -- burn, bury, hide, give away or otherwise forget
newer methods -- dilute, precipitate, distill, react, recycle
stabilize -- Hazardous Chemicals: Information and Disposal Guide by M.A. Armour, L.M. Browne, and G.L. Weir from the University of Alberta
safe storage for return
variety leads to unexpected reactions in drains or space station equivalent
possible on-station utilization/disposal will improve on the best methods developed in response to environmental pressures

e. **Spill Management**
traditional methods -- dyke, neutralize, store, disposal
newer methods for space station -- creative solutions may not eliminate the unexpected mixing of two innocuous reagents which are dangerous in combination. Remember the drains!

HOPE:

a. **New procedures can be developed, e.g.,**
   1. **electrochemical etches**
   2. **soda straw gels for dispensing reagents in space**
   4. **new organometallic reagents of III-V compounds**
   5. **blow-down tunnels versus recirculating reagents in CVD**

b. **Motivation is needed.**

c. **Some accommodation by station designers, i.e., design for the unexpected and prepare detachable modules for use with hazardous reagents. Use also as robotic center-of-mass experimental platform.**

d. **There is an interdependence between the safety limitations which should drive new modifications in the science experiments and the science requirements which should drive new designs for safety.**

AN ADDED BENEFIT:

As the college and small research laboratory provides useful terrestrial examples for the experimental problems anticipated to exist on the space station, so too do the solutions developed for the space station find immediate terrestrial applications.

In thinking for the space station one ought not to forget the commercial possibilities on earth now.

TYPICAL ETCHES:

GaAs	rinses 2-propanol or methanol	
	1:1:5	$H_2O : H_2O_2 : H_2SO_4$
	3:1:1	$H_2SO_4 : H_2O_2 : H_2O$
Si	10:1:1	$H_2O : H_2O_2 : NH_3$
	3:1:1	$H_2O : H_2O_2 : HCl$
	10:1	$H_2O : HF$
	42g/100g	CrO_3 in HF
	50g/100ml	CrO_3 in H_2O
InP	0.2-0.5%	Br_2 in methanol
SnTe	6:3:1	HOAc : HNO_3 : HF
PbSe	4:1:1	glycerol : HOAc : HNO_3
	10:10:1:½	H_2O : KOH : glycerol : H_2O_2
PbSnTe		Br_2, HBr, H_2O, glycerine
HgCdTe	spray etch using N_2 gas: Br_2 in methanol, alkaline glycerine with H_2O_2, HF and H_2O_2 in H_2O rotate sample at >6000 rpm	
GaP	1:3	HNO_3 : HCl (aqua regia)

N91-15939

Design and Development of a Space Station Hazardous Material System For Assessing Chemical Compatibility

Richard T. Congo

NASA/MSFC

November 15, 1988

N91-15539

ABSTRACT

As the Space Station nears reality in funding support from Congress, NASA plans to perform over a hundred different missions in the coming decade. Incrementally deployed, the Space Station will evolve into modules linked to an integral structure. Each module will have characteristic functions, such as logistics, habitation, and materials processing. Because the Space Station is to be "user friendly" for experimenters, NASA is anticipating that a variety of different chemicals will be taken on-board. Accidental release of these potentially toxic chemicals and their chemical compatibility is the focus of this discourse.

The Microgravity Manufacturing Processing Facility (MMPF) will contain the various facilities within the US Laboratory (USL). Each "facility" will have a characteristic purpose, such as alloy solidification or vapor crystal growth. By examining the proposed experiments for each facility, identifying the chemical constituents, their physical state and/or changes, byproducts and effluents, I will be able to identify those payloads which may contain toxic, explosive, or reactive compounds that require processing or containment in mission peculiar waste management systems. Synergistic reactions from mixed effluent streams is of major concern.

Each experiment will have its own data file complete with schematic, chemical listing, physical data, etc. Chemical compatibility information from various databases will provide assistance in the analysis of alternate disposal techniques (pretreatment, separate storage, etc.). Along with data from the Risk Analysis of the Proposed USL Waste Management System, accidental release of potentially toxic and catastrophic chemicals would be eliminated or reduced.

ORGANIZATION:	MARSHALL SPACE FLIGHT CENTER	NAME:
CHART NO.:		DATE.

DESIGN AND DEVELOPMENT OF A

SPACE STATION HAZARDOUS MATERIAL SYSTEM

FOR ASSESSING CHEMICAL COMPATIBILITY

ORGANIZATION: ANALYTICAL AND PHYSICAL CHEMISTRY BRANCH	MARSHALL SPACE FLIGHT CENTER	NAME: R. T. CONGO
CHART NO.:	DESIGN AND DEVELOPMENT OF A SPACE STATION HAZARDOUS MATERIAL SYSTEM FOR ASSESSING CHEMICAL COMPATIBILITY	DATE: NOVEMBER 1988

SPACE STATION USL PHILOSOPHY

- 30-YEAR LIFE
- USER-FRIENDLY
- SAFE

ORGANIZATION: ANALYTICAL AND PHYSICAL CHEMISTRY BRANCH	MARSHALL SPACE FLIGHT CENTER	NAME: R. T. CONGO
CHART NO.:	DESIGN AND DEVELOPMENT OF A SPACE STATION HAZARDOUS MATERIAL SYSTEM FOR ASSESSING CHEMICAL COMPATIBILITY	DATE: NOVEMBER 1988

U. S. LABORATORY

- MICROGRAVITY MANUFACTURING PROCESSING FACILITY
- EXPERIMENTS
- CHARACTERIZATION STUDIES
- HAZARDOUS WASTES
- PROCESS MATERIAL MANAGEMENT SYSTEM

ORGANIZATION: ANALYTICAL AND PHYSICAL CHEMISTRY BRANCH	MARSHALL SPACE FLIGHT CENTER	NAME: R. T. CONGO
CHART NO.:	DESIGN AND DEVELOPMENT OF A SPACE STATION HAZARDOUS MATERIAL SYSTEM FOR ASSESSING CHEMICAL COMPATIBILITY	DATE: NOVEMBER 1988

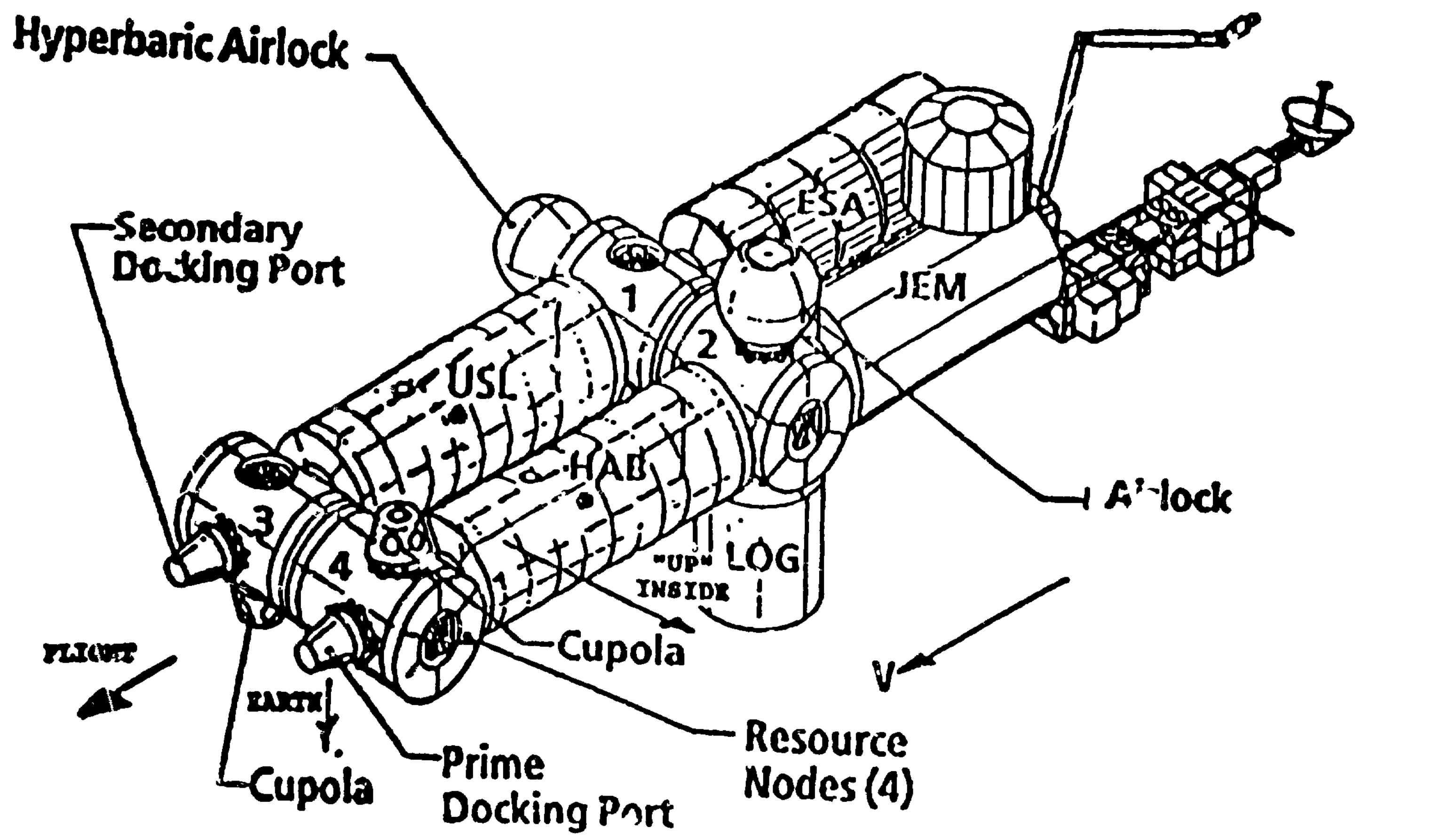


FIGURE 2-1 MODULE CONFIGURATION

FACILITY LIST

ACOUSTIC LEVITATOR
ALLOY SOLIDIFICATION
ATMOSPHERIC MICROPHYSICS
AUTO-IGNITION
BIOREACTOR/INCUBATOR
CONTINUOUS FLOW ELECTROPHORESIS
CRITICAL POINT PHENOMENA
DROPLET/SPRAY BURNING
ELECTROMAGNETIC LEVITATOR
ELECTROSTATIC LEVITATOR
FLOAT ZONE
FLUID PHYSICS
FREE FLOAT LEVITATOR
HIGH TEMPERATURE FURNACE
ISOELECTRIC FOCUSING
OPTICAL FIBER PULLING
ORGANIC AND POLYMER CRYSTAL GROWTH
PREMIXED GAS COMBUSTION
PROTEIN CRYSTAL GROWTH
ROTATING SPHERICAL CONVECTION
SMALL BRIDGEMAN
SOLUTION CRYSTAL GROWTH
SOLID SURFACE BURNING FACILITY
VAPOR CRYSTAL GROWTH
VARIABLE FLOW SHELL GENERATOR

FIGURE 2-10 FULL SYSTEMS LABORATORY (LAUNCH)

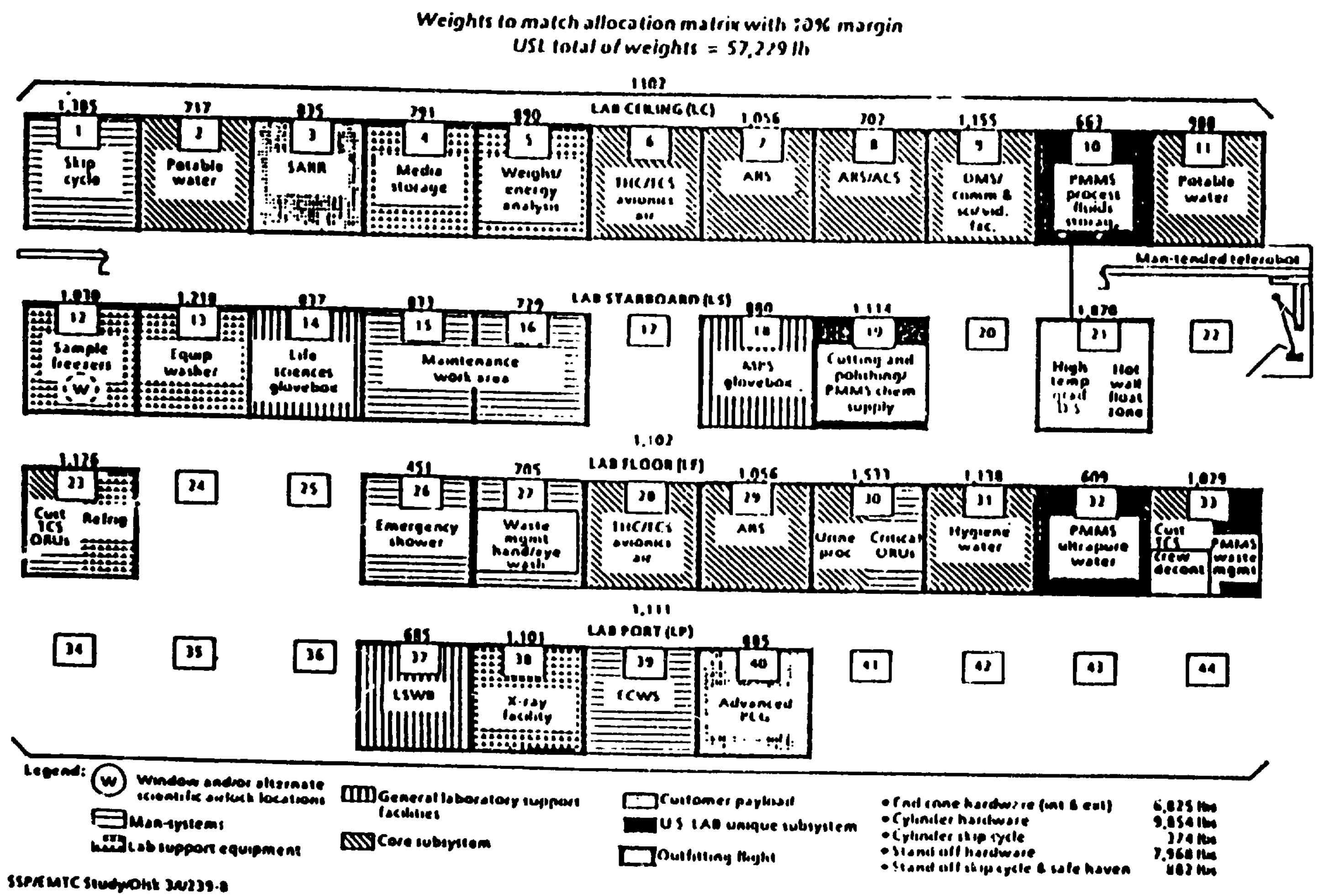


FIGURE 2-11 FULL SYSTEMS LABORATORY (OUTFITTING)

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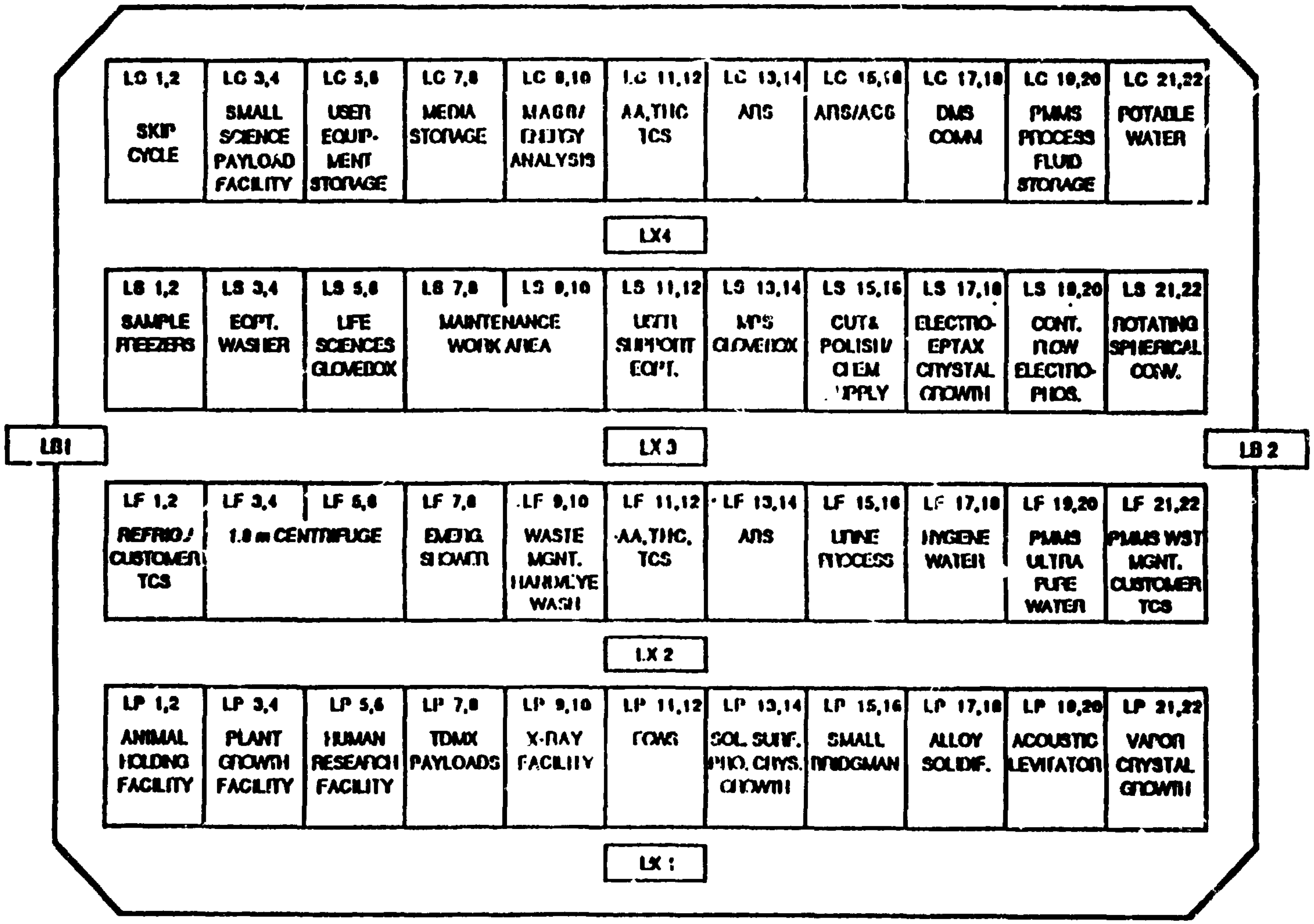


FIGURE 2-2 LAB COMPONENT LOCATIONS

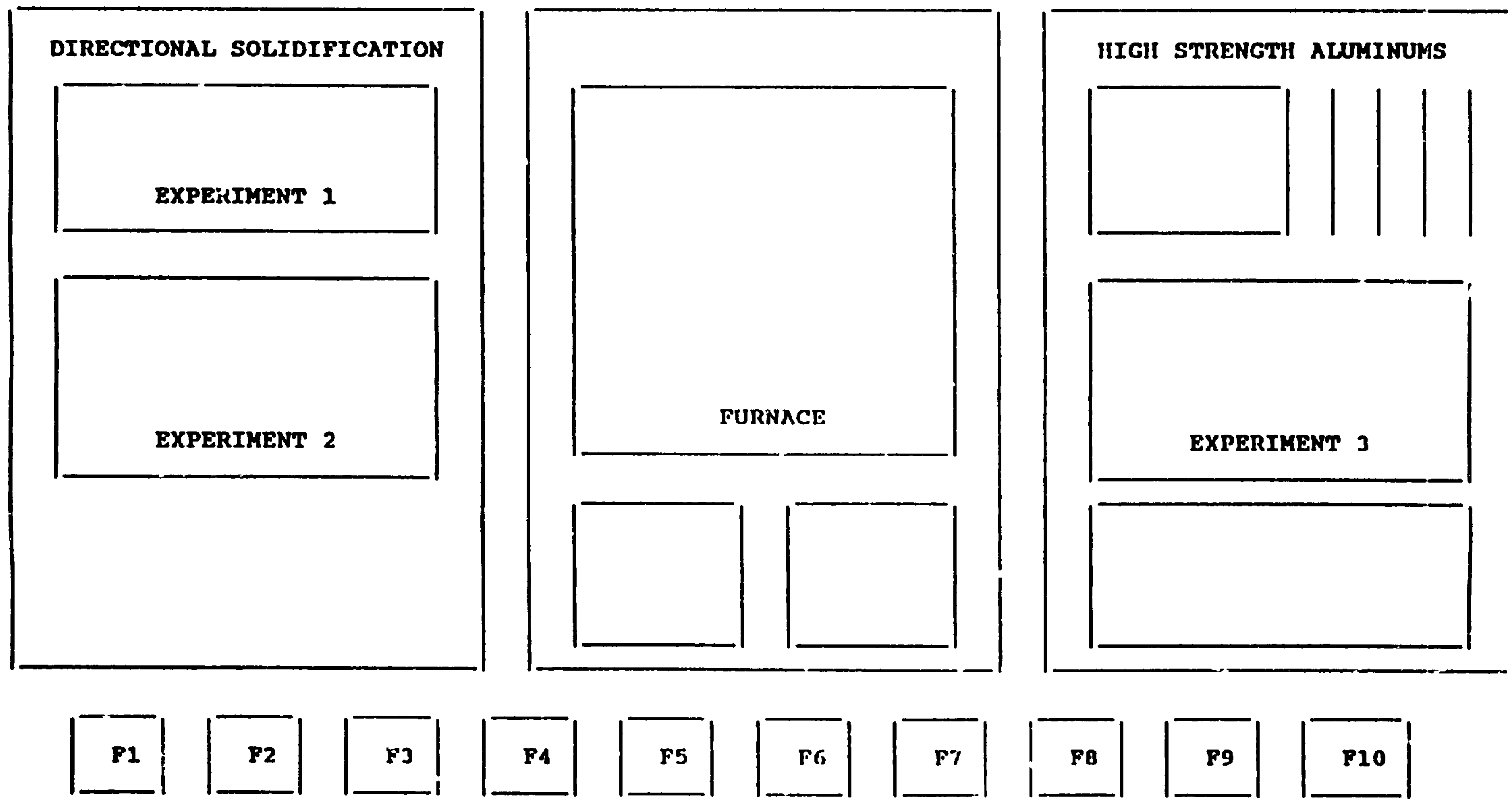
ANALYTICAL AND PHYSICAL
CHEMISTRY BRANCH

R. T. CONGO

DESIGN AND DEVELOPMENT OF A
SPACE STATION HAZARDOUS MATERIAL SYSTEM
FOR ASSESSING CHEMICAL COMPATIBILITY

NOVEMBER 1988

ALLOY SOLIDIFICATION FACILITY



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ALLOY SOLIDIFICATION

- DIRECTIONAL SOLIDIFICATION
- MODIFIED INCONEL 178
- HIGH TEMPERATURE SUPERALLOYS
- LOW CHROMIUM ALLOYS
- MARAGING STEELS
- HIGH STRENGTH ALUMINUMS

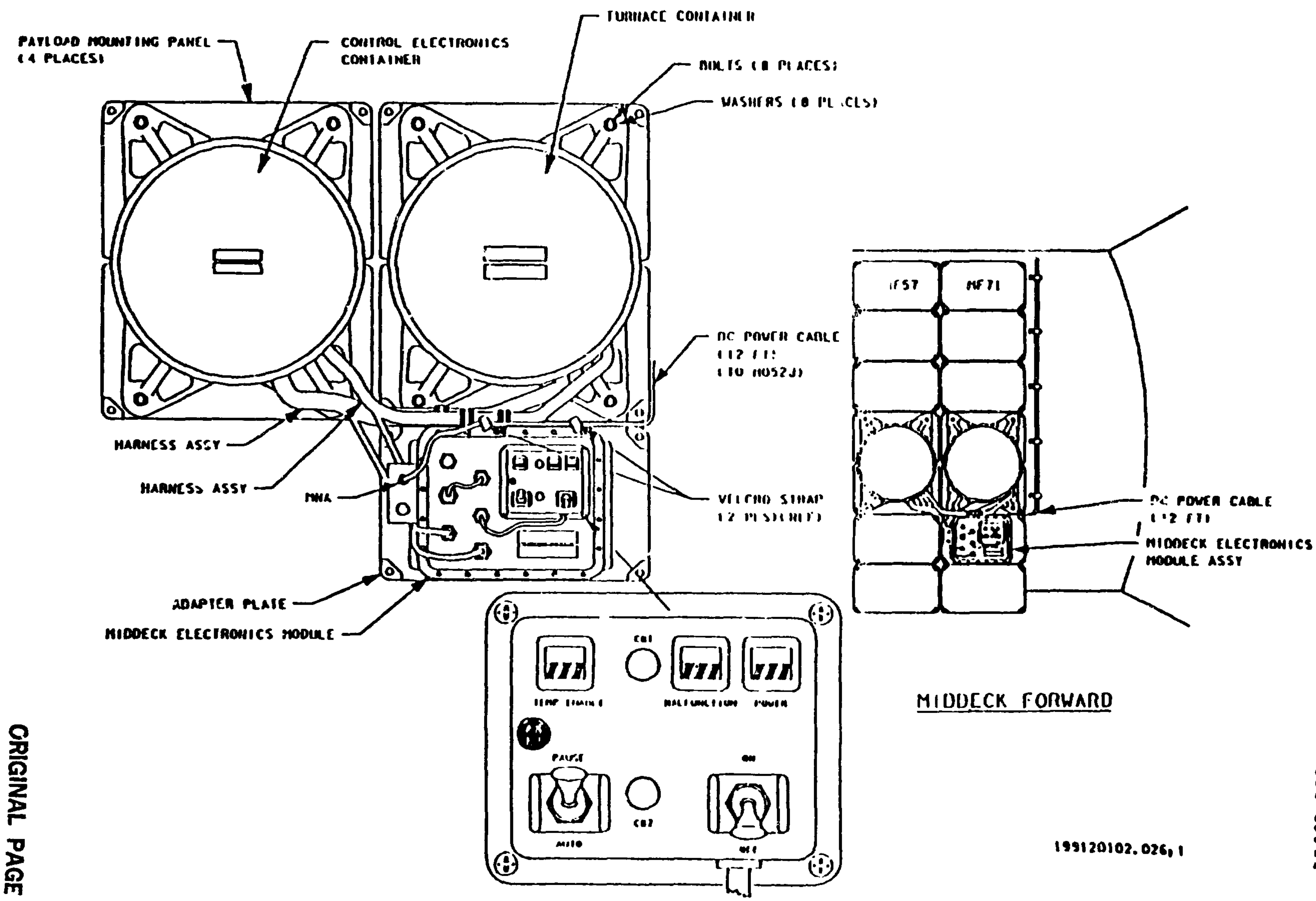

Figure 1-2.- ADSF installation.

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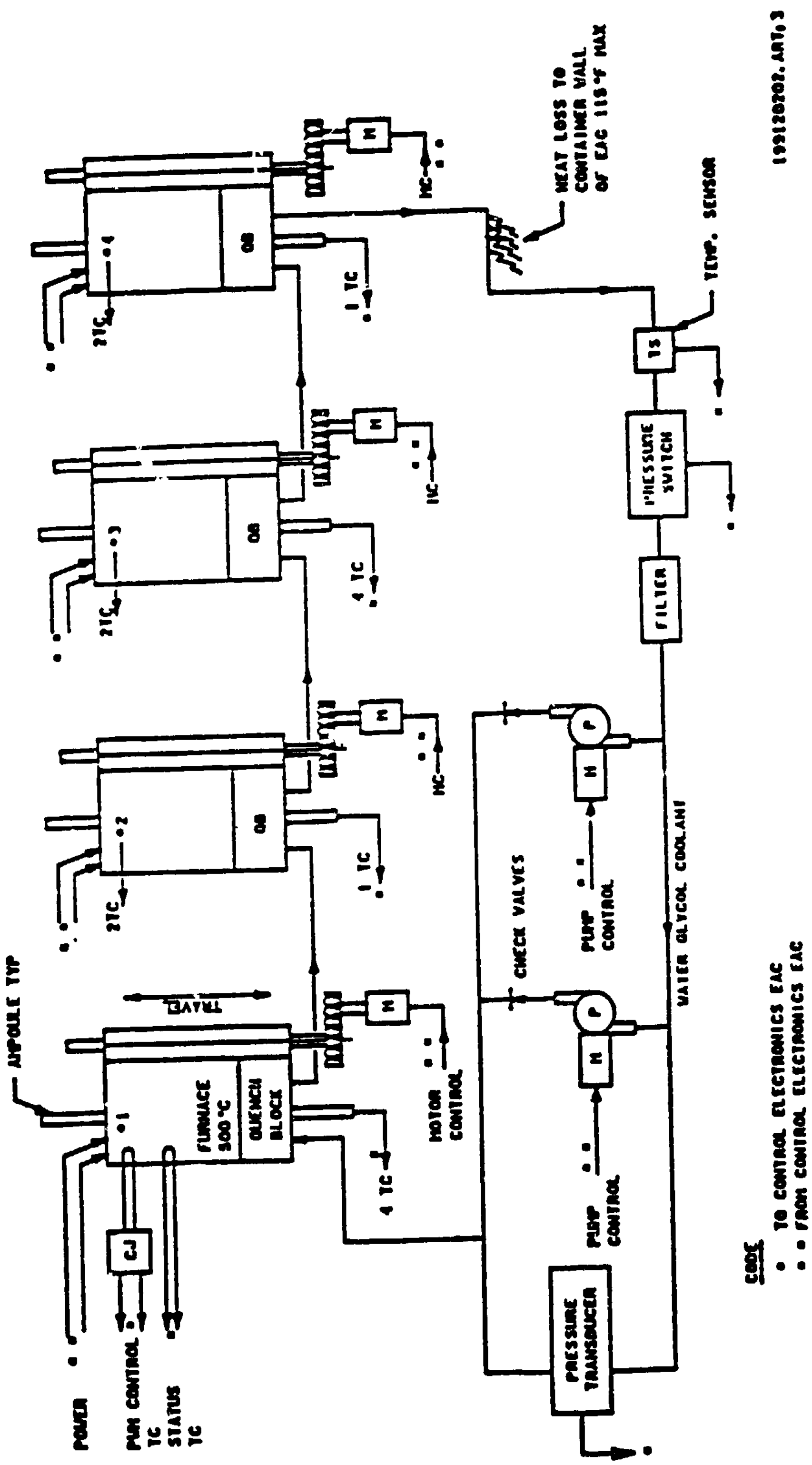

Figure 2-2.- Functional block diagram of furnace system.

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CHART NO.:	DESIGN AND DEVELOPMENT OF A SPACE STATION HAZARDOUS MATERIAL SYSTEM FOR ASSESSING CHEMICAL COMPATIBILITY	DATE: NOVEMBER 1988

BY INVOKING THE CHEMICAL LISTING, WE WOULD OBTAIN THE DETAILED LISTING OF EVERY CHEMICAL ASSOCIATED WITH THE EXPERIMENT.

COPPER
NICKEL
ALUMINUM
IRON
BERYLLIUM
INDIUM
ACETONE
ETHANOL
HYDROGEN
METHANOL
OXYGEN
TOLUENE
ARGON
NITROGEN
WATER

ALLOY SOLIDIFICATION FACILITY 02/25/88

HAZARD CLASS	NAME	FORMULA	SMAC mg/m3	INCOMPATIBILITIES
ASPHYXIANTS	ARGON	Ar	16337.0	NONE
	NITROGEN	N2	0.00	Li,Ti,O3
	WATER	H2O	0.00	NONE DOCUMENTED
FLAMMABLES	ACETONE (2-PROPANONE)	CH3COCH3	712.5	ACIDS,OX,HNO3,H2SO4,ST.BASE, PLASTIC,NITRATES,RED.AGENTS, ALDEHYDES,AMINES,H2O
	ETHANOL	C2H5OH	94.0	OX,ALKALI,ACID
	HYDROGEN	H2	247.3	OX,HEAT,O2,Br2,AIR+Pt,ACETIC ANHYDRIDE,ALDEHYDES,Cl2,F2, Li,CHLORINE TRIFLUORIDE, KETONES,DIOXANE+Ni,Mg+CaCO3, NITROSANISOLE,NITROGEN FLUORIDE
	METHANOL	CH3OH	52.4	ST.OX,CHROMIC ANHYDRIDE
	OXYGEN	O2	0.00	HEAT, OXIDIZABLE MATERIAL
	TOLUENE (METHYL BENZENE)	C6H5CH3	75.3	ST.OX,HNO3,H2SO4,O2, PEROXIDES,HEAT,PLASTICS
FLAMMABLE DUSTS	COPPER	Cu	0.00	ALKALIES,AIR,CHLORATES, BROMATES
	NICKEL	Ni	0.02	ST.ACIDS,S,COMBUST,WOOD
	ALUMINUM	Al	0.00	NONE DOCUMENTED
	IRON	Fe	0.00	NONE DOCUMENTED
TOXINS	BERYLLIUM	Be	0.0004	CCl4,Li,ACID,ALKALI,OX,P, CHLORINATED HYDROCARBONS
	INDIUM	In	0.02	S, MINERAL ACIDS

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USL PAYLOAD WASTE SOURCE ASSESSMENT 16-Sep

HAZASF.DAT

CYCLE DATA	FACILITY			CHARACTERIZATION/SUPPORT EQUIPMENT								
MIN. NO. OF CYCLES 2	ALLOY SOLIDIFICATION FACILITY			FLUIDS GLOVEBOX			AUTOMATED CUTTING/POLISHING			SCANNING ELECTRON MICROSCOPE		
	WASTE TYPE	PHASE	MASS/ CYCLE(KG)	WASTE TYPE	PHASE	MASS/ CYCLE(KG)	WASTE TYPE	PHASE	MASS/ CYCLE(KG)	WASTE TYPE	PHASE	MASS/ CYCLE(KG)
MAX. NO. OF CYCLES	WATER	L	2.0000	NITROGEN	G	0.3750	WATER	L	0.5300	LIQUID NITROGEN	L	1.0100
20	ARGON	G	0.3420	METAL POWDERS	P		METAL POWDERS	P				
	METAL POWDERS	P	0.3540	BERYLLIUM			BERYLLIUM					
PROPOSED NO. OF CYCLES	BERYLLIUM			COPPER			COPPER					
	COPPER			ALUMINUM			ALUMINUM					
	ALUMINUM			INDIUM			INDIUM					
	INDIUM			CARBON STEEL			CARBON STEEL					
	CARBON STEEL			IRON			IRON					
	IRON			NICKEL			NICKEL					
	NICKEL			ETCHANT SOLUTION	L,G		PLASTIC ENCAPSULATE	L,G,P				
	MELT VAPORS	G	0.0010	PLASTIC ENCAPSULATE	L,G,P		CLEANING FLUIDS	L,G				
	CLEANING FLUIDS	L,G	0.0463	CLEANING FLUIDS	L,G		ELECTROPOLISHING SOL.	L,G				

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TABLE 7. FLUIDS/WASTES OF ASF

MATERIAL	MASS PER RUN (kg)	VOLUME PER RUN (liters)	COMMENT
Air	0.896	700.0	Used to refill the furnace canisters after each run
Cleaning Fluid	6.00	6.00	Used to clean furnaces
Distilled Water	8.00	8.00	Used for general facility cleanup
Gaseous Helium	0.00071	4.00	Possible coolant for rapid sample quench
Gloves	0.00002	0.00002	Two pair per run
Inert Gas	0.875	700.0	Used to fill furnace canisters during each run. May include either Ar, N_2, or He
Wipes	0.41×10^{-5}	0.44×10^{-5}	10 wipes per run

Run: 433 min

ETCHING MATERIALS 03/25/88

XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX

HAZARD CLASS	NAME	FORMULA	SMAC(mg/m3)	INCOMPATIBILITIES
IRRITANTS	ACETIC ACID (ETHANOIC ACID)	CH_3COOH	7.40	ST.OX.,CNS PEROXIDES,CAUSTICS,ST.BASE, PERMANGANATES, ACTIVE METALS, PLASTIC,ACETALDEHYDE,CHLORINE TRIFLUORIDE,CHROMIC ANHYDRIDE ACETIC ANHYDRIDE,Mg, ACETONE
	IRON (FERRIC) CHLORIDE	$FeCl_3$	0.00	NONE DOCUMENTED
	OXALIC (ETHANEDIOIC) ACID	$HOOCOOH$	0.00	NONE DOCUMENTED
	ORTHOPHOSPHORIC ACID	H_3PO_4	0.00	NONE DOCUMENTED
	SULFURIC ACID	H_2SO_4	0.00	ORG. MAT,CHLORATES, ACT. METAL
ASPHYXIANTS	WATER	H_2O	0.30	NONE DOCUMENTED
FLAMMABLES	ETHANOL	C_2H_5OH	94.0	OX,ALKALI,ACID
CORROSIVES	AMMONIUM BIFLUORIDE	NH_4HF_2	0.00	NONE DOCUMENTED
	CHROMIC ACID	H_2CrO_4	0.00	RED. AGENTS, ORGANIC MATL
	HYDROCHLORIC ACID	HCl	1.5	ACT.MET,K,Na,Ca,Zn,Mg,Al PDR
	HYDROFLUORIC ACID	HF	0.082	ACTIVE METALS,SAND,GLASS(Si)
	NITRIC ACID	HNO_3	1.0	ORG.MAT,WOOD,TURPENTINE, ACT.METALS,H2S,STONG BASES
	POTASSIUM HYDROXIDE	KOH	0.02	ACID,AIR,NITROMETHANE,H2O, GLASS,Al PWDR,Sn,Zn,ORG.HAL, NITRO COMP,ACTIVE METALS, ACETIC ACID, ACROLEIN,P,CO2, CHLOROFORM+MeOH,STEAM,MOIST, PEROXIDES, COMBUSTIBLES
	SODIUM HYDROXIDE	$NaOH$	0.6	H2O,ACID,FLAM.LIQ,ORG.HAL, ACT.MET,Al PWDR,Sn,Zn,NITRO COMP,NITROMETHANE,PLASTICS
TOXINS	BENZALKONIUM CHLORIDE	$C_6H_5CH_2N(CH_3)_2RCl$	0.00	(MIXTURE, R=C8H17-C18H37)
	COPPER (CUPRIC) CHLORIDE	$CuCl_2$	0.00	NONE DOCUMENTED
	DIHYDROXYDIETHYL ETHER	$CH_2OHCH_2OCH_2CH_2OH$	0.00	(DIETHYLENE GLYCOL) NONE
	HYDROGEN PEROXIDE	H_2O_2	0.28	OX,Fe,Cu,Zn,MANGANESE TRIOX
	POTASSIUM PERMANGANATE	$KMnO_4$	0.00	ORGANIC MATL, OXIDIZERS
	POTASSIUM FERRICYANIDE	$K_3Fe(CN)_6$	0.00	ACIDS, NH3, CHROMIC ACID
	SODIUM NITRATE	$NaNO_3$	0.00	ORGANIC MATERIAL,HEAT(537C)
	SULFAMIC ACID	$HOSO_2NH_2$	0.00	NONE DOCUMENTED
	TRINITROPHENOL (PICRIC ACID)	$C_6H_2(NO_2)_3OH$	0.00	MET.SALTS,HEAT,SHOCK,METALS
UNCLASSIFIED	AMMONIUM SULFATE	$(NH_4)_2SO_4$	0.00	OX,O2,PEROXIDES,POTASSIUM CHLORATE,SODIUM NITRATE, METAL CHLORATES
	LACTIC ACID	$CH_3CHOHCOOH$	0.00	NONE DOCUMENTED
	POTASSIUM METABISULFITE	$K_2S_2O_5$	0.00	NONE DOCUMENTED
	SODIUM CHLORIDE	$NaCl$	0.00	NONE DOCUMENTED

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MACROETCHING MATERIALS 02/25/88

HAZARD CLASS	NAME	FORMULA	SMAC mg/m3	INCOMPATIBILITIES
IRRITANTS	ACETIC ACID (ETHANOIC ACID)	CH3COOH	7.40	ST.OX.,CHR PEROXIDES,CAUSTICS,ST.BASE, PERMANGANATES, ACTIVE METALS, PLASTIC,ACETALDEHYDE,CHLORINE TRIFLUORIDE,CHROMIC ANHYDRIDE, ACETIC ANHYDRIDE,Mg, ACETONE
	AMMONIUM PERSULFATE	(NH4)2S2O8	0.00	ORGANIC MATERIAL
	COPPER SULFATE, PENTAHYDRATE	CuSO4*5H2O	0.00	NONE DOCUMENTED
	IRON (FERRIC) CHLORIDE	FeCl3	0.00	NONE DOCUMENTED
	SODIUM DICHROMATE	Na2Cr2O7	0.00	SUSPECTED CARCINOGEN
	SULFURIC ACID	H2SO4	0.00	ORG. MAT,CHLORATES, ACT. METAL
ASPHYXIANTS	WATER	H2O	0.00	NONE DOCUMENTED
CORROSIVES	CHROMIC ACID	H2CrO4	0.00	RED. AGENTS, ORGANIC MATL
	HYDROCHLORIC ACID	HCl	1.5	ACT.MET,K,Na,Ca,Zn,Mg,Al PDR
	HYDROFLUORIC ACID	HF	0.082	ACTIVE METALS,SAND,GLASS(Si)
	NITRIC ACID	HNO3	1.0	ORG.MAT,WOOD,TURP[illegible]TINE, ACT.METALS,H2S,[illegible]
	SODIUM HYDROXIDE	NaOH	0.4	H2O,ACID,FLAM.LIQ.,[illegible]HAL, ACT.MET,Al PWDR,Sn,Zn,NITRO COMP,NITROMETHANE,PLASTICS
TOXINS	AMMONIUM CHLORIDE	NH4Cl	0.00	NONE DOCUMENTED
	COPPER (CUPRIC) CHLORIDE	CuCl2	0.00	NONE DOCUMENTED
	HYDROGEN PEROXIDE	H2O2	0.28	OX,Fe,Cu,Zn,MANGANESE TRIOX
	MAGNESIUM CHLORIDE	MgCl2	0.00	NONE DOCUMENTED
	SODIUM NITRATE	NaNO3	0.00	ORGANIC MATERIAL,HEAT(537C)
	TRINITROPHENOL (PICRIC ACID)	C6H2(NO2)3OH	0.00	METALLIC SALTS,HEAT,SHOCK,MET
UNCLASSIFIED	IRON (FERROUS) CHLORIDE	FeCl2	0.00	NONE DOCUMENTED
	LACTIC ACID	CH3CHOHCOOH	0.00	NONE DOCUMENTED

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FOR CRYSTAL GROWTH FACILITY

02/25/88

HAZARD CLASS	NAME	FORMULA	SMAC mg/m3	INCOMPATIBILITIES
IRRITANTS	ZINC CHLORIDE	ZnCl2	0.00	POTASSIUM
	CHLORINE	Cl2	0.87	COMBUSTIBLES,PLASTIC,AMMON SALTS,ACETALDEHYDE,ACETYLENE, ALCOHOLS,Al PWDR,NH3,C6H6, CESIUM COMP,Cu,DIBORANE
ASPHYXIANTS	ARGON	Ar	16337.0	NONE
	HELIUM	He	0.00	NONE
	NITROGEN	N2	0.00	Li,Ti,O3
	WATER	H2O	0.30	NONE DOCUMENTED
FLAMMABLES	ACETONE (2-PROPANONE)	CH3COCH3	712.5	ACIDS,OX,HNO3,H2SO4,ST.BASE, PLASTIC,NITRATES,RED.AGENTS, ALDEHYDES,AMINES,H2O
	ACETYLENE (ETHYNE)	C2H2	532.4	OX,Cu,Ag,Hg,CHLORATES,HAL. COMP.,F2,K,NOx
	ETHANOL	C2H5OH	94.0	OX,ALKALI,ACID
	METHANOL	CH3OH	52.4	ST.OX,CHROMIC ANHYDRIDE
	OXYGEN	O2	0.00	HEAT, OXIDIZABLE MATERIAL
FLAMMABLE DUSTS	COBALT	Co	0.00	OX, NITRATES
	NICKEL	Ni	0.02	ST. ACIDS,S,COMB[illegible],WOOD
CORROSIVES	HYDROCHLORIC ACID	HCl	1.5	ACT.MET,K,Na,Ca,Zn,Mg,Al PDR
	HYDROFLUORIC ACID	HF	0.082	ACTIVE METALS,SAND,GLASS(Si)
	NITRIC ACID	HNO3	1.0	ORG.MAT,WOOD,TURPENTINE, ACT.METALS,H2S,STONG BASE.
TOXINS	ARSENIC	As	0.002	BROMATES,CHLORATES,CHROMIUM TRIOXIDE,AgNO3,SODIUM PER-OXIDE,NITROGEN TRIFLUORIDE, ACIDS,HALOGENS,Na,K,Li,Zn,H2 ACETYLIDES,Pd,Pt
	CADMIUM	Cd	0.01	OX,S,Se,Te
	CADMIUM IODIDE	CdI2	0.00	NONE DOCUMENTED
	CADMIUM SULFIDE	CdS	0.00	OX,S,Se,Te
	CADMIUM SELENIDE	CdSe	0.00	NONE DOCUMENTED
	CADMIUM TELLURIDE	CdTe	0.00	NONE DOCUMENTED
	GALLIUM	Ga	4.50	ACT.MET,ALKALI,HAL.COMP,ACID HCl,HNO3
	GALLIUM ARSENIDE	GaAs	0.178	NONE
	HYDROGEN BROMIDE	HBr	0.00	NONE DOCUMENTED (HYD.BROMIC AC
	HYDROGEN PEROXIDE	H2O2	0.28	OX,Fe,Cu,Zn,MANGANESE TRIOX
	HYDROGEN IODIDE	HI	0.00	F2,HClO4,O2,P,HNO3,O3,KClO4
	IODINE	I2	0.1	NH3,ACETYLENE,Al PDR,ACT.MET
	INDIUM	In	0.02	S, MINERAL ACIDS
	INDIUM PHOSPHIDE	InP	0.00	NONE DOCUMENTED
	MERCURY	Hg	0.006	ACETYLENE, NH3
	MERCURIC BROMIDE	HgBr2	0.60	NONE DOCUMENTED
	MERCURIC CHLORIDE	HgCl2	0.00	NONE DOCUMENTED
	MERCURIC IODIDE	HgI2	0.006	NONE DOCUMENTED
	MERCUROUS IODIDE	Hg2I2	0.006	NONE DOCUMENTED
	MERCURY CADMIUM TELLURIDE	HgCdTe	0.00	NONE DOCUMENTED
	TELLURIUM	Te	0.02	ST.OX,CHLORINE TRIFLUORIDE, F2, K

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ZINC TELLURIDE	ZnTe	0.00	NONE DOCUMENTED

PAYLOAD WASTE SOURCE ASSESSMENT 16-Sep

HAZVC6.DAT

CYCLE DATA — REQ. NO. OF CYCLES: 1 — MAX. NO. OF CYCLES: 90 — PROPOSED NO. OF CYCLES

FACILITY

VAPOR CRYSTAL GROWTH FACILITY

WASTE TYPE	PHASE	MASS/ CYCLE(KG)
[illegible]	G	0.3130
AIR	G	0.5300
CLEANING FLUIDS	L,G	
WEAK SOLUTIONS OF THE FOLLOWING REAGENTS:		
HYDROGEN PEROXIDE	L,G	
HYDROFLUORIC ACID	L,G	
METHANOL	L,G	
NITRIC ACID	L,G	
HYDROCHLORIC ACID	L,G	
SAMPLE MATERIAL	S,P	
HgCdTe	S,P	
GaAs	S,P	
InP	S,P	
ZnTe ?	S,P	
CdSe	S,P	
GaP ?	S,P	
Ge	S,P	
Si	S,P	
TRANSPORT GASES	G	
HgBr2	G	
I2	G	
HgCl2	G	
HgI2	G	
HgI	G	
TRACE ZnCl2 ?	G	
TRACE WATER	G	
TRACE HCl	G	
TRACE HI	G	
TRACE Hg	G,P	
TRACE Cl2	G	
AMPULE FRAGMENTS	P	
BOULE FRAGMENTS	P	

CHARACTERIZATION/SUPPORT EQUIPMENT

FLUIDS GLOVEBOX

WASTE TYPE	PHASE	MASS/ CYCLE(KG)
NITROGEN	G	0.375
SAMPLE MATERIAL	S,P	
HgCdTe	S,P	
GaAs	S,P	
InP	S,P	
ZnTe	S,P	
CdSe	S,P	
GaP	S,P	
Ge	S,P	
Si	S,P	
AMPULE FRAGMENTS	P	
BOULE FRAGMENTS	P	
CLEANING FLUIDS	L,G	
WEAK SOLUTIONS OF THE FOLLOWING REAGENTS:		
HYDROGEN PEROXIDE	L,G	
HYDROFLUORIC ACID	L,G	
METHANOL	L,G	
NITRIC ACID	L,G	
HYDROCHLORIC ACID	L,G	
ETCHANTS	L,G	
HYDROGEN PEROXIDE	L,G	
HYDROFLUORIC ACID	L,G	
METHANOL	L,G	
NITRIC ACID	L,G	
HYDROCHLORIC ACID	L,G	

AUTOMATED CUTTING/POLISHING

WASTE TYPE	PHASE	MASS/ CYCLE(KG)
WATER	L	0.5000
AMPULE FRAGMENTS	P	
BOULE FRAGMENTS	P	
PLASTIC ENCAPSULATE	L,S,P	
CLEANING FLUIDS	L,G	
WEAK SOLUTIONS OF THE FOLLOWING REAGENTS:		
HYDROGEN PEROXIDE	L,G	
HYDROFLUORIC ACID	L,G	
METHANOL	L,G	
NITRIC ACID	L,G	
HYDROCHLORIC ACID	L,G	
SAMPLE MATERIAL	S,P	
HgCdTe	S,P	
GaAs	S,P	
InP	S,P	
ZnTe	S,P	
CdSe	S,P	
GaP	S,P	
Ge	S,P	
Si	S,P	

FOURIER TRANSFORM INFRARED SPECTROMETER

WASTE TYPE	PHASE	MASS/ CYCLE(KG)
NITROGEN	G	0.0420
AIR	G	0.0400
LIQUID NITROGEN	L	0.1500
CLEANING FLUIDS	L,G	

GAS CHROMATOGRAPH

WASTE TYPE	PHASE	MASS/ CYCLE(KG)
NITROGEN	G	0.0010
HELIUM	G	[illegible]
ARGON	G	[illegible]
LIQUID NITROGEN	L	0.5100
AIR	G	0.0020
ACETYLENE	G	0.001

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TABLE 7. CONTAMINATES PRODUCED BY VAPOR CRYSTAL FACILITY

CONTAMINATE	EXPERIMENT	CREW	EQUIPMENT	REMARKS
Argon or Helium	100%	See Remark	Purge gas which must remove contaminants from growth module.	See Section 5.1. May displace O_2
H_2O		Contains extermely toxic particles (Hg, Cd, Te, Cl, Br, Ga, As, In, P, Zn, Se) or reactive chemicals (HF, H_2O_2, CH_3OH, HNO_3, and/or HCl).	Used in substrate pre-run preparation and post-run cleaning.	Must be completely removed from crystal surface after etching to prevent adverse effects on growth.
Cleaning Fluid	TBD	TBD	Must be completely removed from growth module before next run.	Probably (HF, H_2O_2, CH_3OH, HNO_3, and/or HCl).
Transport Gases	100%	Very toxic to crew if inhaled.	Reactive at high temperatures with metals.	Defined candidates are I_2, HgI, $HgCl_2$, $HgBr_2$, $ZnCl_2$, HCl, HBr, and HI.
Sample	TBD	Toxic to crew. See Remark.	Produced by cleaning walls of growth module.	Expected candidates are GaAs, InP, ZnTe, CdSe, CdS, PbSnTe, and HgCdTe, and undefined materials.

Run length = 16 hrs.
— All numbers are based on primary IOC candidates.

ORGANIZATION: ANALYTICAL AND PHYSICAL CHEMISTRY BRANCH	MARSHALL SPACE FLIGHT CENTER	NAME: R. T. CONGO
CHART NO.:	DESIGN AND DEVELOPMENT OF A SPACE STATION HAZARDOUS MATERIAL SYSTEM FOR ASSESSING CHEMICAL COMPATIBILITY	DATE: NOVEMBER 1988

DATABASE QUERIES FOR MSDS

- CHEM PRO
- HAZARD LINE
- CHEM ABSTRACTS
- NATIONAL INSTITUTE OF HEALTH
- HAZ MET ETC.

ORGANIZATION: ANALYTICAL AND PHYSICAL CHEMISTRY BRANCH	MARSHALL SPACE FLIGHT CENTER	NAME: R. T. CONGO
CHART NO.:	DESIGN AND DEVELOPMENT OF A SPACE STATION HAZARDOUS MATERIAL SYSTEM FOR ASSESSING CHEMICAL COMPATIBILITY	DATE: NOVEMBER 1988

LIQUIDS:

- HYDROFLUORIC ACID
- NITRIC ACID
- ACETIC ACID
- SILVER NITRATE
- MAGNESIUM IODIDE
- HYDROGEN PEROXIDE
- WATER
- SODIUM HYDROXIDE
- CUPRIC NITRATE
- BROMINE
- SODIUM HYPOCHLORITE
- POTASSIUM HYDROXIDE
- POTASSIUM FERRICYANIDE
- HYDROCHLORIC ACID
- METHANOL
- PERCHLORIC ACID
- BENZENE
- TRICHLOROETHYLENE
- ACETONE
- TOLUENE
- FREON 22
- FREON 113
- ALLYL ALCOHOL
- N-BUTYL ALCOHOL
- CYCLOHEXANOL
- ISOPROPYL ALCOHOL
- PHENOL
- ACROLEIN
- TRIMETHYL BENZENE
- INDENE
- XYLENE
- DIISOBUTYL KETONE
- MEK
- FURAN
- BUTYL LACTATE

LIQUIDS (CONT'D)

- DICHLOROMETHANE
- TRICHLOROETHANE
- POLYPHENYLENE SULFIDES
- TRIGLYCINE SULFATE SOLUTION
- GLUTERALDEHYDE
- AMMONIA
- LATEX SOLUTION
- BUFFER SOLUTION
- CULTURE MEDIUM
- STAINING SOLUTION
- LIQUID CHROMATOGRAPHY CARRIER
- RAW PROTEIN SOLUTION
- DEVELOPER
- FIXER
- BIOCIDE/DISINFECTANT
- QUENCH SOLUTION
- BURN CATALYTIC AND SUPPRESSANT COMPOUNDS
- POLISHING SOLUTION
- MONOMER SOLUTION

GASES:

- OXYGEN
- NITROGEN
- HYDROGEN
- CARBON DIOXIDE
- CARBON MONOXIDE
- HELIUM
- ARGON
- WATER VAPOR
- XENON
- LIGHT HYDROCARBONS
- CHLORINE
- FLUORINE
- FREON 22
- FREON 113

GASES (CONT'D):

- HALON (1301, 1211, NOT SPECIFIED)
- VAPORS FROM OTHER LIQUID WASTES

PARTICULATES:

- GERMANIUM
- SILICON
- GALLIUM ARSENIDE
- SEED CRYSTAL FRAGMENTS
- METALLIC OXIDES
- BOULE FRAGMENTS
- GLASS AMPOULE FRAGMENTS
- GLASS FIBER PARTICLES
- SMOKE
- MICROBES
- MERCURY CADMIUM TELLURODE
- SODIUM HYDROXIDE
- CADMIUM SULFIDE
- TUNGSTEN
- BERYLLIUM
- PLASTIC ENCAPSULATION FRAGMENTS
- SOLDER
- RESIN POWDER
- ALUMINUM POWDER
- POLISHING ABRASIVES
- ZEOLITE
- PRODUCT FRAGMENTS
- LATEX SPHERES
- GRAPHITE
- POLYPHENYLENE SULFIDE SPHERES
- SODIUM ALUMINATE
- SODIUM HYPOCHLORITE
- LIQUID MERCURY
- MERCURY CADMIUM TELLURIDE

MATERIAL SAFETY DATA SHEET   OHS23590   474

OCCUPATIONAL HEALTH SERVICES, INC.
450 SEVENTH AVENUE, SUITE 2407
NEW YORK, NEW YORK 10123
(800) 443-MSDS   (212) 967-1100

EMERGENCY CONTACT:
JOHN S. BRANSFORD, JR.   (615)292-1180

SUBSTANCE IDENTIFICATION

CAS-NUMBER 108-88-3
RTEC-NUMBER XS5250000

SUBSTANCE: TOLUENE

TRADE NAMES/SYNONYMS:
TOLUOL: PHENYL METHANE: METHYL BENZENE: METHYLBENZOL: METHYLBENZENE: PHENYLMETHANE: METHACIDE: U220: STCC 4909305: UN 1294: T-290: T-299: T-330: T-324: T-324-S: T-324-SK: T-323: T-323-S: BENZENE, METHYL-: ANTISALIA: OHS23590

CHEMICAL FAMILY:
HYDROCARBON, AROMATIC

MOLECULAR FORMULA: C7-H8   MOLECULAR WEIGHT: 92.0

CERCLA RATINGS (SCALE 0-3): HEALTH=3 FIRE=3 REACTIVITY=0 PERSISTENCE=1
NFPA RATINGS (SCALE 0-4): HEALTH=2 FIRE=3 REACTIVITY=0

COMPONENTS AND CONTAMINANTS

COMPONENT: TOLUENE   PERCENT: >99

EXPOSURE LIMIT:
TOLUENE:
200 PPM OSHA TWA; 300 PPM OSHA ACCEPTABLE CEILING CONCENTRATION
500 PPM FOR 10 MINUTES OSHA ACCEPTABLE MAXIMUM PEAK ABOVE THE ACCEPTABLE CEILING CONCENTRATION FOR AN 8 HOUR SHIFT
100 PPM ACGIH TWA; 150 PPM ACGIH STEL
100 PPM NIOSH RECOMMENDED TWA; 200 PPM NIOSH RECOMMENDED 10 MINUTE CEILING
50 PPM ROHM AND HAAS RECOMMENDED TWA; 75 PPM ROHM AND HAAS RECOMMENDED STEL

1000 POUNDS CERCLA SECTION 103 REPORTABLE QUANTITY

PHYSICAL DATA

DESCRIPTION: CLEAR, COLORLESS LIQUID WITH AN AROMATIC ODOR.

BOILING POINT: 231 F (111 C)   MELTING POINT: -139 F (-95 C)

SPECIFIC GRAVITY: 0.866   EVAPORATION RATE: (BUTYL ACETATE=1) 2.24

SOLUBILITY IN WATER: 0.05%   VAPOR DENSITY: 3.2

VAPOR PRESSURE: 22 MMHG @ 20 C   ODOR-THRESHOLD: 0.2-5 PPM

OTHER SOLVENTS (SOLVENT - SOLUBILITY):
ACETONE, BENZENE, ALCOHOL, CHLOROFORM, ETHER, GLACIAL ACETIC ACID, CARBON DISULFIDE, DIMETHYL SULFOXIDE, LIGROIN, OTHER HYDROCARBONS

FIRE AND EXPLOSION DATA

FIRE AND EXPLOSION HAZARD
DANGEROUS FIRE HAZARD WHEN EXPOSED TO HEAT OR FLAME.

VAPORS ARE HEAVIER THAN AIR AND MAY TRAVEL A CONSIDERABLE DISTANCE TO A SOURCE OF IGNITION AND FLASH BACK.

VAPOR-AIR MIXTURES ARE EXPLOSIVE ABOVE FLASH POINT.

DUE TO LOW ELECTROCONDUCTIVITY OF THE SUBSTANCE, FLOW OR AGITATION MAY. GENERATE ELECTROSTATIC CHARGES RESULTING IN SPARKS WITH POSSIBLE IGNITION.

FLASH POINT: 40 F (4 C) (CC)   UPPER EXPLOSION LIMIT: 7.1%

LOWER EXPLOSION LIMIT: 1.2%   AUTOIGNITION TEMP.: 896 F (480 C)

FLAMMIBILITY CLASS (OSHA): IB

FIREFIGHTING MEDIA:
DRY CHEMICAL, CARBON DIOXIDE, HALON, WATER SPRAY OR STANDARD FOAM (1987 EMERGENCY RESPONSE GUIDEBOOK, DOT P 5800.4).

FOR LARGER FIRES, USE WATER SPRAY, FOG OR STANDARD FOAM (1987 EMERGENCY RESPONSE GUIDEBOOK, DOT P 5800.4).

FIREFIGHTING:
MOVE CONTAINER FROM FIRE AREA IF POSSIBLE. COOL FIRE-EXPOSED CONTAINERS WITH WATER FROM SIDE UNTIL WELL AFTER FIRE IS OUT. STAY AWAY FROM STORAGE TANK ENDS. FOR MASSIVE FIRE IN STORAGE AREA, USE UNMANNED HOSE HOLDER OR MONITOR NOZZLES, ELSE WITHDRAW FROM AREA AND LET FIRE BURN. WITHDRAW IMMEDIATELY IN CASE OF RISING SOUND FROM VENTING SAFETY DEVICE OR ANY DISCOLORATION OF STORAGE TANK DUE TO FIRE (1987 EMERGENCY RESPONSE GUIDEBOOK, DOT P 5800.4, GUIDE PAGE 27).

EXTINGUISH ONLY IF FLOW CAN BE STOPPED; USE WATER IN FLOODING QUANTITIES AS FOG, SOLID STREAMS MAY SPREAD FIRE. COOL CONTAINERS WITH FLOODING AMOUNTS OF WATER, APPLY FROM AS FAR A DISTANCE AS POSSIBLE. AVOID BREATHING TOXIC VAPORS. KEEP UPWIND.

WATER MAY BE INEFFECTIVE (NFPA FIRE PROTECTION GUIDE ON HAZARDOUS MATERIALS, EIGHTH EDITION).

TRANSPORTATION

DEPARTMENT OF TRANSPORTATION HAZARD CLASSIFICATION 49CFR172.101:
FLAMMABLE LIQUID

DEPARTMENT OF TRANSPORTATION LABELING REQUIREMENTS 49CFR172.101 AND 172.402:
FLAMMABLE LIQUID

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DEPARTMENT OF TRANSPORTATION PACKAGING REQUIREMENTS: 49CFR173.119
EXCEPTIONS: 49CFR173.118

TOXICITY

TOLUENE:
300 PPM EYE-HUMAN IRRITATION; 500 MG SKIN-RABBIT MODERATE IRRITATION; 435 MG SKIN-RABBIT MILD IRRITATION; 2 MG/24 HOURS EYE-RABBIT SEVERE IRRITATION; 870 UG EYE-RABBIT MILD IRRITATION; 100 MG/30 SECONDS RINSED EYE-RABBIT MILD IRRITATION; 200 PPM INHALATION-HUMAN TCLO; 100 PPM INHALATION-MAN TCLO; 50 MG/KG ORAL-HUMAN LDLO; 5000 MG/KG ORAL-RAT LD50; 4000 PPM/4 HOURS INHALATION-RAT LCLO; 12,124 MG/KG SKIN-RABBIT LD50; 1600 PPM INHALATION-GUINEA PIG LCLO; 800 MG/KG INTRAPERITONEAL-RAT LDLO; 1960 MG/KG INTRAVENOUS-RAT LD50; 5320 PPM/8 HOURS INHALATION-MOUSE LC50; 1126 MG/KG INTRAPERITONEAL-MOUSE LD50; 2000 MG/KG UNREPORTED-MOUSE LD50; 6900 MG/KG UNREPORTED-RAT LD50; MUTAGENIC DATA (RTECS); REPRODUCTIVE EFFECTS DATA (RTECS).
CARCINOGEN STATUS: NONE.

TOLUENE IS A SKIN, EYE, AND MUCOUS MEMBRANE IRRITANT, CENTRAL NERVOUS SYSTEM DEPRESSANT, AND NEUROTOXIN. POISONING MAY AFFECT THE HEART, LIVER, KIDNEYS, AND BLOOD. STIMULENTS SUCH AS EPINEPHRINE OR EPHEDRINE MAY INDUCE VENTRICULAR FIBRILLATION. TOLUENE INHIBITS MITOCHONDRIAL OXIDATIVE PHOSPHORYLATION. CONSUMPTION OF ALCOHOLIC BEVERAGES MAY ENHANCE THE TOXIC EFFECTS.

EPIDEMIOLOGICAL STUDIES INVOLVING PETROLEUM REFINERY WORKERS INDICATE PERSONS WITH ROUTINE EXPOSURE TO PETROLEUM OR ONE OF ITS CONSTITUENTS MAY BE AT AN INCREASED RISK TO THE DEVELOPMENT OF BENIGN NEOPLASMS, DIGESTIVE SYSTEM CANCERS, AND SKIN CANCER, PARTICULARLY MELANOMA.

HEALTH EFFECTS AND FIRST AID

INHALATION:
TOLUENE:
IRRITANT/NARCOTIC/NEUROTOXIN.
2000 PPM IMMEDIATELY DANGEROUS TO LIFE OR HEALTH.

ACUTE EXPOSURE- THE LEVEL REQUIRED TO PRODUCE NARCOSIS CAN EXIST WITHOUT ASSOCIATED RESPIRATORY TRACT IRRITATION. ODOR DETECTION IS INSUFFICIENT FOR WARNING DUE TO OLFACTORY FATIGUE. 200-600 PPM FOR UP TO 8 HOURS CAUSED MILD UPPER RESPIRATORY TRACT IRRITATION, FATIGUE, WEAKNESS, CONFUSION, HEADACHE, NAUSEA, IMPAIRED COORDINATION AND REACTION TIME, PARESTHESIAS OF THE SKIN, EUPHORIA, DIZZINESS, AND DILATED PUPILS. 800 PPM CAUSED RAPID IRRITATION, NASAL MUCOUS SECRETION, METALLIC TASTE, DROWSINESS, AND IMPAIRED BALANCE. AFTEREFFECTS INCLUDING NERVOUSNESS, MUSCULAR FATIGUE, AND INSOMNIA LASTED FOR SEVERAL DAYS. A WORKER FOUND UNCONSCIOUS AFTER EXPOSURE TO HIGH VAPOR CONCENTRATIONS FOR 18 HOURS DEVELOPED HEPATIC AND RENAL DAMAGE WITH MYOGLOBINURIA. RECOVERY WAS COMPLETE WITHIN 6 MONTHS. HEMATOLOGIC EFFECTS OCCUR RARELY WITH EXPOSURE TO HIGH CONCENTRATIONS. RECOVERY USUALLY FOLLOWS REMOVAL FROM EXPOSURE. EXTREME INHALATION MAY CAUSE DEATH BY PARALYSIS OF THE RESPIRATORY CENTER.

CHRONIC EXPOSURE- REPEATED OR PROLONGED EXPOSURE MAY CAUSES MUCOUS MEMBRANE IRRITATION, VOMITING, INSOMNIA, NOSEBLEEDS, CHEST PAIN, EUPHORIA, HEADACHE, VERTIGO, NAUSEA, ANOREXIA, BAD TASTE, MOMENTARY LOSS OF MEMORY, PALPITATIONS, EXTREME WEAKNESS, LOSS OF COORDINATION AND IMPAIRMENT OF

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REACTION TIME, TINNITUS, ALCOHOL INTOLERANCE, PETECHIAE AND ABNORMAL BLEEDING. LEUKOPENIA WITH BONE MARROW HYPOPLASIA HAS BEEN REPORTED OCCASIONALY, BUT MAY BE DUE TO BENZENE CONTAMINATION. EXAMINATION OF WORKERS EXPOSED TO 100-1100 PPM REVEALED HEPATOMEGALY, MILD MACROCYTOSIS, MODERATE ERYTHROPENIA, AND ABSOLUTE LYMPHOCYTOSIS, BUT NO LEUKOPENIA. OTHER WORKERS EXPOSED TO TOLUENE FUMES DEVELOPED LEUKOPENIA AND ESPECIALLY NEUTROPENIA. WITHIN 6 MONTHS, THEY SHOWED INCREASED COAGULATION TIME AND DECREASED PROTHROMBIN LEVEL. PERIODONTAL EFFECTS WERE ALSO NOTED. CARDIAC SENSITIZATION MAY OCCUR AND MAY RESULT IN CARDIAC ARREST DUE TO VENTRICULAR FIBRILLATION. REPEATED INHALATION OF TOLUENE TO THE POINT OF EUPHORIA HAS CAUSED IRREVERSIBLE ENCEPHALOPATHY WITH CEREBELLAR ATAXIA. RHYTHMIC LIMB MOVEMENTS, UNSTEADINESS, BIZZARE BEHAVIOR, EMOTIONAL LABILITY AND OPTIC ATROPHY, AND DIFFUSE CEREBRAL ATROPHY. OTHER NEUROPSYCHIATRIC EFFECTS MAY INCLUDE LETHARGY, HALLUCINATIONS, COMA, DIZZINESS, SYNCOPE, PARESTHESIAS, AND PERIPHERAL NEUROPATHY. INTENTIONAL SNIFFING CAN PRODUCE RENAL TUBULAR DEFECTS WITH METABOLIC ACIDOSIS, ELECTROLYTE ABNORMALITIES AND POTASSIUM LOSS. SEVERE MUSCLE WEAKNESS LEADING TO LIMB PARALYSIS AND CARDIAC ARRHYTHMIAS MAY RESULT FROM THE HYPOKALEMIA; HOWEVER, SENSORY FUNCTION AND TENDON REFLEXES ARE NOT IMPAIRED. GASTROINTESTINAL EFFECTS MAY INCLUDE ABDOMINAL PAIN, NAUSEA, VOMITING, AND HEMATEMESIS. CHROMOSOME CHANGES WERE OBSERVED IN SOME WORKERS UP TO TWO YEARS AFTER CESSATION OF EXPOSURE TO TOLUENE. WOMEN OCCUPATIONALLY EXPOSED TO TOLUENE AND OTHER VARNISH SOLVENTS HAVE REPORTED MENSTRUAL DISORDERS, UNDERWEIGHT OFFSPRING WHO DID NOT NURSE WELL, AND FETAL ASPHYXIA. DYSMENORRHEA HAS BEEN REPORTED IN WOMEN OCCUPATIONALLY EXPOSED TO TOLUENE LEVELS OF 60-100 PPM. EFFECTS ON THE FETUS AND FETAL DEVELOPMENTAL ABNORMALITIES HAVE BEEN REPORTED IN OFFSPRING OF FEMALE RATS AND MICE FOLLOWING REPEATED EXPOSURE DURING GESTATION.

FIRST AID- REMOVE FROM EXPOSURE AREA TO FRESH AIR IMMEDIATELY. IF BREATHING HAS STOPPED, PERFORM ARTIFICIAL RESPIRATION. KEEP PERSON WARM AND AT REST. GET MEDICAL ATTENTION IMMEDIATELY.

SKIN CONTACT:
TOLUENE:
IRRITANT.

ACUTE EXPOSURE- CONTACT WITH THE LIQUID MAY CAUSE IRRITATION, SCALING, CRACKING AND DERMATITIS. SKIN ABSORPTION DOES OCCUR, BUT IT IS GENERALLY TOO SLOW TO PRODUCE SIGNS OF ACUTE SYSTEMIC TOXICITY. PARESTHESIAS OF THE SKIN MAY OCCUR FROM VAPOR EXPOSURE.

CHRONIC EXPOSURE- REPEATED OR PROLONGED CONTACT WITH THE LIQUID MAY CAUSE DEFATTING OF THE SKIN, RESULTING IN A DRY, FISSURED DERMATITIS. TEN TO TWENTY APPLICATIONS TO RABBIT SKIN PRODUCED SLIGHT TO MODERATE IRRITATION AND SLIGHT NECROSIS.

AN EPIDEMIOLOGICAL STUDY OF PETROLEUM REFINERY WORKERS HAS REPORTED ELEVATIONS IN STANDARD MORTALITY RATIOS FOR SKIN CANCER ALONG WITH A DOSE-RESPONSE RELATIONSHIP WHICH INDICATES AN ASSOCIATION BETWEEN ROUTINE WORKPLACE EXPOSURE TO PETROLEUM OR ONE OF ITS CONSTITUENTS AND SKIN CANCER, PARTICULARLY MELANOMA.

FIRST AID- REMOVE CONTAMINATED CLOTHING AND SHOES IMMEDIATELY. WASH AFFECTED AREA WITH SOAP OR MILD DETERGENT AND LARGE AMOUNTS OF WATER UNTIL NO EVIDENCE OF CHEMICAL REMAINS (APPROXIMATELY 15-20 MINUTES). GET MEDICAL ATTENTION IMMEDIATELY.

EYE CONTACT:
TOLUENE:
IRRITANT.

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ACUTE EXPOSURE- CONTACT WITH THE LIQUID MAY CAUSE CORNEAL BURNS IF NOT PROMPTLY REMOVED. VAPORS MAY CAUSE NOTICABLE IRRITATION AND LACRIMATION AT 300-800 PPM, AND EXTREMELY HIGH CONCENTRATIONS MAY CAUSE BLURRING OF VISION. CORNEAL LESIONS, VERY FINE VACOULES, HAVE BEEN REPORTED IN WORKERS EXPOSED TO A SOLVENT MIXTURE CONTAINING TOLUENE. THE LESIONS SUBSIDED FOLLOWING SEVERAL DAYS OF NON-EXPOSURE. SIMILAR LESIONS HAVE BEEN PRODUCED IN CATS FOLLOWING EXPOSURE TO TOLUENE.

CHRONIC EXPOSURE- REPEATED OR PROLONGED CONTACT MAY CAUSE CONJUNCTIVITIS. RARELY, SYSTEMIC OCULAR DISTURBANCES, SUCH AS "REDDENING OF THE VISION", HAVE OCCURRED.

FIRST AID- WASH EYES IMMEDIATELY WITH LARGE AMOUNTS OF WATER, OCCASIONALLY LIFTING UPPER AND LOWER LIDS, UNTIL NO EVIDENCE OF CHEMICAL REMAINS (APPROXIMATELY 15-20 MINUTES). GET MEDICAL ATTENTION IMMEDIATELY.

INGESTION:
TOLUENE:
NARCOTIC.

ACUTE EXPOSURE- MAY CAUSE NAUSEA, VOMITING, COLIC, DIARRHEA, BURNING SENSATION IN THE EPIGASTRIUM, HEADACHE, TINNITUS, DIZZINESS, WEAKNESS, EUPHORIA, DROWSINESS AND INCOORDINATION. IF LARGE AMOUNTS ARE INGESTED, SYMPTOMS MAY PROGRESS TO INCLUDE SHALLOW, RAPID RESPIRATION, TREMORS, VENTRICULAR IRREGULARITIES WITH FIBRILLATION, CONVULSIONS, STUPOR AND UNCONSCIOUSNESS. METABOLIC ACIDOSIS AND LIVER AND KIDNEY DAMAGE MAY OCCUR. APPROXIMATELY 15-30 MILLILITERS IS THE HUMAN LETHAL DOSE. ASPIRATION OF THE LIQUID INTO THE LUNGS MAY CAUSE COUGHING, GAGGING, ACUTE HEMORRHAGIC PNEUMONITIS AND RAPIDLY PULMONARY EDEMA.

CHRONIC EXPOSURE- NO EFFECTS WERE REPORTED IN RATS FEED UP TO 590 MG/KG/DAY FOR 193 DAYS. EFFECTS ON THE FETUS AND FETAL DEVELOPMENTAL ABNORMALITIES HAVE BEEN REPORTED FOLLOWING REPEATED ADMINISTRATION TO PREGNANT MICE.

FIRST AID- EXTREME CARE MUST BE USED TO PREVENT ASPIRATION. USE GASTRIC LAVAGE WITH ACTIVATED CHARCOAL AND A CUFFED ENDOTRACHEAL TUBE WITHIN 15 MINUTES. IN THE ABSENCE OF DEPRESSION OR CONVULSIONS OR IMPAIRED GAG REFLEX, IPECAC EMESIS CAN BE DONE. WHEN VOMITING BEGINS, KEEP HEAD BELOW THE HIPS TO PREVENT ASPIRATION. AFTER VOMITING STOPS, GIVE 30-60 MILLILITERS OF FLEET'S PHOSPHO-SODA DILUTED 1:4 IN WATER. MAINTAIN AIRWAY, BLOOD PRESSURE AND RESPIRATION. (DREISBACH, HANDBOOK OF POISONING, 11TH ED.) GET MEDICAL ATTENTION. TREATMENT MUST BE ADMINISTERED BY QUALIFIED MEDICAL PERSONNEL.

ANTIDOTE:
NO SPECIFIC ANTIDOTE. TREAT SYMPTOMATICALLY AND SUPPORTIVELY.

REACTIVITY SECTION

REACTIVITY:
STABLE UNDER NORMAL TEMPERATURES AND PRESSURES.

INCOMPATIBILITIES:
TOLUENE:

ALLYL CHLORIDE + DICHLOROETHYL ALUMINUM OR ETHYLALUMINUM SESQUICHLORIDE: POSSIBLE EXPLOSION.
BROMINE TRIFLUORIDE (SOLID): VIOLENT REACTION.
DINITROGEN TETRAFLUORIDE: FORMS EXPLOSIVE MIXTURE.
NITRIC ACID: INTENSE REACTION.
NITRIC ACID + MIXED ACIDS: POSSIBLE RUNAWAY OR EXPLOSIVE REACTION.

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NITRIC ACID + SULFURIC ACID: EXPLOSIVE REACTION.
NITROGEN TETROXIDE: EXPLOSIVE REACTION.
OXIDIZERS (STRONG): FIRE AND EXPLOSION HAZARD.
PLASTICS, RUBBER, AND COATINGS: MAY BE ATTACKED.
SILVER PERCHLORATE: FORMATION OF SHOCK SENSITIVE COMPLEX.
SULFURIC ACID: EXOTHERMIC REACTION.
TETRANITROMETHANE: EXTREMELY VIOLENT EXPLOSIVE REACTION.
URANIUM HEXAFLUORIDE: VIGOROUS REACTION WITH THE SEPARATION OF CARBON.

DECOMPOSITION:
THERMAL DECOMPOSITION PRODUCTS MAY INCLUDE TOXIC OXIDES OF CARBON.

POLYMERIZATION:
HAZARDOUS POLYMERIZATION HAS NOT BEEN REPORTED TO OCCUR UNDER NORMAL TEMPERATURES AND PRESSURES.

STORAGE-DISPOSAL

OBSERVE ALL FEDERAL, STATE AND LOCAL REGULATIONS WHEN STORING OR DISPOSING OF THIS SUBSTANCE.

STORAGE

STORE IN ACCORDANCE WITH 29 CFR 1910.106.

PROTECT AGAINST PHYSICAL DAMAGE. OUTSIDE OR DETACHED STORAGE IS PREFERABLE. INSIDE STORAGE SHOULD BE IN A STANDARD FLAMMABLE LIQUIDS STORAGE ROOM OR CABINET. SEPARATE FROM OXIDIZING MATERIALS (NFPA 49, HAZARDOUS CHEMICALS DATA, 1975).

BONDING AND GROUNDING: SUBSTANCES WITH LOW ELECTROCONDUCTIVITY, WHICH MAY BE IGNITED BY ELECTROSTATIC SPARKS, SHOULD BE STORED IN CONTAINERS WHICH MEET THE BONDING AND GROUNDING GUIDELINES SPECIFIED IN NFPA 77-1983, RECOMMENDED PRACTICE ON STATIC ELECTRICITY.

STORE AWAY FROM INCOMPATIBLE SUBSTANCES.

CONDITIONS TO AVOID

MAY BE IGNITED BY HEAT, SPARKS OR FLAMES. VAPORS MAY TRAVEL TO A SOURCE OF IGNITION AND FLASH BACK. CONTAINER MAY EXPLODE IN HEAT OF FIRE. VAPOR EXPLOSION HAZARD INDOORS, OUTDOORS OR IN SEWERS. RUNOFF TO SEWER MAY CREATE FIRE OR EXPLOSION HAZARD.

SPILLS AND LEAKS

SOIL-RELEASE:
DIG HOLDING AREA SUCH AS LAGOON, POND OR PIT FOR CONTAINMENT.

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DIKE FLOW OF SPILLED MATERIAL USING SOIL OR SANDBAGS OR FOAMED BARRIERS SUCH AS POLYURETHANE OR CONCRETE.

USE CEMENT POWDER OR FLY ASH TO ABSORB LIQUID MASS.

IMMOBILIZE SPILL WITH UNIVERSAL GELLING AGENT.

REDUCE VAPOR AND FIRE HAZARD WITH FLUOROCARBON WATER FOAM.

AIR-RELEASE:
KNOCK DOWN VAPORS WITH WATER SPRAY. KEEP UPWIND.

WATER-SPILL:
LIMIT SPILL MOTION AND DISPERSION WITH NATURAL BARRIERS OR OIL SPILL CONTROL BOOMS.

APPLY DETERGENTS, SOAPS, ALCOHOLS OR ANOTHER SURFACE ACTIVE AGENT TO THICKEN SPILLED MATERIAL.

APPLY UNIVERSAL GELLING AGENT TO IMMOBILIZE TRAPPED SPILL AND INCREASE EFFICIENCY OF REMOVAL.

IF DISSOLVED, APPLY ACTIVATED CARBON AT TEN TIMES THE SPILLED AMOUNT IN THE REGION OF 10 PPM OR GREATER CONCENTRATION.

USE SUCTION HOSES TO REMOVE TRAPPED SPILL MATERIAL.

USE MECHANICAL DREDGES OR LIFTS TO EXTRACT IMMOBILIZED MASSES OF POLLUTION AND PRECIPITATES.

OCCUPATIONAL-SPILL:
SHUT OFF IGNITION SOURCES. STOP LEAK IF YOU CAN DO IT WITHOUT RISK. USE WATER SPRAY TO REDUCE VAPORS. FOR SMALL SPILLS, TAKE UP WITH SAND OR OTHER ABSORBENT MATERIAL AND PLACE INTO CONTAINERS FOR LATER DISPOSAL. FOR LARGER SPILLS, DIKE FAR AHEAD OF SPILL FOR LATER DISPOSAL. NO SMOKING, FLAMES OR FLARES IN HAZARD AREA. KEEP UNNECESSARY PEOPLE AWAY; ISOLATE HAZARD AREA AND RESTRICT ENTRY.

PROTECTIVE EQUIPMENT SECTION

VENTILATION:
PROVIDE LOCAL EXHAUST OR GENERAL DILUTION VENTILATION TO MEET PUBLISHED EXPOSURE LIMITS. VENTILATION EQUIPMENT MUST BE EXPLOSION-PROOF.

RESPIRATOR:
THE FOLLOWING RESPIRATORS AND MAXIMUM USE CONCENTRATIONS ARE RECOMMENDATIONS BY THE U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES, NIOSH POCKET GUIDE TO CHEMICAL HAZARDS OR NIOSH CRITERIA DOCUMENTS; OR DEPARTMENT OF LABOR, 29CFR1910 SUBPART Z.
THE SPECIFIC RESPIRATOR SELECTED MUST BE BASED ON CONTAMINATION LEVELS FOUND IN THE WORK PLACE AND BE JOINTLY APPROVED BY THE NATIONAL INSTITUTE OF OCCUPATIONAL SAFETY AND HEALTH AND THE MINE SAFETY AND HEALTH ADMINISTRATION.

TOLUENE:
1000 PPM- ANY CHEMICAL CARTRIDGE RESPIRATOR WITH ORGANIC VAPOR CARTRIDGE(S).
ANY SUPPLIED-AIR RESPIRATOR.
ANY POWERED AIR-PURIFYING RESPIRATOR WITH ORGANIC VAPOR

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CARTRIDGE(S).
ANY SELF-CONTAINED BREATHING APPARATUS.

2000 PPM- ANY SUPPLIED-AIR RESPIRATOR OPERATED IN A CONTINUOUS FLOW MODE.
ANY SELF-CONTAINED BREATHING APPARATUS WITH A FULL FACEPIECE.
ANY SUPPLIED-AIR RESPIRATOR WITH A FULL FACEPIECE.
ANY AIR-PURIFYING FULL FACEPIECE RESPIRATOR (GAS MASK) WITH A CHIN-STYLE OR FRONT OR BACK-MOUNTED ORGANIC VAPOR CANISTER.

ESCAPE- ANY AIR-PURIFYING FULL FACEPIECE RESPIRATOR (GAS MASK) WITH A CHIN-STYLE OR FRONT OR BACK-MOUNTED ORGANIC VAPOR CANISTER.
ANY APPROPRIATE ESCAPE-TYPE SELF-CONTAINED BREATHING APPARATUS.

FOR FIREFIGHTING AND OTHER IMMEDIATELY DANGEROUS TO LIFE OR HEALTH CONDITIONS:

SELF-CONTAINED BREATHING APPARATUS WITH FULL FACEPIECE OPERATED IN PRESSURE DEMAND OR OTHER POSITIVE PRESSURE MODE.

SUPPLIED-AIR RESPIRATOR WITH FULL FACEPIECE AND OPERATED IN PRESSURE-DEMAND OR OTHER POSITIVE PRESSURE MODE IN COMBINATION WITH AN AUXILIARY SELF-CONTAINED BREATHING APPARATUS OPERATED IN PRESSURE-DEMAND OR OTHER POSITIVE PRESSURE MODE.

CLOTHING:
EMPLOYEE MUST WEAR APPROPRIATE PROTECTIVE (IMPERVIOUS) CLOTHING AND EQUIPMENT TO PREVENT REPEATED OR PROLONGED SKIN CONTACT WITH THIS SUBSTANCE.

GLOVES:
EMPLOYEE MUST WEAR APPROPRIATE PROTECTIVE GLOVES TO PREVENT CONTACT WITH THIS SUBSTANCE.

EYE PROTECTION:
EMPLOYEE MUST WEAR SPLASH-PROOF OR DUST-RESISTANT SAFETY GOGGLES TO PREVENT EYE CONTACT WITH THIS SUBSTANCE.

AUTHORIZED - OCCUPATIONAL HEALTH SERVICES, INC.

CREATION DATE: 10/25/84 REVISION DATE: 03/22/89

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MATERIAL SAFETY DATA SHEET ACC14370 502

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SUBSTANCE IDENTIFICATION

CAS-NUMBER 71-55-6

SUBSTANCE: **1,1,1-TRICHLOROETHANE**

TRADE NAMES/SYNONYMS:
METHYL CHLOROFORM; ETHYLIDYNE CHLORIDE; UN 2831; T-391; T-398; ACC14370

CHEMICAL FAMILY:
HYDROCARBON, ALIPHATIC

MOLECULAR FORMULA: C2-H3-CL3 MOL WT: 133.41

CERCLA RATINGS (SCALE 0-3): HEALTH=1 FIRE=0 REACTIVITY=2 PERSISTENCE=3
NFPA RATINGS (SCALE 0-4): HEALTH=3 FIRE=1 REACTIVITY=1

COMPONENTS AND CONTAMINANTS

COMPONENT: 1,1,1-TRICHLOROETHANE PERCENT: >95

COMPONENT: INHIBITOR TO PREVENT CORROSION OF METALS PERCENT: <5

OTHER CONTAMINANTS: NONE

EXPOSURE LIMIT:
350 PPM OSHA TWA
350 PPM ACGIH TWA; 450 ACGIH STEL
350 PPM NIOSH RECOMMENDED 15 MINUTE CEILING

PHYSICAL DATA

DESCRIPTION: COLORLESS LIQUID WITH A MILD CHLOROFORM-LIKE ODOR.

BOILING POINT: 165 F (74 C) MELTING POINT: -36 F (-32 C)

SPECIFIC GRAVITY: 1.3 EVAPORATION RATE: (CCL4=1) 1 TTE

SOLUBILITY IN WATER: 0.44% VAPOR DENSITY: 4.6

VAPOR PRESSURE: 100 MMHG @ 20 C ODOR-THRESHOLD: 20-100 PPM

OTHER SOLVENTS (SOLVENT - SOLUBILITY):
ACETONE, BENZENE, CCL4, METHANOL, AND ETHER.

FIRE AND EXPLOSION DATA

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FIRE AND EXPLOSION HAZARD
NEGLIGIBLE FIRE HAZARD AND EXPLOSION HAZARD WHEN EXPOSED TO HEAT OR FLAME.

FLASH POINT: NONFLAMMABLE

UPPER EXPLOSION LIMIT: 10.5%

LOWER EXPLOSION LIMIT: 8.0%

AUTOIGNITION TEMP.: 998 F (537 C)

FLAMMIBILITY CLASS (OSHA): IIIA

FIREFIGHTING MEDIA:
DRY CHEMICAL, CARBON DIOXIDE OR HALON
(1987 EMERGENCY RESPONSE GUIDEBOOK, DOT P 5800.4).

FOR LARGER FIRES, USE WATER SPRAY, FOG OR STANDARD FOAM
(1987 EMERGENCY RESPONSE GUIDEBOOK, DOT P 5800.4).

FIREFIGHTING:
STAY AWAY FROM STORAGE TANK ENDS. COOL CONTAINERS EXPOSED TO FLAMES WITH WATER FROM SIDE UNTIL WELL AFTER FIRE IS OUT (1987 EMERGENCY RESPONSE GUIDEBOOK, DOT P 5800.4, GUIDE PAGE 74).

TOXICITY

27 GM/M3/10 MIN INHALATION-MAN LCLO; 1000 PPM INHALATION-RAT LCLO; 10300 MG/KG ORAL-RAT LD50; 11240 ORAL-MOUSE LD50; MUTAGENIC DATA (RTECS); REPRODUCTIVE EFFECTS DATA (RTECS); INDEFINITE ANIMAL CARCINOGEN (IARC). DATA AVAILABLE DO NOT PERMIT EVALUATION OF CARCINOGENICITY OF 1,1,1-TRICHLOROETHANE TO BE MADE.
1,1,1-TRICHLOROETHANE IS A SKIN IRRITANT AND CENTRAL NERVOUS SYSTEM DEPRESSANT. EXPOSURE MAY IRRITATE THE EYES AND MUCOUS MEMBRANES. POISONING MAY AFFECT THE CARDIOVASCULAR SYSTEM AND LIVER. ALCOHOLIC BEVERAGES MAY ENHANCE THE SYSTEMIC EFFECTS.

HEALTH EFFECTS AND FIRST AID

INHALATION:
NARCOTIC. 1000 PPM IS IMMEDIATELY DANGEROUS TO LIFE AND HEALTH.

ACUTE EXPOSURE- INDIVIDUALS EXPOSED TO 900-1000 PPM FOR 20 MINUTES EXPERIENCED LIGHT-HEADEDNESS, INCOORDINATION, AND IMPAIRED EQUILIBRIUM. EXPOSURE TO A HIGHER CONCENTRATIONS OF EXTINDED PERIODS OF TIME MAY CAUSE CENTRAL NERVOUS SYSTEM DEPRESSION WITH DIZZINESS, INCOORDINATION DROWSINESS, INCREASED REACTION TIME, UNCONSCIOUSNESS, AND DEATH. "SUDDEN DEATHS" MAY OCCUR DUE TO SENSITIZATION OF THE MYOCARDIUM TO EPINEPHRINE. (CAUSING CARDIAC ARRYTHMIA). DEATH MAY ALSO BE CAUSED BY ASPHYXIA DUE TO THE REDUCTION IN OXYGEN AGAILABLE FOR BREATHING. AT EXTREMELY HIGH CONCENTRATIONS, LIVER AND KIDNEY INJURY MAY OCCUR. REPEATED EXPOSURE TO THE POINT OF ANESTHESIA MAY CAUSE REVERSIBLE HEPATITIS (ANIMAL).

CHRONIC EXPOSURE- IN EXPERIMENTAL ANIMALS, LIVER AND KIDNEY DAMAGE HAVE BEEN MINIMAL. SEE ANIMAL MUTAGENIC AND REPRODUCTIVE EFFECTS REFERENCES IN TOXICITY SECTION. AT 1000 TO 10,000 PPM:

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3-MONTH EXPOSURES OF ANIMALS CAUSED SOME PATHOLOGIC CHANGES IN THE LIVERS AND LUNGS OF SOME SPECIES. WHEN REPEATED, REDUCED TO 500 PPM: PATHOLOGIC CHANGES WERE ELIMATED, BUT THERE WAS SOME GROWTH LOSS.

FIRST AID- REMOVE FROM EXPOSURE AREA TO FRESH AIR IMMEDIATELY. IF BREATHING HAS STOPPED, GIVE ARTIFICIAL RESPIRATION. IF BREATHING WITH DIFFICULTY, GIVE OXYGEN. REMOVE ANY CONTAMINATED CLOTHING. DO NOT GIVE EPINEPHRINE (ADRENALIN). KEEP AFFECTED PERSON WARM AND AT REST. GET MEDICAL ATTENTION IMMEDIATELY.

SKIN CONTACT:
IRRITANT.

ACUTE EXPOSURE- CONTACT WITH THE LIQUID MAY CAUSE IMMEDIATE IRRITATION AND REDNESS. THE SUBSTANCE CAN BE ABSORBED TO A MODERATE DEGREE PRODUCING SYSTEMIC EFFECTS OF DIZZINESS, HEADACHE, INCOORDINATION, AND DROWSINESS.

CHRONIC EXPOSURE- REPEATED SKIN CONTACT MAY PRODUCE A DRY, SCALY, FISSURED DERMATITIS DUE TO THE DEFATTING PROPERTIES OF THE LIQUID. SEE ANIMAL MUTAGENIC AND REPRODUCTIVE REFERENCES IN TOXICITY SECTION.

FIRST AID- REMOVE CONTAMINATED CLOTHING AND SHOES IMMEDIATELY. WASH AFFECTED AREA WITH SOAP OR MILD DETERGENT AND LARGE AMOUNTS OF WATER UNTIL NO EVIDENCE OF CHEMICAL REMAINS (APPROXIMATELY 15-20 MINUTES). GET MEDICAL ATTENTION IMMEDIATELY.

EYE CONTACT:
IRRITANT.

ACUTE EXPOSURE- HIGH VAPOR CONCENTRATIONS (800-1000 PPM) MAY CAUSE IRRITATION AND REDDNESS. DIRECT CONTACT OF THE LIQUID MAY CAUSE TEMPORARY INJURY WITH COMPLETE RECOVERY EXPECTED IN 48 HOURS. DIRECT APPLICATION TO THE EYES OF RABBITS HAS CAUSED CONJUNCTIVAL IRRITATION, BUT NO CORNEAL DAMAGE.

CHRONIC EXPOSURE- NO EFFECTS KNOWN IN HUMANS.

FIRST AID- WASH EYES IMMEDIATELY WITH LARGE AMOUNTS OF WATER, OCCASIONALLY LIFTING THE UPPER AND LOWER LIDS, UNTIL NO EVIDENCE OF CHEMICAL REMAINS (APPROXIMATELY 10-20 MINUTES). GET MEDICAL ATTENTION.

INGESTION:
NARCOTIC.

ACUTE EXPOSURE- SYMPTOMS PROGRESS THROUGH HEADACHE, DIZZINESS, NAUSEA, FAINTING, RESPIRATORY DEPRESSION, HYPOTENSION, ARRHYTHMIAS, AND UNCONSCIOUSNESS. LIVER AND KIDNEY DAMAGE MAY OCCUR. THE ADULT FATAL DOSE IS ESTIMATED TO BE 5 ML.

FIRST AID- GET MEDICAL ATTENTION IMMEDIATELY. IF MEDICAL ATTENTION IS NOT IMMEDIATELY AVAILABLE, AND IF VICTIM IS CONSCIOUS, ATTEMPT TO INDUCE VOMITING BY TOUCHING FINGER TO BACK OF THROAT.

REACTIVITY SECTION

REACTIVITY:
STABLE UNDER NORMAL CONDITIONS. REACTS VIOLENTLY WITH ALKALI, EARTH-ALKALINE,

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AND WITH VARIOUS METAL POWDERS. THE SUBSTANCE CAN BE HYDROLYZED BY WATER TO FORM HYDROCHLORIC ACID AND ACETIC ACID. THE SUBSTANCE WILL REACT WITH STRONG CAUSTICS, SUCH AS CAUSTIC SODA OR CAUSTIC POTASH TO FORM FLAMMABLE OR EXPLOSIVE MATERIAL. AN INHIBITOR IS REQUIRED TO PREVENT THE CORROSION OF METALS.

INCOMPATIBILITIES:

ACETONE + BASE: EXPLOSION.
LIQUID OXYGEN + IGNITION SOURCE: EXPLOSION.
SODIUM-POTASSIUM ALLOY + LIQUID OXYGEN WITH AN ENERGY SOURCE: EXPLOSION.
STRONG OXIDIZERS: VIOLENT REACTION.
STRONG CAUSTICS: VIOLENT REACTION.
CHEMICALLY ACTIVE METALS (ALUMINUM POWDER, SODIUM, POTASSIUM, MAGNESIUM POWDER): VIOLENT REACTION.
NATURAL RUBBER: DECOMPOSES.
SODIUM: SPONTANEOUSLY FLAMMABLE COMPOUND FORMED.
SODIUM HYDROXIDE: SPONTANEOUSLY FLAMMABLE COMPOUND FORMED.
NITROGEN TETRAOXIDE: EXPLODES.

DECOMPOSITION:
THE SUBSTANCE WILL DECOMPOSE AT HIGH TEMPERATURES UPON CONTACT WITH HOT METAL OR UNDER ULTRAVIOLET RADIATION TO PRODUCE TOXIC AND CORROSIVE GASES SUCH AS HYDROGEN CHLORIDE, DICHLOROACETYLENE, AND VERY SMALL AMOUNTS OF CHLORINE AND PHOSGENE.

POLYMERIZATION:
HAZARDOUS POLYMERIZATION HAS NOT BEEN REPORTED TO OCCUR UNDER NORMAL TEMPERATURES AND PRESSURES.

CONDITIONS TO AVOID

MAY BURN BUT DOES NOT IGNITE READILY. CONTAINER MAY EXPLODE IN HEAT OF FIRE. AVOID ULTRAVIOLET RADIATION. AVOID OPEN FLAMES, WELDING ARCS OR OTHER HIGH TEMPERATURE SOURCES, WHICH INDUCE THERMAL DECOMPOSITION OR EXPLOSION. AVOID AUTOIGNITION TEMPERATURE, 537 C.

SPILLS AND LEAKS

OCCUPATIONAL-SPILL:
SHUT OFF IGNITION SOURCES. STOP LEAK IF YOU CAN DO IT WITHOUT RISK. FOR SMALL LIQUID SPILLS, TAKE UP WITH SAND, EARTH OR OTHER ABSORBENT MATERIAL. FOR LARGER SPILLS, DIKE FAR AHEAD OF SPILL FOR LATER DISPOSAL. NO SMOKING, FLAMES OR FLARES IN HAZARD AREA! KEEP UNNECESSARY PEOPLE AWAY.

PROTECTIVE EQUIPMENT SECTION

VENTILATION:
PROVIDE LOCAL EXHAUST VENTILATION SYSTEM TO MEET PUBLISHED EXPOSURE LIMITS.

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RESPIRATOR:

500 PPM- CHEMICAL CARTRIDGE RESPIRATOR WITH AN ORGANIC VAPOR CARTRIDGE.
SUPPLIED-AIR RESPIRATOR.
SELF-CONTAINED BREATHING APPARATUS.

1000 PPM- SELF-CONTAINED BREATHING APPARATUS WITH A FULL FACEPIECE OPERATED IN PRESSURE-DEMAND OR OTHER POSITIVE-PRESSURE MODE, OR EQUIVILENT RESPIRATOR.

ESCAPE- ANY ESCAPE SELF-CONTAINED BREATHING APPARATUS.

FIREFIGHTING- SELF-CONTAINED BREATHING APPARATUS WITH A FULL FACEPIECE OPERATED IN PRESSURE-DEMAND OR OTHER POSITIVE PRESSURE MODE.

CLOTHING:

EMPLOYEE MUST WEAR APPROPRIATE PROTECTIVE (IMPERVIOUS) CLOTHING AND EQUIPMENT TO PREVENT ANY POSSIBILITY OF SKIN CONTACT WITH THIS SUBSTANCE.

GLOVES:

EMPLOYEE MUST WEAR APPROPRIATE PROTECTIVE GLOVES TO PREVENT CONTACT WITH THIS SUBSTANCE.

EYE PROTECTION:

EMPLOYEE MUST WEAR SPLASH-PROOF OR DUST-RESISTANT SAFETY GOGGLES AND A FACESHIELD TO PREVENT CONTACT WITH THIS SUBSTANCE.

WHERE THERE IS ANY POSSIBILITY THAT AN EMPLOYEE'S EYES MAY BE EXPOSED TO THIS SUBSTANCE, THE EMPLOYER SHALL PROVIDE AN EYE-WASH FOUNTAIN WITHIN THE IMMEDIATE WORK AREA FOR EMERGENCY USE.

AUTHORIZED - FISHER SCIENTIFIC

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CREATION DATE: 05/15/85 REVISION DATE: 09/16/87

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CHART NO.:	DESIGN AND DEVELOPMENT OF A SPACE STATION HAZARDOUS MATERIAL SYSTEM FOR ASSESSING CHEMICAL COMPATIBILITY	DATE: NOVEMBER 1988

FLUIDS COMMONLY USED IN THE LAB MODULE

- CARBON DIOXIDE
- OXYGEN
- NITROGEN
- ARGON
- HELIUM
- HYDROGEN
- WATER

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PMMS WASTE MANAGEMENT METHODOLOGY

- SOLID EFFLUENTS
  - FILTER PARTICULATES
  - BAG AND STORE
- GASEOUS EFFLUENTS
  - SINGLE MANIFOLD
  - PROCESS AND/OR STORE
  - PERIODIC VENTING
- LIQUID EFFLUENTS
  - PREPROCESS
  - SINGLE MANIFOLD TO ACCUMULATOR/WATER RECLAMATION SYSTEM
    OR
  - SEGREGATE AND STORE

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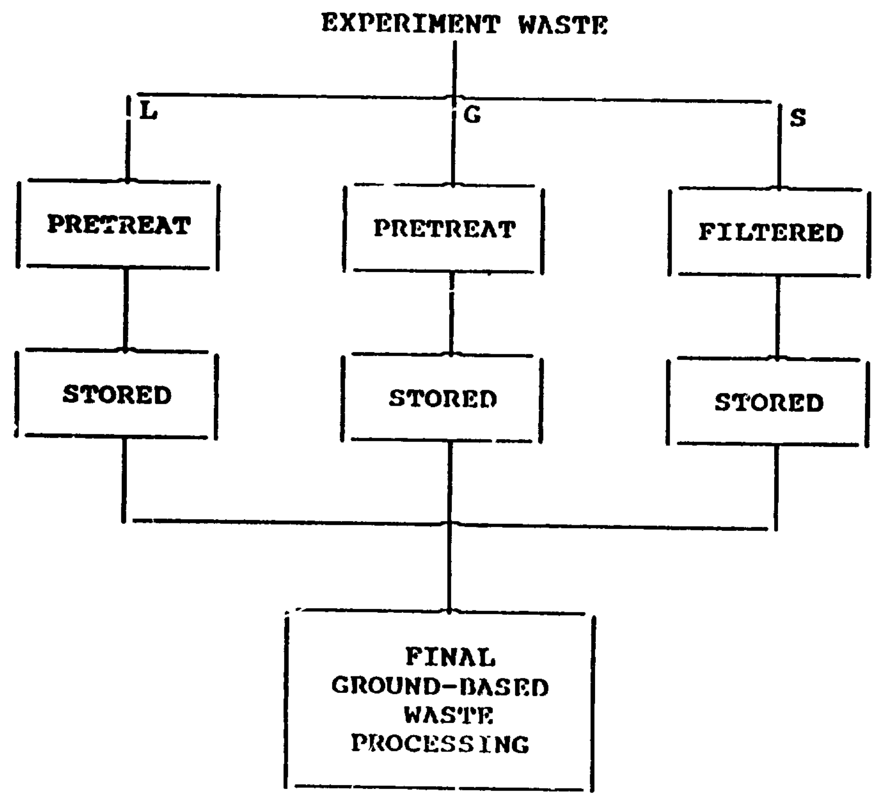

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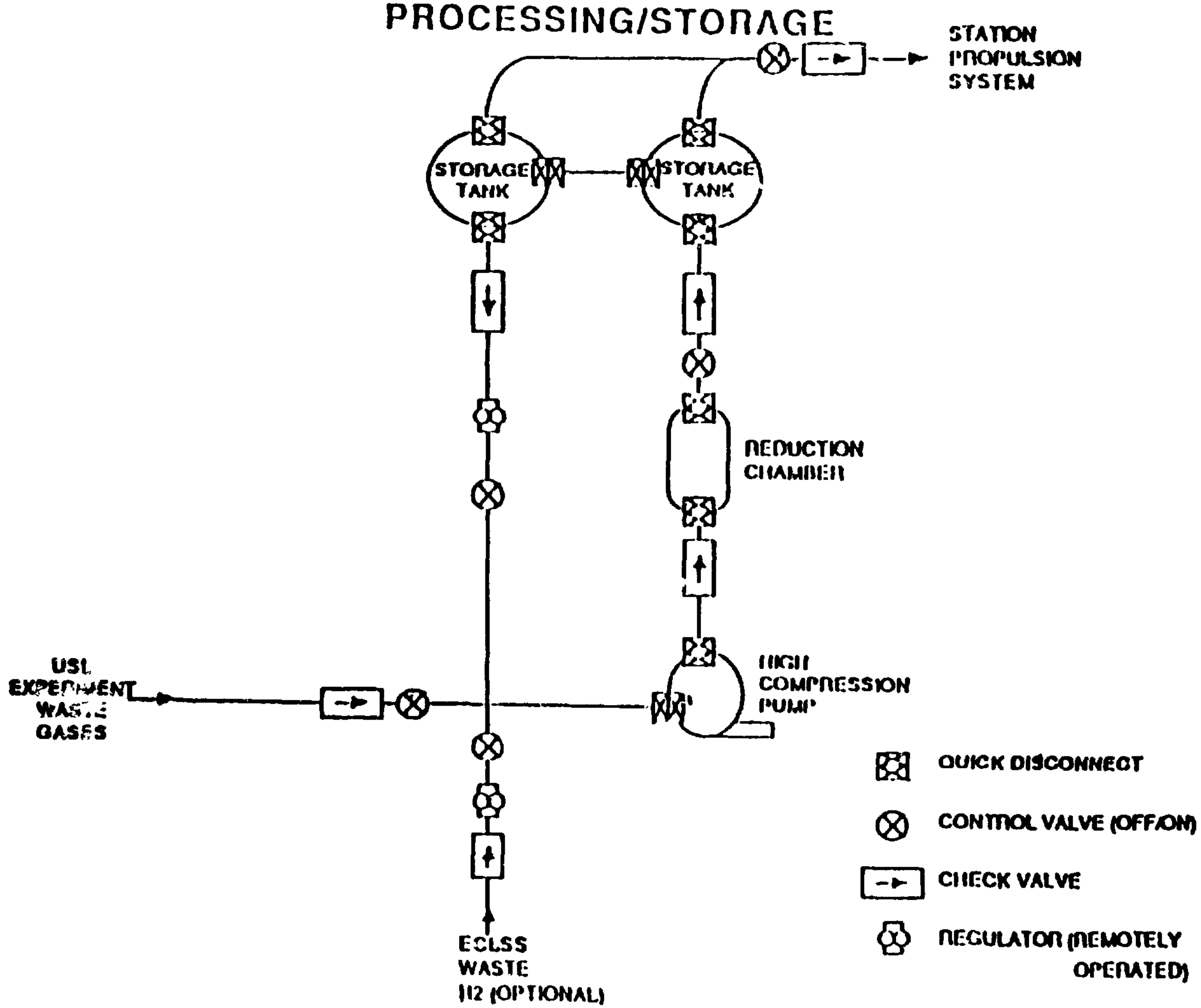
EXTERNAL USL WASTE GAS PROCESSING/STORAGE



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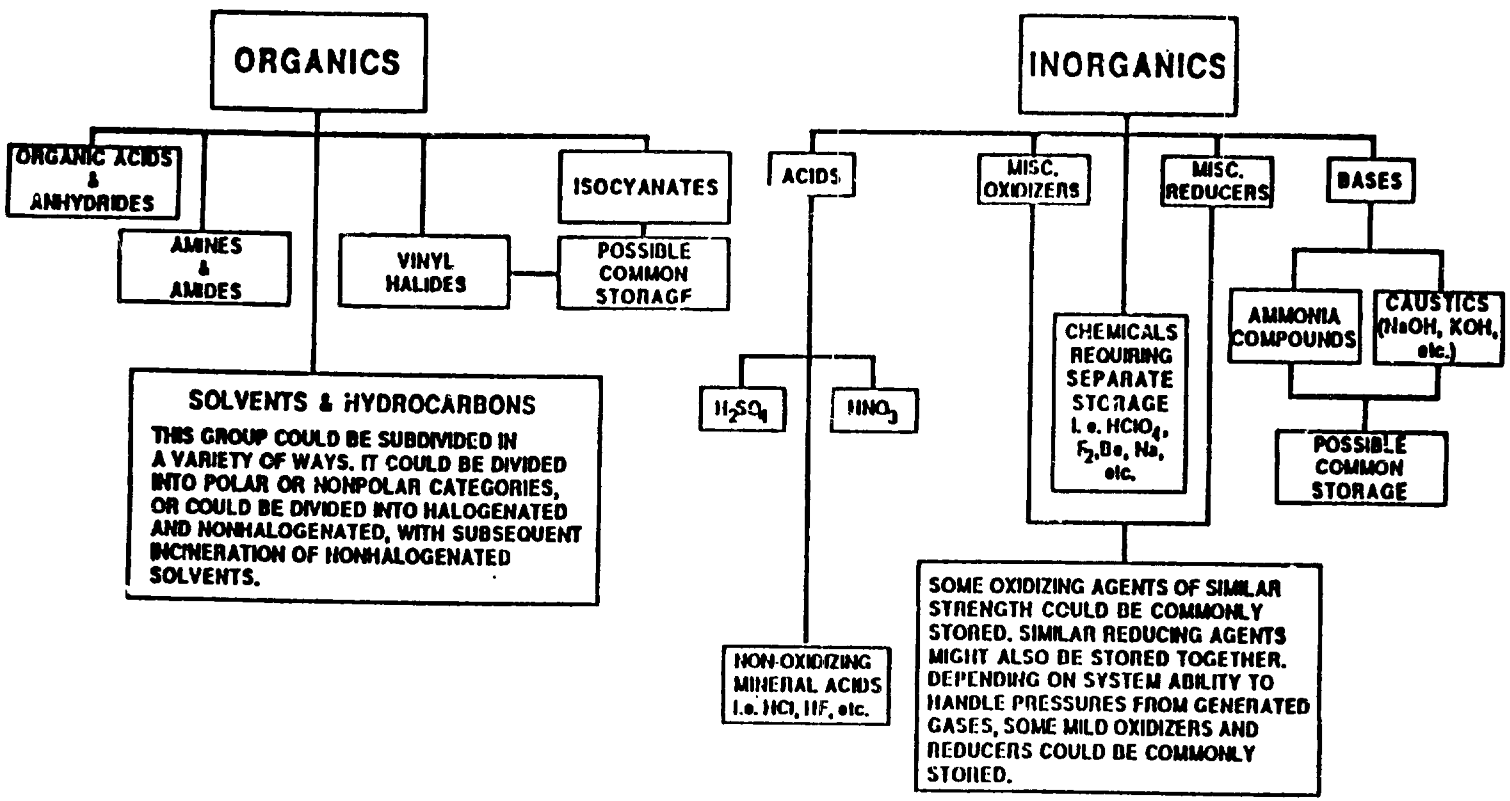
SYSTEM FOR GROUPING COMPATIBLE WASTES



MATERIALS INCOMPATIBILITY

- EFFLUENT/SYSTEM
- EFFLUENT/EFFLUENT

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HAZARDOUS EFFLUENT/SYSTEM COMPONENT INTERACTIONS

- IN THE PRESENCE OF F_2, HCl CAN FORM ClF_3. UNDER DYNAMIC CONDITIONS, ClF_3 BREAKS DOWN TEFLON. (ClF_3 ALSO REACTS VIOLENTLY WITH HNO_3, H_2SO_4, METALS, METAL OXIDES, ORGANICS, AND H_2O)
- HCl, HNO_3, AND HF ARE CORROSIVE TO METAL FITTINGS. $HClO_4$ COULD BE INCOMPATIBLE WITH ORGANIC COMPONENTS.
- H_2O_2 HANDLING SYSTEMS MUST BE FREE OF IRON, BRASS, COPPER, AND MONEL.
- THE COMPLEXITY OF SEPARATE PLUMBING FROM GLOVEBOXES TO VARIOUS WASTE CONTAINERS COULD INCREASE THE RISK OF AN EXPERIMENTER DISCARDING WASTE INTO THE WRONG CHANNEL. IN A WORST CASE SCENARIO, AN EXPLOSION WOULD OCCUR.

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HAZARDOUS EFFLUENT/EFFLUENT INTERACTIONS

COMMON STORAGE COULD RESULT IN DANGEROUS REACTIONS:

- AMMONIA REACTS EXPLOSIVELY WITH HALOGENS.
- AMMONIUM HYDROXIDE REACTS WITH HYDROGEN PEROXIDE TO LIBERATE LARGE AMOUNTS OF OXYGEN, AND FORMS EXPLOSIVE PRODUCTS WITH NITRIC ACID.
- FLUORINE GAS CAUSES MANY ORGANICS, METALS, AND HALOGENS TO IGNITE; AND MAY BE EXPLOSIVE WHEN COMBINED WITH NITRIC ACID, OXYGEN, CARBON MONOXIDE, AND PERCHLORIC ACID.
- PERCHLORIC ACID REACTS VIOLENTLY WITH GRAPHITE, DEHYDRATING AGENTS SUCH AS SULFURIC ACID, ACETIC ACID, AND POTASSIUM HYDROXIDE; KEYTONES; AND OTHERS. FIRES HAVE BEEN KNOWN TO ERUPT YEARS AFTER A SPILL.
- HYDROGEN PEROXIDE REACTS EXPLOSIVELY WITH MANY ORGANICS, PARTICULARLY SOLVENTS.

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HAZARDOUS EFFLUENT/EFFLUENT INTERACTIONS

STORAGE I. I CATEGORIES IS HAZARDOUS:

- HYDROCHLORIC AND SULFURIC ACIDS, OFTEN MIXED IN LABS, HAVE BEEN KNOWN TO CAUSE EXPLOSIONS WHEN STORED IN COMMON WASTE CONTAINERS.
- NITRIC ACID MIXED WITH ACETIC ACID FORMS EXPLOSIVE PRODUCTS AT TEMPERATURES ABOVE 60°C.
- NOT ALL ORGANICS ARE COMPATIBLE (ANHYDRIDES INCOMPATIBLE WITH AMINES, AROMATIC AMINES INCOMPATIBLE WITH ALDEHYD[illegible], ETC.).
- CATEGORIZED STORAGE ACCORDING TO EPA REGULATIONS HAS RESULTED IN NUMEROUS INCIDENTS IN EH32. THESE INCIDENTS WERE NOT DANGEROUS IN AN EARTH BOUND LAB, BUT WOULD BE CATASTROPHIC IN A CLOSED ENVIRONMENT.

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SPACE STATION WASTE MANAGEMENT PROBLEMS:

- RELIES ON SINGLE SYSTEM
- WIDE VARIETY OF REACTIVE AND CORROSIVE WASTES
- PERIODIC VENTING
- CONFLICT BETWEEN "USER-FRIENDLY" AND SAFE:
  —CONTROL BY LIMITING MATERIALS AND TIMELINING

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HAZARDOUS MATERIALS COMPATIBILITY RESEARCH IS REQUIRED TO ADDRESS THE FOLLOWING:

- WHAT MATERIALS ARE AVAILABLE FOR USE IN THE VARIOUS COMPONENTS (LINES, TANKS, VALVES, FITTINGS, ETC.) OF THE PMMS?
- WHAT DEGRADATION OF THESE MATERIALS WILL OCCUR DUE TO DIRECT ACTION OF WASTES?
- HOW WOULD THESE MATERIALS RESPOND TO SUDDEN EXPOSURE TO HIGH PRESSURES AND TEMPERATURES IN THE EVENT OF AN EXPLOSIVE REACTION WITHIN THE LINE?
- WHAT PROCESS WASTES MUST BE PROHIBITED FROM THE SYSTEM ENTIRELY? OR WHAT LEVEL OF DILUTION WOULD ALLOW THEIR DISPOSAL?

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RESEARCH OBJECTIVES

- DEVELOP DATABASE OF PROCESS AND WASTE MATERIALS AND POTENTIAL REACTION PRODUCTS
- DEVELOP DATABASE OF CANDIDATE SYSTEM MATERIALS
- IDENTIFY CANDIDATE COMPONENTS FOR PROPOSED AND ALTERNATE DISPOSAL TECHNOLOGIES
- ESTABLISH CATAGORIES OF COMPATIBLE WASTES
- ESTABLISH APPROPRIATE SYSTEM MATERIALS FOR WASTE CATAGORIES
- EVALUATE COMPONENTS FOR EFFECTIVENESS AND MATERIAL PERFORMANCE
- EVALUATE PRETREATMENTS, POST TREATMENTS, AND ALTERNATE TECHNOLOGIES
- FLAG CORROSION PROBLEM AREAS WITHIN SYSTEM

Acknowledgements

I would like to thank those individuals whose inputs into the development of the Materials Compatibility Laboratory at MSFC and Core Module Integration Facility Systems Evaluation has been most appreciative. These are Ms. Dinah Higgins, Ms. Wendy Alter, Mr. Jimmy Perkins, Ms. Stephania Darby, and Mr. Jay Perry. Exerpts from our combined efforts were used in some of the figures and tables presented earlier.

TOPIC: SPACE STATION HAZARDOUS MATERIALS DEFINITION, LABELING, AND OTHER SAFETY-RELATED ISSUES

PRESENTED TO: SPACE STATION TOXIC AND REACTIVE MATERIALS HANDLING WORKSHOP

PRESENTED BY: PAUL GALLOWAY
TELEDYNE-BROWN ENGINEERING

TELEDYNE
BROWN ENGINEERING

NOVEMBER 30, 1988

SPACE STATION FREEDOM HAZARDOUS MATERIALS HANDLING

TOPICS OF PRESENTATION

1) HAZARDOUS MATERIAL DEFINITION

2) PROPOSED SPACE STATION CHEMICAL CONTAINER LABELING SYSTEM

3) CONCEPTUALIZED SPACE STATION USL CHEMICAL SPILL SCENARIO

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SUMMARY OF AN EXISTING HAZARDOUS MATERIALS DEFINITION

REFERENCE: "PRUDENT PRACTICES FOR DISPOSAL OF CHEMICALS FROM LABORATORIES", 1983

- EXPLOSIVE
  - E.G., COMMERCIAL EXPLOSIVES
- [USL] COMPRESSED GAS - FLAMMABLE
  - GAS UNDER PRESSURE > 40 PSIA @ 70 F OR 104 PSIA @ 130 F
  - LIQUID WITH VAPOR PRESSURE > 40 PSIA @ 100 F
- [USL] COMPRESSED GAS - NONFLAMMABLE
  - GAS UNDER PRESSURE > 40 PSIA @ 70 F OR 104 PSIA @ 130 F
- POISONOUS GAS OR LIQUID - POISON CLASS A
  - SPECIFIC LIST OF TEN DEADLY COMPOUNDS
- [USL] IGNITABLE LIQUID
  - LIQUID HAVING A CLOSED CUP FLASH POINT < 200 F
- ORGANIC PEROXIDE

[USL] DENOTES THE POTENTIAL USE THIS CLASS OF MATERIAL ON THE USL

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SPACE STATION FREEDOM HAZARDOUS MATERIALS HANDLING

SUMMARY OF AN EXISTING HAZARDOUS MATERIALS DEFINITION

REFERENCE: "PRUDENT PRACTICES FOR DISPOSAL OF CHEMICALS FROM LABORATORIES", 1983

- [USL] ● FLAMMABLE SOLID
- [USL] ● CORROSIVE MATERIAL
  - ▶ pH < 2 OR >12.5
- [USL] ● POISONOUS LIQUID OR SOLID - POISON CLASS B
  - ▶ LD50 < 50 mg/kg — ALBINO RAT - ORAL - 200 TO 300 g WEIGHT
  - ▶ LD50 < 200 mg/kg — ALBINO RABBIT - DERMAL - 2 TO 3 kg WT - 24 HR EXP.
  - ▶ LC50 < 200 mg/kg — ALBINO RAT - INHAL. - 200 TO 300 g WT - 1 HR EXP.
- [USL] ● OXIDIZER
- ● RADIOACTIVE MATERIAL
- ● ETIOLOGIC AGENTS
  - ▶ MICRO-ORGANISMS AND THEIR TOXINS WHICH CAUSE HUMAN DISEASE

[USL] DENOTES THE POTENTIAL USE THIS CLASS OF MATERIAL ON THE USL

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SPACE STATION FREEDOM HAZARDOUS MATERIALS HANDLING

THE PROPOSED SPACE STATION CHEMICAL CONTAINER LABELING SYSTEM IS A COMBINATION OF THREE EXISTING U.S. GROUND-BASED LABELING SYSTEMS

- DEPARTMENT OF TRANSPORTATION (DOT) HAZARDOUS MATERIAL WARNING LABELS
- NATIONAL FIRE PROTECTION ASSOCIATION (NFPA) HAZARD IDENTIFICATION SYSTEM
- COMPREHENSIVE ENVIRONMENTAL RESPONSE, COMPENSATION, AND LIABILITY ACT OF 1980 (CERCLA) HAZARD RANKING SYSTEM

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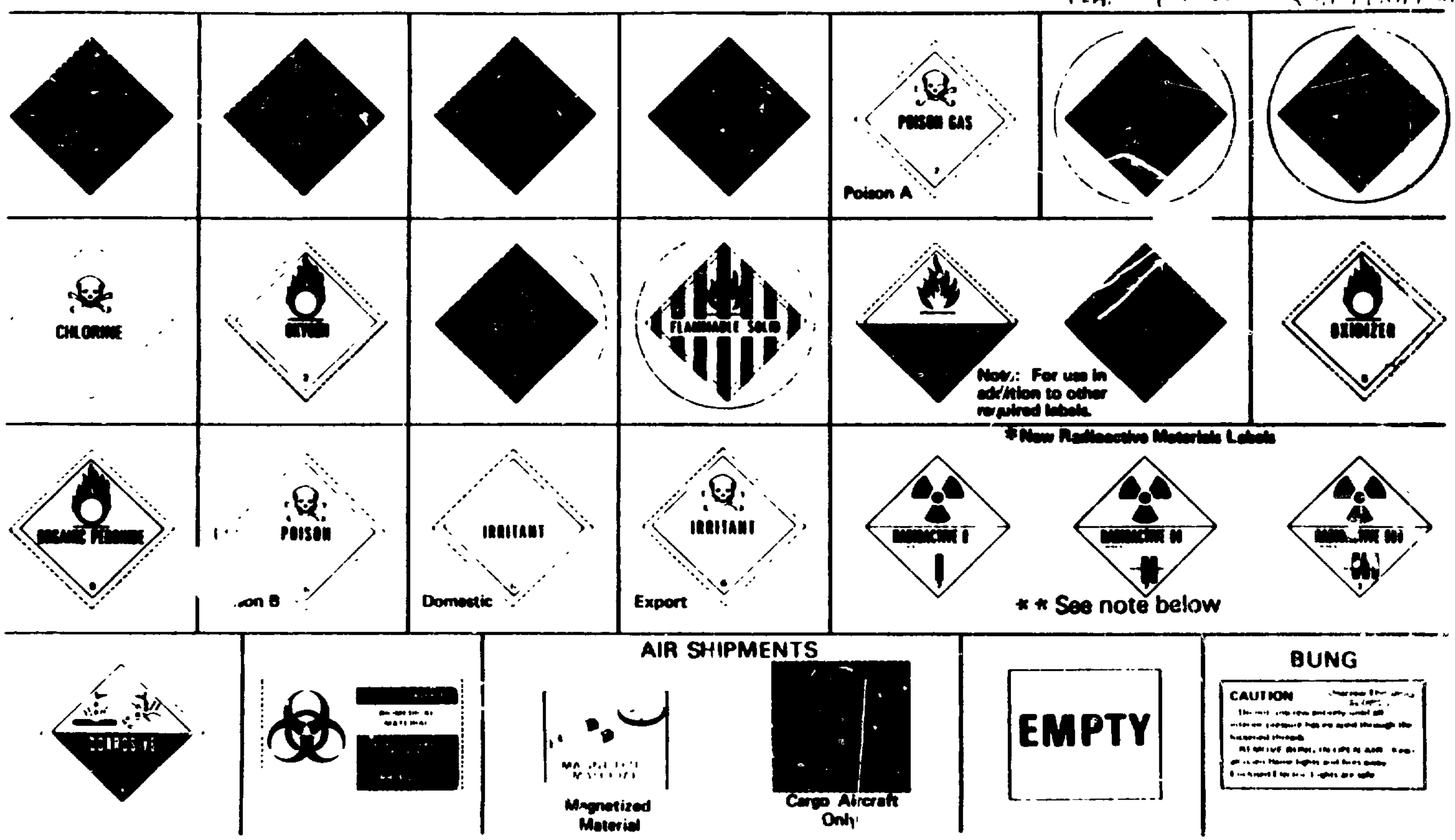
SPACE STATION HAZARDOUS MATERIALS HANDLING

DOT Hazardous Materials Warning Lables



◯ DENOTES ANTICIPATED SPACE STATION MATERIALS

REFERENCE: TITLE 49, CODE OF FEDERAL REGULATIONS, PART 172

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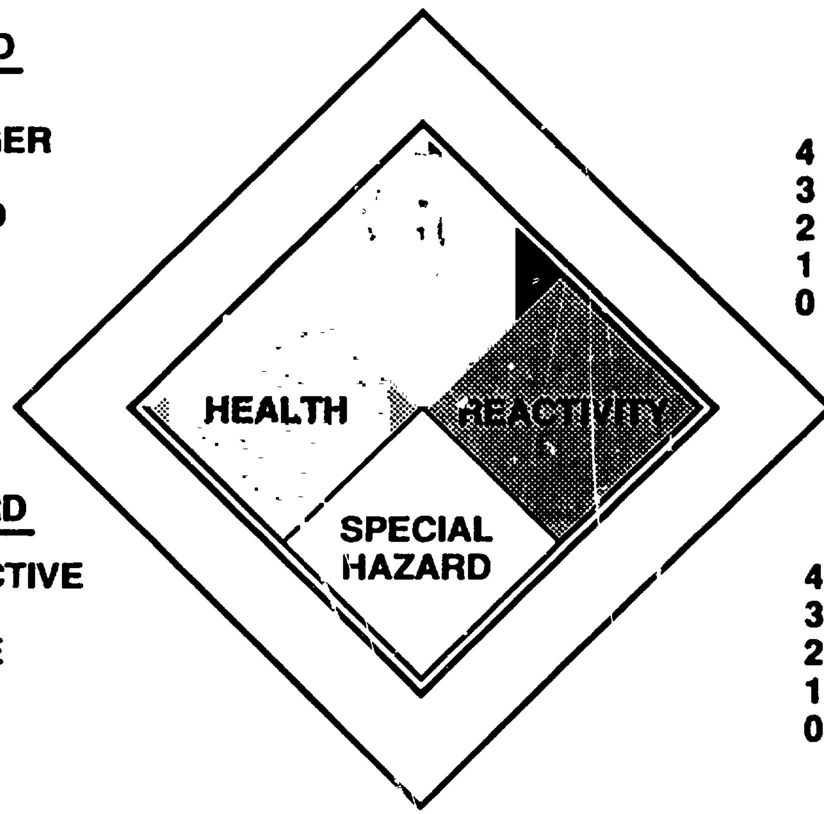
SPACE STATION HAZARDOUS MATERIALS HANDLING

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA) HAZARD IDENTIFICATION SYSTEM



HEALTH HAZARD

4 - DEADLY
3 - EXTREME DANGER
2 - DANGEROUS
1 - SLIGHT HAZARD
0 - NO HAZARD

FIRE HAZARD (FLASH POINTS)

4 - BELOW 73°F
3 - BELOW 100°F
2 - BELOW 200°F
1 - ABOVE 200°F
0 - WILL NOT BURN

SPECIAL HAZARD

W - WATER REACTIVE
OX - OXIDIZER
☢ - RADIOACTIVE

REACTIVITY

4 - MAY DETONATE
3 - EXPLOSIVE
2 - UNSTABLE
1 - NORMALLY STABLE
0 - STABLE

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SPACE STATION FREEDOM HAZARDOUS MATERIALS HANDLING

CERCLA HAZARD RANKING SYSTEM

TOXICITY

3 - SEVERE TOXICITY
2 - MODERATE TOXICITY
1 - SLIGHT TOXICITY
0 - NO TOXICITY

FLAMMABILITY

3 - FLASH POINT BELOW 100 °F
2 - FLASH POINT >100 °F AND < 200 °F
1 - FLASH POINT ABOVE 200 °F
0 - WILL NOT BURN

PERSISTENCE (BIODEGRADABILITY)

3 - HIGHLY PERSISTENT COMPOUND
2 - PERSISTENT COMPOUND
1 - SOMEWHAT PERSISTENT COMPOUND
0 - NONPERSISTENT COMPOUND

REACTIVITY

3 - MAY DETONATE
2 - UNSTABLE
1 - NORMALLY STABLE
0 - STABLE

REFERENCE: CODE OF FEDERAL REGULATIONS (CFR) 40, PART 300

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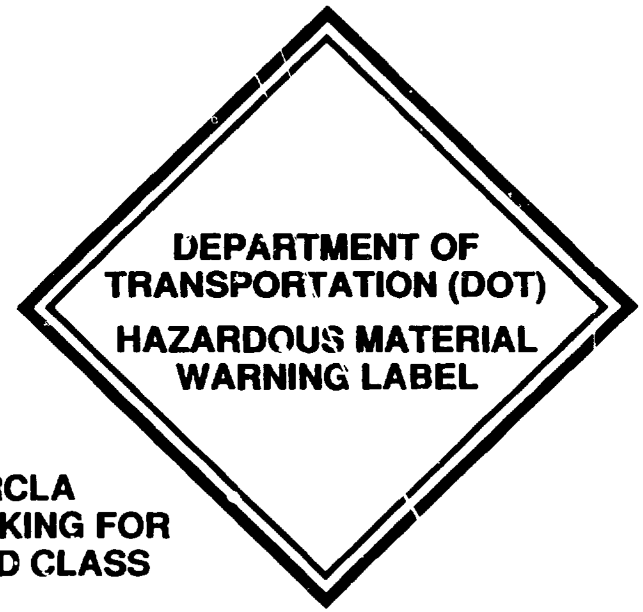
Space Station Hazardous Materials Handling

PROPOSED SPACE STATION CHEMICAL CONTAINER LABELING SYSTEM

(BLUE) HEALTH *	(RED) FIRE *
(WHITE) PERSISTANCE *	(YELLOW) REACTIVITY *

CHEMICAL NAME

* USE 0-3 CERCLA HAZARD RANKING FOR EACH HAZARD CLASS



SPACE STATION HAZARD DATA BASE 4- DIGIT CODE

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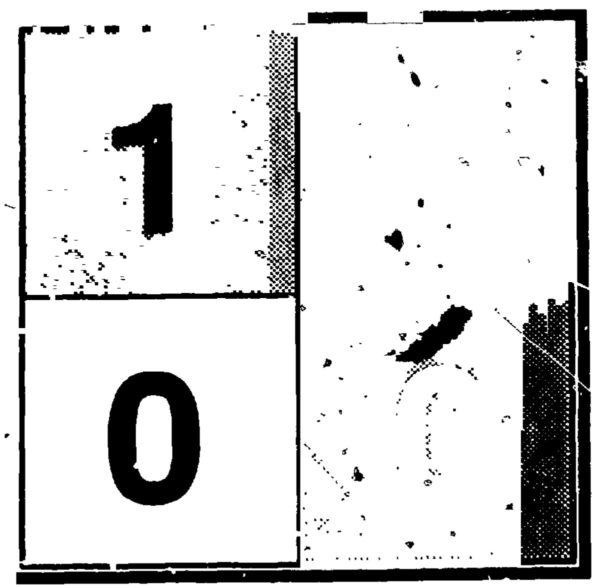
PROPOSED SPACE STATION CHEMICAL CONTAINER LABELING SYSTEM



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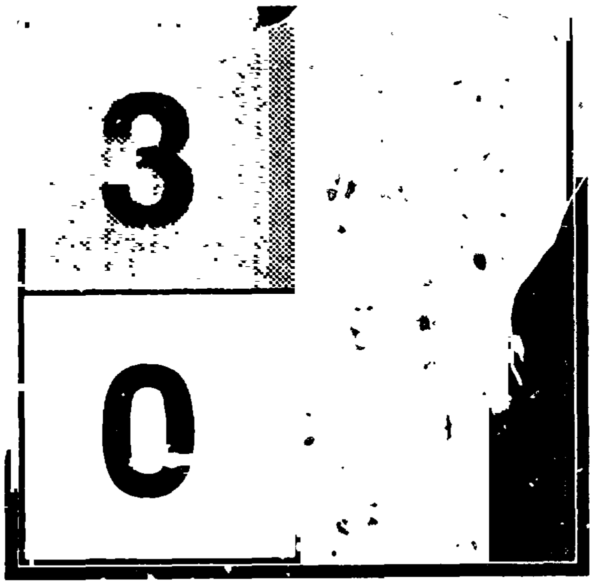

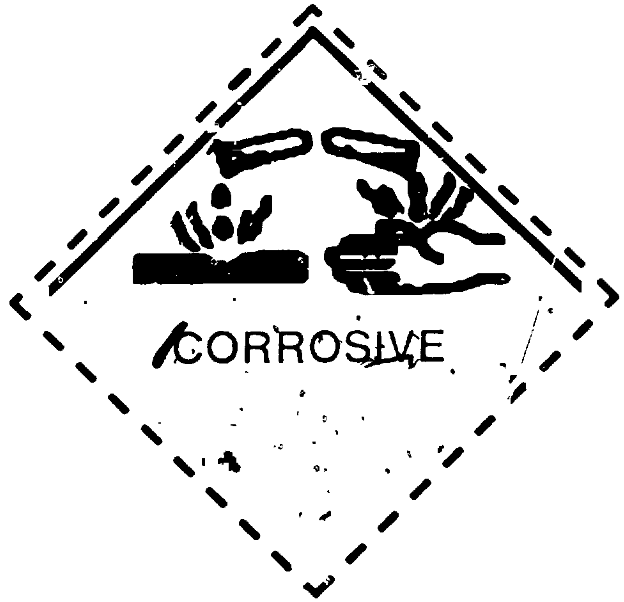

HYDROGEN FLUORIDE

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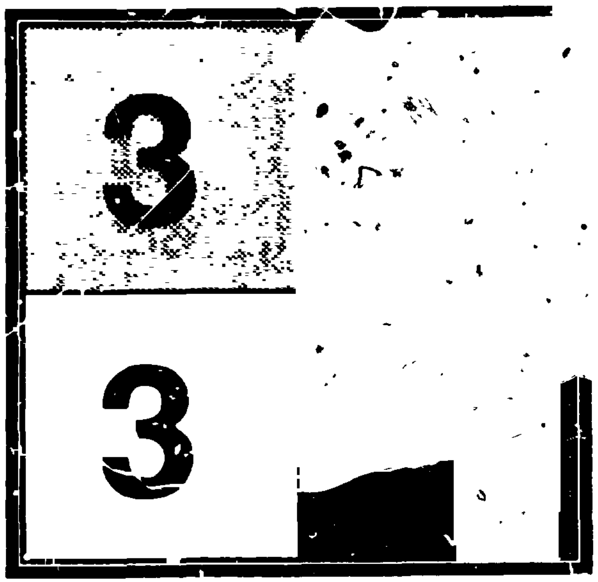

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SPACE STATION FREEDOM HAZARDOUS MATERIALS HANDLING

CONCEPTUALIZED USL SPILL SCENARIO

1) A CREWMAN IS CHANGING OUT AN EXPERIMENT RACK FOR RETURN TO EARTH
2) A QUICK-DISCONNECT ON THE WASTE LINE FAILS UPON REMOVAL AND EXPOSES THE CREW MEMBER TO AN ORGANIC LIQUID
3) THE CREWMAN OR OTHER CREW MEMBERS DECIDE TO UTILIZE THE EMERGENCY SHOWER WHICH IS LOCATED IN THE USL
4) WHILE THE CREWMAN IS USING THE EMERGENCY SHOWER, THE RELEASED ORGANIC IS DIFFUSING THROUGHOUT THE USL AND TO OTHER STATION MODULES
5) THE CREW MEMBER EMERGING FROM THE EMERGENCY SHOWER MUST RE-ENTER A CONTAMINATED USL MODULE, THEN, EXIT THE USL BEFORE IT CAN BE ISOLATED

PRIMARY QUESTION: IS THE USL MODULE THE OPTIMAL LOCATION FOR THE EMERGENCY SHOWER?

POTENTIAL SOLUTION: LOCATE THE EMERGENCY SHOWER IN A NODE. THIS WILL PERMIT IMMEDIATE ISOLATION OF THE USL. PROVIDE A PORTABLE AIRLOCK FOR INITIAL RE-ENTRY OF THE USL

TELEDYNE
BROWN ENGINEERING

PAUL GALLOWAY
NOVEMBER 30,1988

SESSION 3

SUMMARY AND KEY ISSUES IDENTIFICATION

by

Session 3 Chairman: Richard Tyson

NASA - Code R

SESSION 3

SUMMARY

Session 3 presentations addressed various chemical and contamination detection methods currently under study, under development, and those used in industry. In a general overview of chemical detection, several existing detection devices were shown along with their specifications and capabilities. Applications of MS/MS technology for Space Station internal contamination detection was addressed by Teledyne CME. A presentation on the applications of fiber optics technology for chemical containment detectors discussed Ramam scattering, fluorescence-based optrodes, absorbance-based pH sensors, organochloride optrodes, remote fiber optics spectroscopy, general categories of fibers, and bending losses and other limitations. Another presentation on particulate detection technology discussed optical particle counters, condensation nucleation counters, electrical aerosol analyzers, electrostatic precipitators, a cascade impactor, aerodynamic particle sizers, and a summary of optical, electrical, and mechanical detector methods. Also, overviews of both the Space Station Freedom life sciences glovebox and materials processing glovebox were given. These presentations touched lightly on glovebox contamination control systems, potential hazardous materials, and material handling issues affecting design. A presentation on USL chemical hazard remediation addressed the objectives of the PMMS, USL chemical storage, USL chemical handling, USL chemical isolation, USL waste handling requirements, potentially hazardous operations in the USL, hazard remediation approach, criteria for USL experiment materials screening, development of USL material classification and waste remediation techniques, PMMS approach to handling hazardous chemicals, rack-level waste handling methodology, and personal protective equipment. A presentation on the safety practices of ground-based electronic crystal growth discussed considerations in selection of facility, equipment, and personnel. Facility safety, equipment safety, personnel protection, and training were also addressed in this presentation. A presentation addressing the importance of biological systems in treatment discussed treatment methods for toxic chemicals in water, soil, sediment, and sludge. Among the methods discussed were: microbial reduction of metals, bacterial reduction of metals, sulfate reduction, solubility of metal sulfides, and filtration methods. A presentation on exhaust gas conditioning equipment and technology addressed issues of growing concerns, causes of fires at semiconductor plants, and central conditioning methods and equipment. The last presentation in Session 3 discussed reactive bed plasma systems for contamination control. This method addressed phosgene decomposition, benzene decomposition, and aerosol removal mechanisms.

KEY ISSUES

1. Combining all wastes into one pipeline or tank is a concept that has been abandoned on the ground. Ground systems similar to the needs of Space Station Freedom use dedicated treatment and processing at each facility location. Combining wastes may create too much of an explosion potential.

2. Development of a hazardous materials classification system that astronauts can quickly and easily use in emergency situations needs to be implemented early in the Space Station program.

3. Applying biological systems for combating waste treatment in the Space Station modules s . .med to be a new idea for many of the attendees. Comments suggested that this method be investigated for application to the Station.

4. The Space Station Program should fully utilize existing technology and where no existing technology meets all the requirements, new technology should be developed and then shared with the ground-based industrial and scientific communities.

N91-15940

DISCOURSE FOR SLIDE PRESENTATION:

AN OVERVIEW OF CHEMICAL DETECTION SYSTEMS

Randy Alan Peters*, Theodore J. Galen*, Duane L. Pierson,

Toxicology Laboratory, Biomedical Laboratories Branch,

Johnson Space Center, Houston

*KRUG International

This presentation is a brief overview of some potentially useful analytical techniques currently available for the investigation of gas phase contaminates in ambient air. I would like to acknowledge my supervisor, Ted Galen and our technical monitor, Duane Pierson who both assisted in making this presentation possible.

The scope of this presentation includes a brief overview of some of the analytical techniques currently used in monitoring and analyzing permanent gases and selected volatile organic compounds in air. Sampling techniques and the exact analytical methods used to identify and quantitate specific compounds are not included in the presentation. Further, I need to state that this presentation is not an endorsement of any of the hardware or systems mentioned for any project applications.

This is a basic outline of what I will discuss. First, I will discuss some of the analytical considerations in developing a specific method. Next, I will discuss four broad groups of hardware are: compound class specific personal monitors, gas chromatographic systems, infrared spectroscopic systems, and mass spectrometric residual gas analyzer systems. Under the group of personal monitors, I will discuss three types of detectors: (A) catalytic sensor based systems, (B) Photoionization detectors, (C) wet or dry chemical reagent systems. Under gas chromatograph based systems I will cover five detector systems used in combination with a GC: (A) thermal conductivity detectors, (B) photoionization detectors, (C) fourier transform infra-red spectrophotometric systems, (D) quadrapole, mass spectrometric systems and (E) a relatively recent development- a surface acoustic wave vapor detector.

I would like to begin with a brief outline of some basic analytical considerations in developing a method for a specific application. First, the analytical problem should be as well defined as possible using the information and data available. The need for qualitative information may require the exact, stereospecific identification each species, or the need may only require a general classification (such as halocarbons and alcohols). The expected levels of the species to be monitored will influence the instrument sensitivity and range required. The system should produce useful information in time to respond to significant changes in the species monitored. The method of standardization and quality assurance will vary with the analytical system and the required level of precision. The basic analytical requirements of the problem guides the selection of suitable types of methods. The selection of suitable methods narrows the selection specific hardware and procedures. The actual testing of the hardware selected should produce sufficient data to make comparisons between candidate systems. Following some iterative testing and modification, the precision and accuracy of the final prototype is carefully estimated. The amount of operator training required usually is dependent on the level of automation of the system.

This is a list of twelve criterion usually included in the selection of suitable types of methods: the reported detection limits and dynamic range, the samples needed and type of inlet used, the overall speed of analysis, the ruggedness and resistance to vibration, the reported accuracy, the interference from other sample components, the predictability of performance of the system, the training required, the physical dimensions and power needed to operate the system, the other utilities needed (such as vacuum), and the potential hazards in operating the system.

This is a photo of a personal monitor which contains four separate sensors for carbon monoxide, explosive gases, hydrogen sulfide and molecular oxygen. The unit has a digital read-out and it can be used with a data logger.

This is the same monitor with the protective cover removed from over the sensors. The sensor which responds to volatile organics is a catalytic, pellistor type sensor and, the CO, H2S and O2 sensors are electrochemical type sensors.

This is a summary of some of the important characteristics of the multi-sensor, personal monitor. The overall dimensions of the monitor unit are 2.3 inches by 4 by 9 inches and it weighs approximately 3 pounds. The unit depicted above is designed to respond to the three permanent gases and catalytically oxidizable organics. The response range of the above unit is '0' to 500 ppm for carbon monoxide. The unit is powered by alkaline batteries. Some of the limitations of may include: short battery charge life, single point calibration for a specific compound with the assumption that the response is linear over the full range, and the sensitivity and selectivity of the sensors is dependent on the red-ox potential of compounds reaching the sensors. The response of each sensor is calibrated against one or more gas phase standards. The estimated run to run precision is about 5 % of the reading. One advantage of having these monitors present is that response is immediate to any change in the levels of the target compounds.

This is a prototype total hydrocarbon monitor designed for us to demonstrate the possibilities of size reduction for personal monitors. The unit is literally shirt pocket - size, it has a digital display range in hundredths of ppms and it could be fabricated with a threshold alarm.

The unit dimensions are 1.5 by 2.5 by 3.75 inches.
The weight of this unit is much less than a pound.
The semiconductor sensor responds to oxidizable organics.
The response range to is from about 0.1 to 1000 ppm for many organics.
The monitor is powered by an alkaline battery.
Limitations of particular interest are similar to the previous unit in that the response is dependent on the organic compounds present in the air and on the partial pressure of oxygen.
The response time is less than a minute.
The system is calibrated with a single point external standard.
The level of precision or repeatability is about 2% of the reading.

This unit is based on a photoionization detector. When the compound of interest passes into the detector cell, it absorbs a quanta of energy 'hv' emitted by the UV source and the compound is ionized. The cations are collected at an electrode surface producing a measurable signal.

The dimensions are 5 by 9 by 6 inches.
The weight of the unit is 5 pounds.
The unit responds to species with photoionization potentials below the energy of the lamp (around 10eV) and some exceptions above this limit.
The digital display range is from 1 to 2000ppm.
The monitor is powered by a 12V battery.
Limitations of particular interest are the low selectivity and the variable sensitivity to the various volatile organics.
The response time is sufficiently fast to allow this type of detector to be used with capillary gas chromatography.
The system is calibrated with a single, volatile organic standard.
The level of precision or repeatability is reported as around 2% of the reading from run to run.

This is a wet or dry chemical reagent tube system for monitoring various individual compounds. The system consists of a hand operated sample pump used to draw an air sample through disposable glass tubes containing the chemical reagents and indicators.

The weight of the pump plus several disposable tubes is about 2 pounds.
There are over 300 different reagent tubes available to measure various permanent gases and volatile organic compounds.
The reported response range to benzene is from 2 to 60ppm.

The pump is hand operated.
Limitations of particular interest are the training required for interpreting the indicator changes, and the disposal of the used reagent tubes.
The response time varies from 1 to 5 minutes for various tubes.
The tube response may be calibrated by a duplicate run of an external standard.
The level of precision or repeatability of the benzene tubes is reported as plus or minus 1ppm for a 5ppm reading.

The next broad group of analytical systems is based on the gas chromatographic separation of the compounds of interest prior to detection by one or more devices.

This is a photograph of a portable, dual column, dual detector gas chromatograph manufactured for environmental applications. The temperatures of the individual columns are controlled independently. The columns have different stationary phases and are about 10 meters in length. The chromatograms are typically 2 minutes long. The detectors are both micro chip sized thermal conductivity detectors. The response of the detectors can be transferred to a separate integrator and the data can then be down loaded to a 'lap-top' personal computer.

This is a view of the internal packaging of the unit showing the two individually insulated columns with the chip size detectors.
The dimensions of the MTI GC are 6" by 10" by 14".
The unit weighs only 5 pounds.
The miniature thermal conductivity detectors respond to most permanent gases and volatile organic compounds.
The detector response range is reported as from 1ppm and extending to 6 orders of magnitude.
The unit requires a helium carrier source, 120Vac power, and some type of recording device.
Limitations of particular interest are: short columns have limited 'peak capacity', compound identification is based on retention time, the need for an additional, very fast recording device or integration device and the detector sensitivity does not extend below the ppm level.
The average chromatogram for simple mixtures is less than 5 minutes long.
The system is calibrated using one or more external standards.
The chromatographic repeatability has been reported as better than 5% from run to run.

Here is another commercially available, portable gas chromatographic system. This unit is now available with capillary columns and temperature control. The unit also contains an integrator capable of making concentration calculations based on an external standard runs saved in memory and are continuously updated. The unit can be operated remotely through a modem and it contains an internal reservoir for the carrier gas. The unit is available with a photoionization detector only at this time.

This is a view of internal configuration of the unit showing the column area. This particular unit is one of the older models without temperature control.

This unit's overall measurements are 18" by 13" by 6".
The entire system weighs 26 pounds.
The detector responds to most volatile organic compounds.
The response range is reported as 0.1ppb to over 100ppm.
The system requires high purity air to replenish the internal pressurized reservoir and operates from a rechargeable 12V battery.
Limitations of particular interest of this version are the ambient temperature column, limited 'peak capacity' of the short column, and the variable retention times resulting from no independent temperature control.
The average run is about 10 minutes for simple mixtures.
The system is calibrated using an internal pressurized container of an external standard gas mixture.
The chromatographic repeatability is better than 5% run to run.

Here is a photograph of a laboratory model of a sequential, gas chromatograph, Fourier transform infrared spectrophotometer, quadrapole mass spectrometer with the dual computer operating system. This system is capable of generating a tremendous amount of analytical data from a single sample. The FTIR and mass spec. data complement one another in that the infrared spectra can be used to distinguish between certain isomers of the same compound and supply additional structural data the mass spectra may not supply. Notice the relatively small size of the FTIR component of the system: which may suggest the possibility of a portable, GC/FTIR unit the future.

The FTIR component dimensions are 12" by 10" by 26".
The weight of the FTIR unit is 55 pounds.
The unit responds to infrared absorbing species and produces mass spectral data to any species eluting off the column.
The FTIR response range is from ppb to above 100ppm and is approximately one to two orders of magnitude less sensitive than the mass spectrometer.
The sys em requires liquid nitrogen for the IR cell, He carrier gas and operates off 120Vac.
One limitation of interest is the tremend s amount of computer memory space required for a single GC run.
The average run time for a sample of moderate complexity is 45 minutes.
The system is calibrated by external standard, internal standard or standard addition methods depending on the application.
The level of chromatographic repeatability is about 5% from run to run and depends on the conditions used.

Another interesting system is this combined, gas chromatograph, quadrapole mass spectrometer system. In this case the recently developed version of the mass spectrometer has an extremely small footprint. The metal box contains the ion source, the quadrapole flight tube and all the electronics boards.

The mass spectrometer dimensions are roughly 12" by 8" by 26"
The weight of MS without the pump and other hardware is about 48 pounds.
The system responds to any permanent gas or volatile organic which can be eluted of the column.
The system can be used to detect sample components from ppt to about 100ppm.
The system requires mechanical roughing vacuum for the oil diffusion pump, high purity helium carrier gas and 120Vac power.
Two of the limitations are the peak capacity of selected capillary column and the nearly indistinguishable mass spectra produced from some isomers.
The average run time under certain conditions is 45 minutes.
The system is often calibrated using external standards for quantitative determinations.
The level of chromatographic precision is 5% for some applications.

Another recently developed type of GC detector intended for ambient air monitoring is the surface acoustical wave vapor sensor. One commercially available unit is now being developed for production which includes a packed column gas chromatograph and uses ambient air as the carrier gas. The dimensions of the unit are reported by the manufacturer as 12" by 10" by 5". The unit weighs 15 pounds. The detector can be custom designed to be sensitive to a broad group of volatile organics commonly found in environmental air. The response range is reported as ppb to ppm. The unit may be run off a rechargeable gell cell battery. One of the reported limitations is that the present sensor too slow for capillary columns. The average chromatogram is 5 min. long.

The third group of monitors is based on infra-red spectrophotometry. This is a portable, commercially available dispersive IR unit designed for environmental applications.

The dimensions of this unit are 28" by 9" by 11".
The weight of this unit is 30 pounds which makes it very difficult to carry for any length of time.
The system responds in a scanning mode or fixed frequency mode to species in the sampled air which absorb in the IR region from 650 to 4000 cm-1.
The response range to benzene is reported as 2.2 to 50ppm.
The monitor is powered by a rechargeable NiCd battery.
Limitations of particular interest are the short battery charge life, the sensitivity compounds such as benzene and the loss of selectivity for specific compounds in complex mixtures often found in air samples.

The response time is less than a minute in fixed frequency mode. The system is calibrated with an external standard gas mixture. The level of repeatability is reported as about 15% from run to run.

The forth and final group of analytical systems that I will briefly discuss is based on small quadrapole mass spectrometers with some type of specialized inlet system other than a gas chromatograph. One approach to the sample inlet problem has recently been published in Analytical Chemistry by Scott A. McLuckey and his colleagues at the Oak Ridge National Laboratory where they reported an estimated limit of detection of 1.4 ppt for head-space vapor over solid TNT using their atmospheric sampling glow discharge ionization source.

This is a photograph of a commercially available, quadrapole residual gas analyzer system. This particular unit is used by the toxicology laboratory a JSC as vacuum measuring device. The unit is part of a vacuum oven system use to evacuate and clean air sample cylinders and stainless steel chambers used to perform materials out-gassing measurements. The ion source and flight tube are located in this area of the vacuum system. The system is maintained at approximately 10 to the minus 7 torr by a turbo pump backed by a mechanical roughing pump. The control and acquisition electronics are located in this module with digital display of several mass channels for N2 and CO, O2, et cetera. The mass range of this quadrapole is to 65 amu. The unit is remotely operated and data is down-loaded to a personal computer. In this application, the mass spectrometer is used to measure extremely low levels of permanent gases and trace contaminants by single mass assignments of these compounds and simple ion patterns of isotopic abundances. Other commercially available systems have been used with ambient pressure, differentially pumped inlets to monitor air contaminants.

This presentation is by no means an exhaustive listing of the wide variety of methods and hardware available for monitoring and analyzing volatile organic compounds in air. The adaptation of existing analytical systems to monitor spacecraft breathing environment has some obvious advantages for saving time and resources in hardware development. The engineering and safety constraints should be coordinated with the analytical considerations in the selection and modification of candidate hardware. Iterative testing and evaluation of the analytical performance of each candidate system during development would aid achieving the best results

CHEMICAL-BIOLOGICAL MASS SPECTROMETER

GREG MARSH

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IN THIS ROOM:

TELEDYNE CME CBMS PROGRAM MANAGER = GEOFF DAVIS

TELEDYNE CME CBMS TECHNICAL DIRECTOR = GREG MARSH, Ph.D.

BRUKER-FRANZEN ANALYTIK GESCHÄFTSFÜHRER = JOCHEN FRANZEN, Ph.D.

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WHAT IS A CBMS?

- MASS SPECTROMETER ABLE TO SEE CHEMICAL AND BIOLOGICAL THREATS AT SUB-TOXIC CONCENTRATIONS IN AMBIENT AIR
- SMART BLACK BOX THAT CAN ALERT SOLDIER TO BOTH KNOWN AND UNKNOWN THREATS IN TIME FOR SURVIVAL
- SMART BLACK BOX THAT AUTOMATICALLY INTERROGATES ALL UNUSUAL AIRBORNE SUBSTANCES, SEARCHING FOR TOXICITY, AND ITSELF, STRIVING FOR INSTRUMENTAL PERFECTION
- ADAPTABLE, RUGGED FIELD TOOL THAT MAY BE CARRIED BY ONE MAN, AND USED WITH MINIMAL TECHNICAL TRAINING

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ADDITIONAL CBMS CONCEPT MODEL SPECIFICATIONS

- 40 POUNDS OR LESS IN WEIGHT
- 4 CUBIC FEET OR LESS IN VOLUME
- 600 WATTS OR LESS IN POWER CONSUMPTION
- OPERATION UNDER SEVERE CLIMATIC CONDITIONS
- NBC CONTAMINATION SURVIVABILITY
- STRESS RESISTANT
- MODULAR

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WHERE ARE WE?

- PHASE ONE CULMINATED WITH DELIVERY OF DEMONSTRATION MODEL IN JULY 1988
- PHASE TWO WILL INVOLVE CONSTRUCTION OF BREADBOARD AND CONCEPT MODELS (26 - 30 MONTHS)
- DEMONSTRATION MODEL MAY BE THE MOST SENSITIVE MASS SPECTROMETER EVER BUILT; IT IS ALSO ONE OF THE FASTEST AND SMALLEST MASS SPECTROMETERS IN EXISTENCE

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DELIVERED DEMONSTRATION MODEL

- 8 CUBIC FEET + PC/AT + 2 DISPLAY SCREENS
- ABOUT 100 POUNDS WITHIN CUBIC FRAME
- UNDER 600 WATT POWER CONSUMPTION
- DUAL PUMPING SYSTEM
- 15 LITERS/SECOND THROUGH AEROSOL CONCENTRATOR
- MOVING METAL RIBBON PYROLYZER
- 50 SCANS/SECOND OVER FULL MASS RANGE
- LESS THAN 10 PPB SIMULANT DETECTED

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QUISTOR CHARACTERISTICS

- 42 MICROSECONDS PER AMU SCAN RATE
- 50 SCANS OF M/Z 20 520 EVERY SECOND
- BUFFER GAS NOT NECESSARY,
  MOIST AIR NOT A PROBLEM!
- IONS WITH ANY PARTICULAR M/Z VALUE MAY BE ISOLATED, AND THEN EXCITED TO YIELD DAUGHTER IONS BY COLLISION INDUCED DECOMPOSITION

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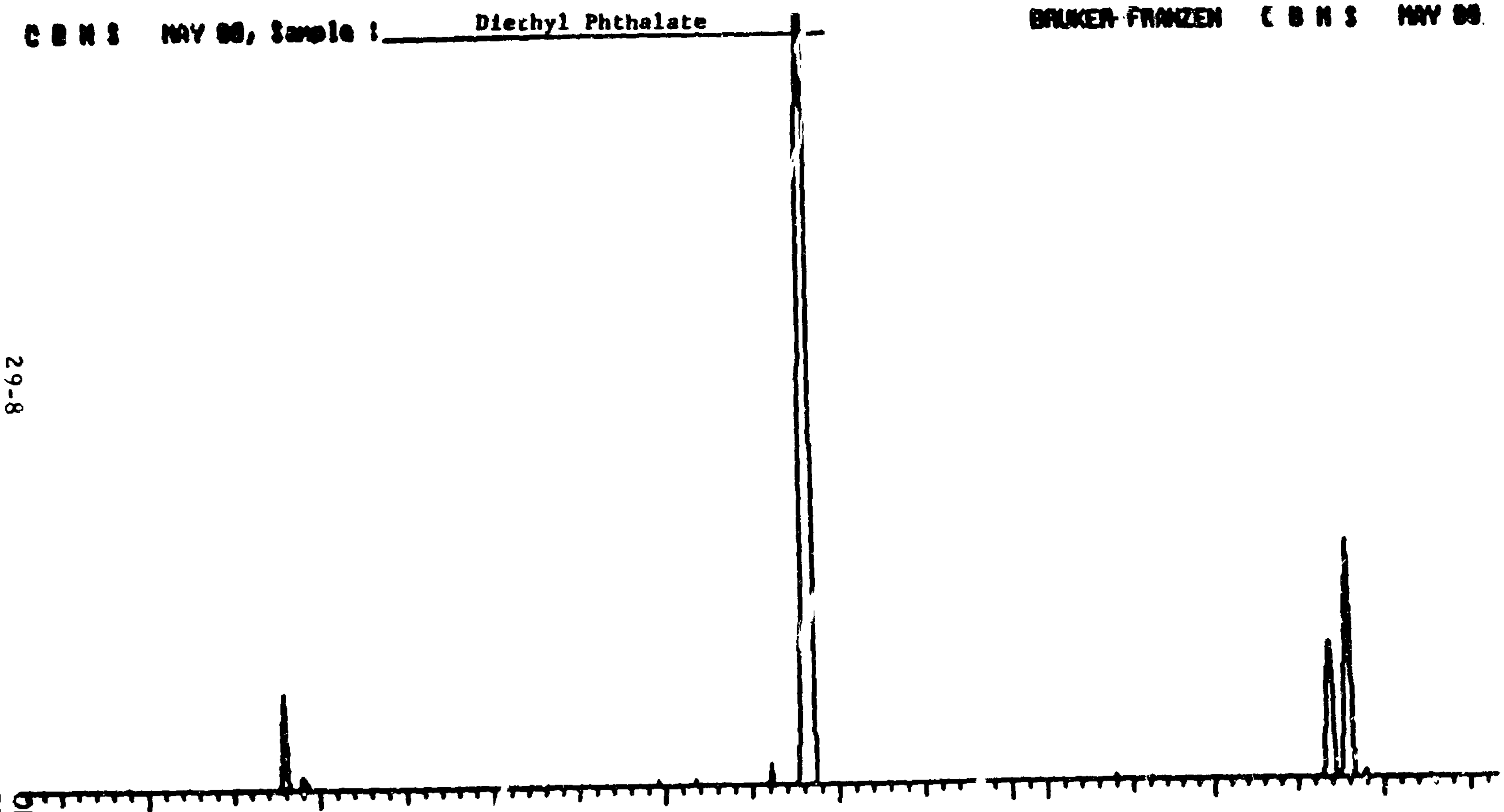

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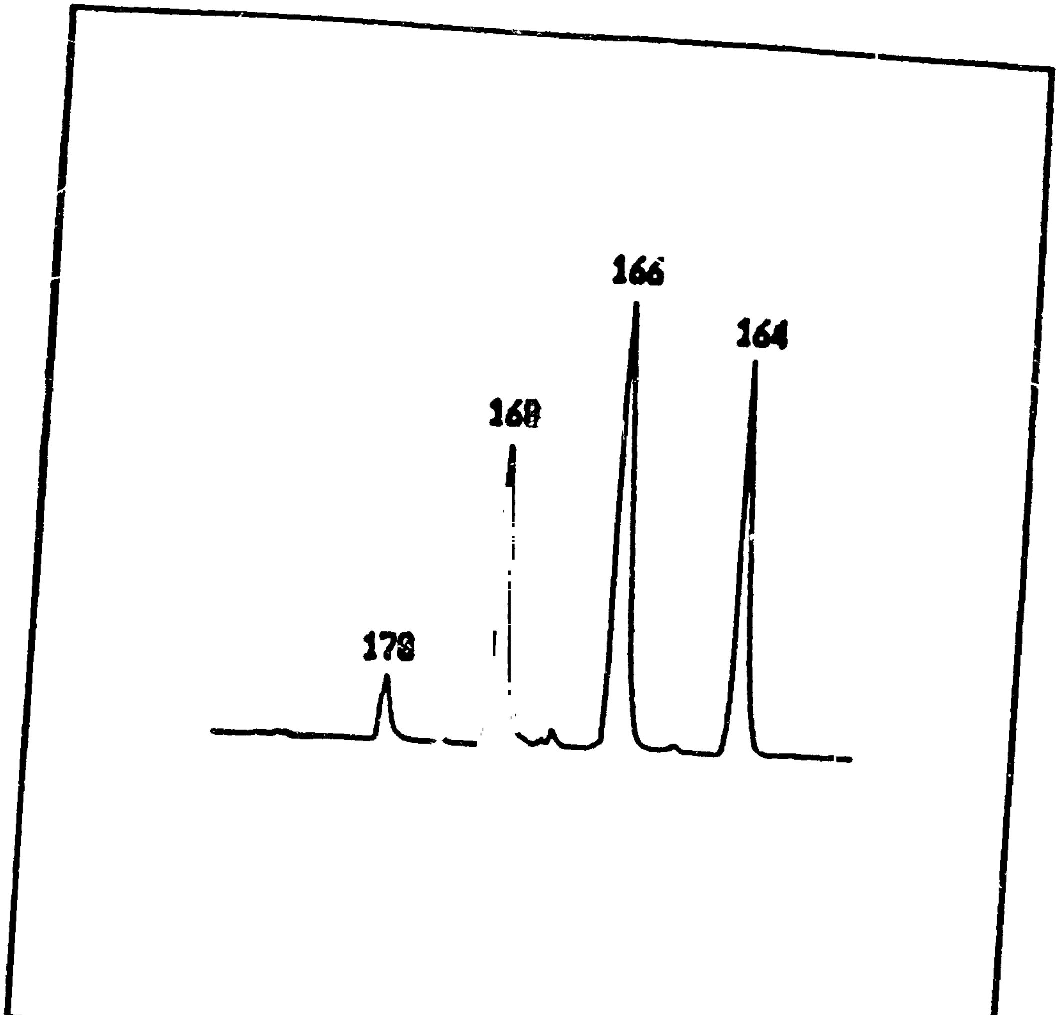

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Bruker Franzen Analytik GmbH Bremen, FRG	measured by: R.-H.Bebling (Quistor MS)
Sample: C_2Cl_4	Spectrum No.:
Project: CD Mini Mass Spectrometer	Date: JUN 198[illegible]

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BIOLOGICAL DETECTION

- REQUIRES OBSERVATION OF 60 VIRUSES PER LITER OF AIR
  - => ENRICHMENT OF 10^9
  - => MASS FLUX OF 1 FEMTOGRAM/SECOND
- AEROSOL CONCENTRATOR IS 3-STAGE VIRTUAL IMPACTOR
  - => CONCENTRATION OF 1 - 15 μM PARTICLES BY 30,000-FOLD
- PYROLYSIS CHAMBER COLLECTS MATERIAL FOR 10 SECONDS BEFORE PYROLYSIS AT 450°C
- MEMBRANE ENRICHES MOLECULES > M/Z 150 BY 1000-FOLD

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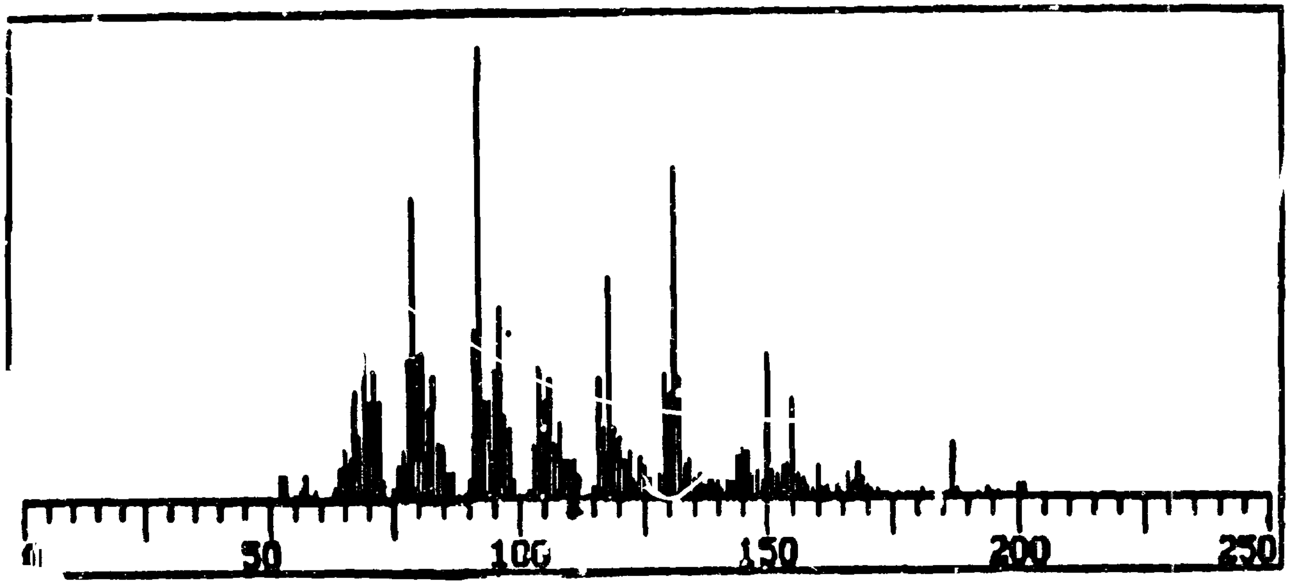
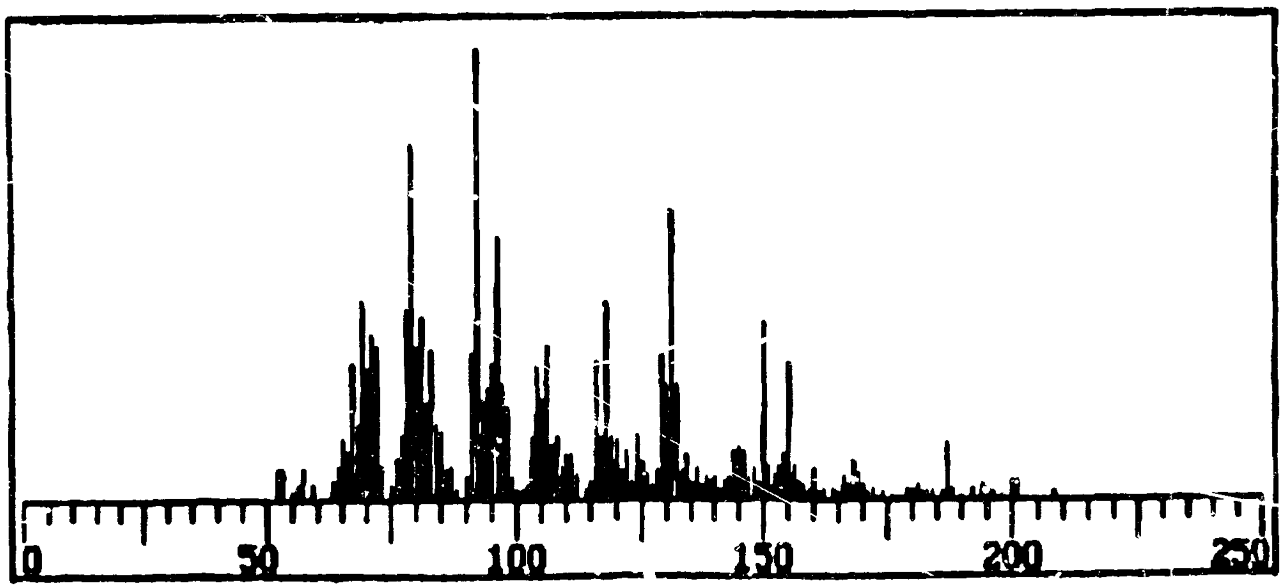


Pseudomonas fluorescens

Bruker-Franzen Analytik GmbH, Bremen - Software Dept.



Pseudomonas fluorescens

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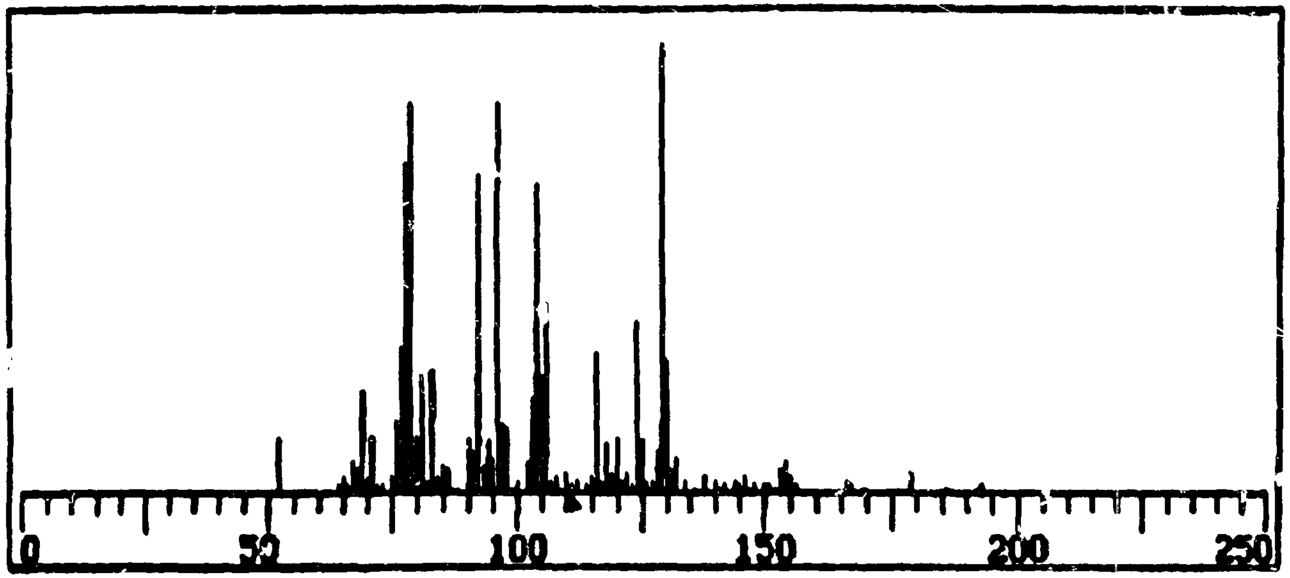
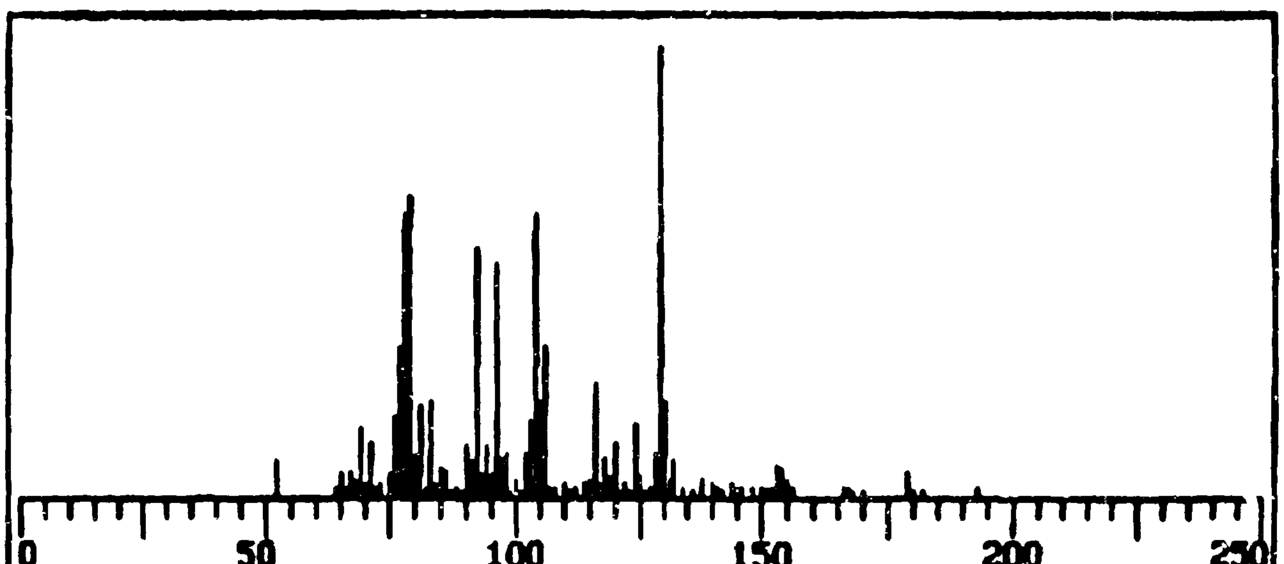


Serratia marcescens

Bruker-Franzen Analytik GmbH, Bremen - Software Dept.



Serratia marcescens

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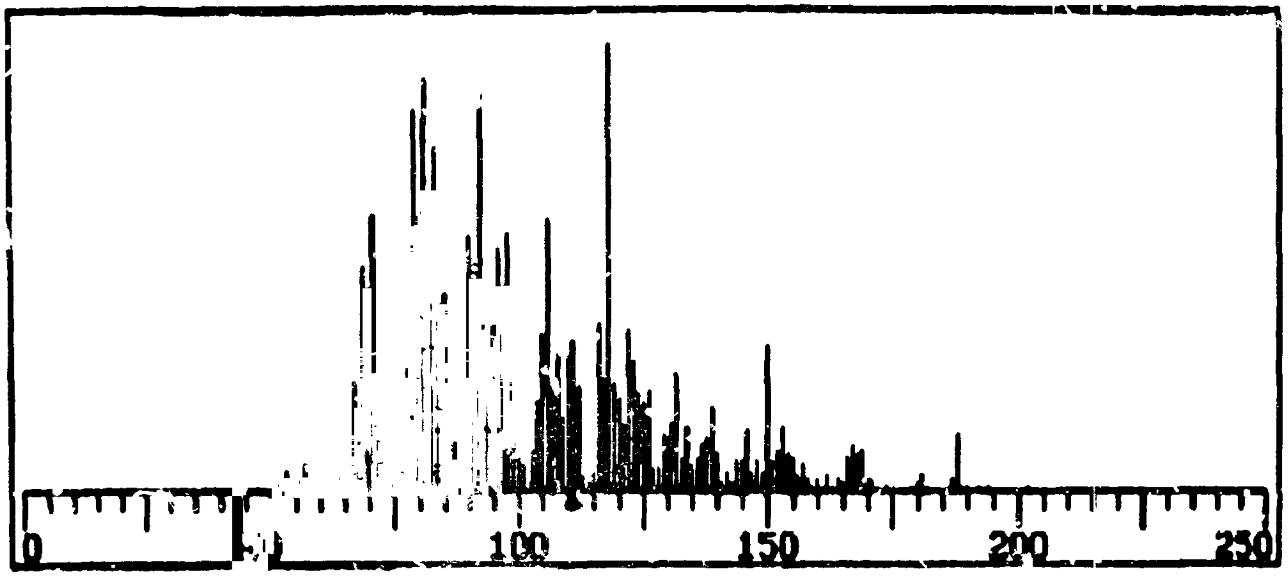
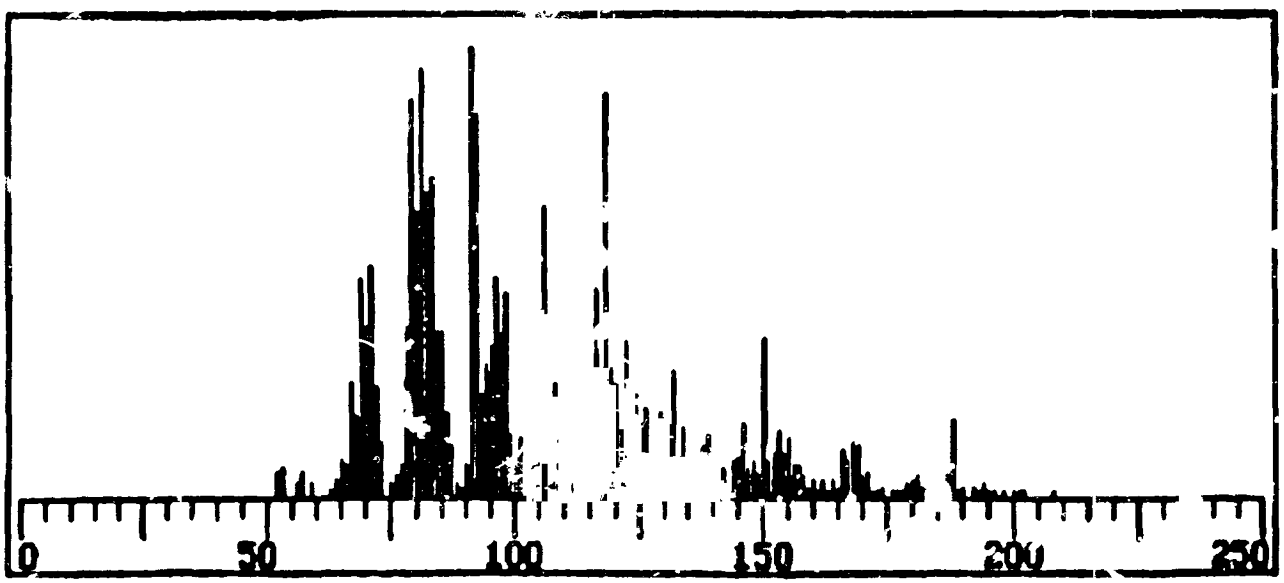


B. globigii spores

Bruker-Franzen Analytik GmbH, Bremen - Software Dept.



B. globigii spores

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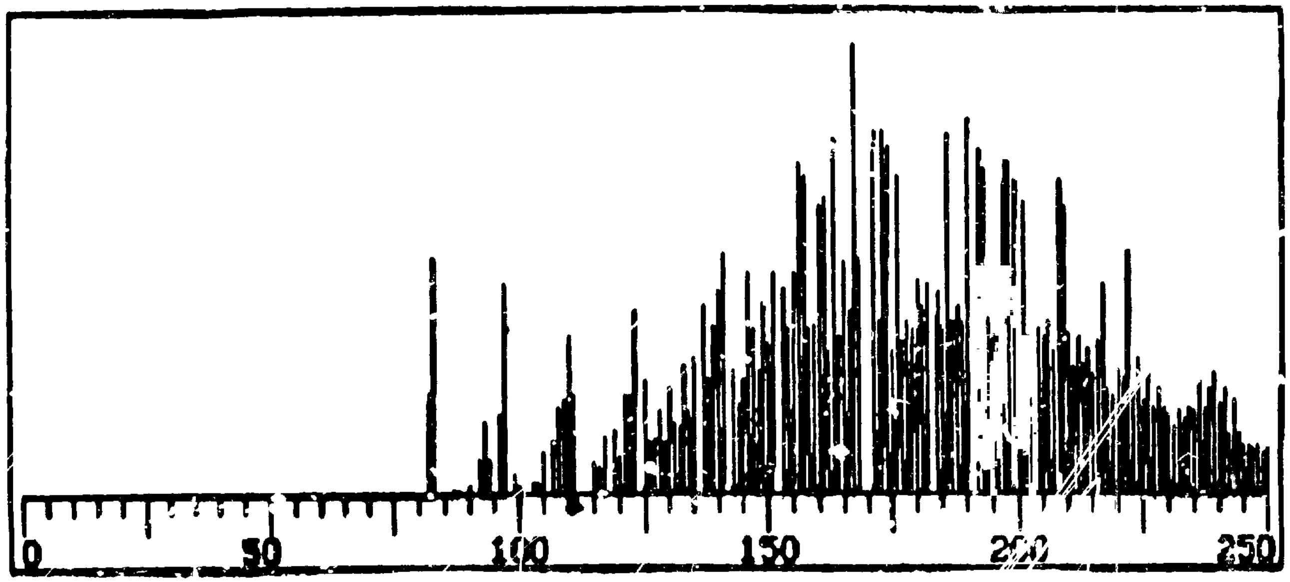
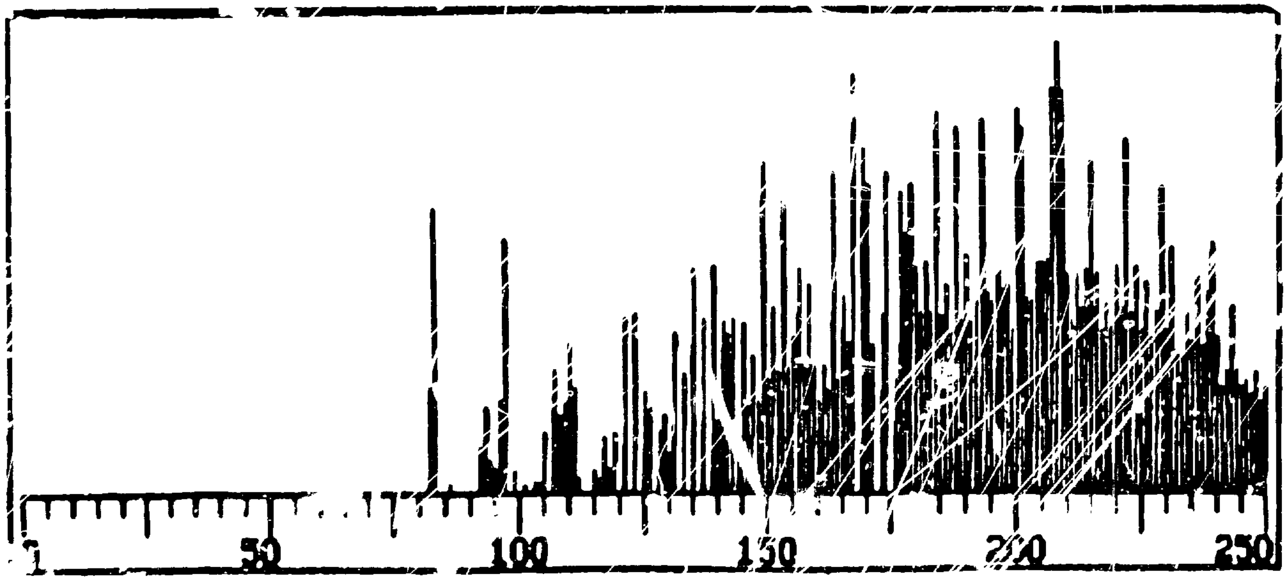


Lycophodium spores

Bruker-Franzen Analytik GmbH, Bremen - Software Dept.



Lycophodium spores

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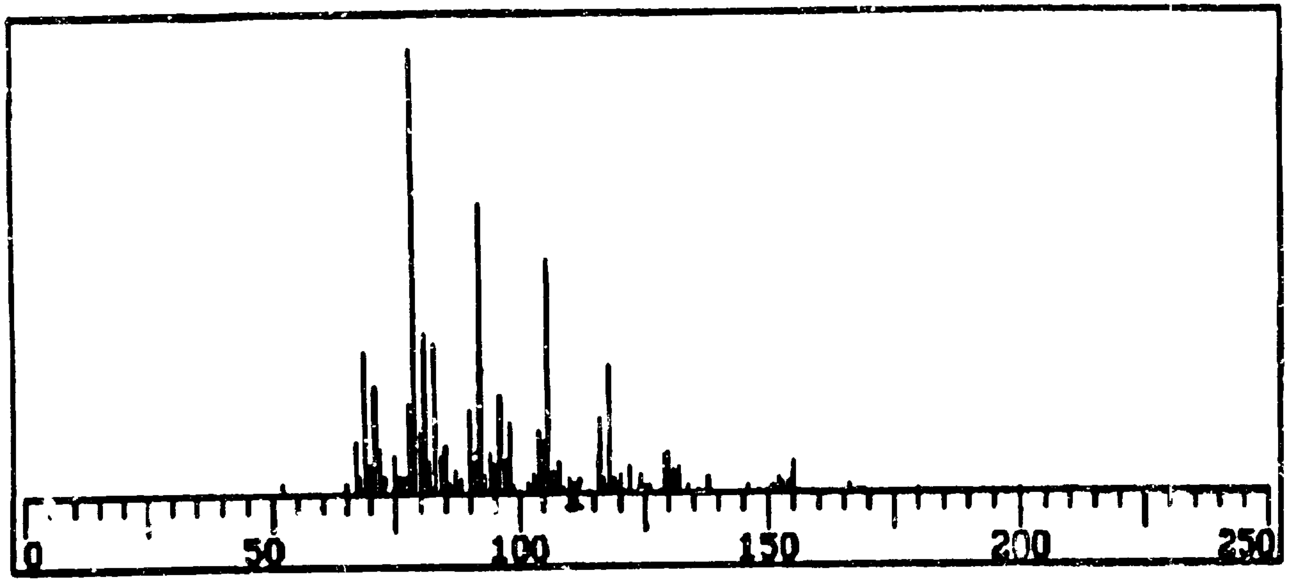
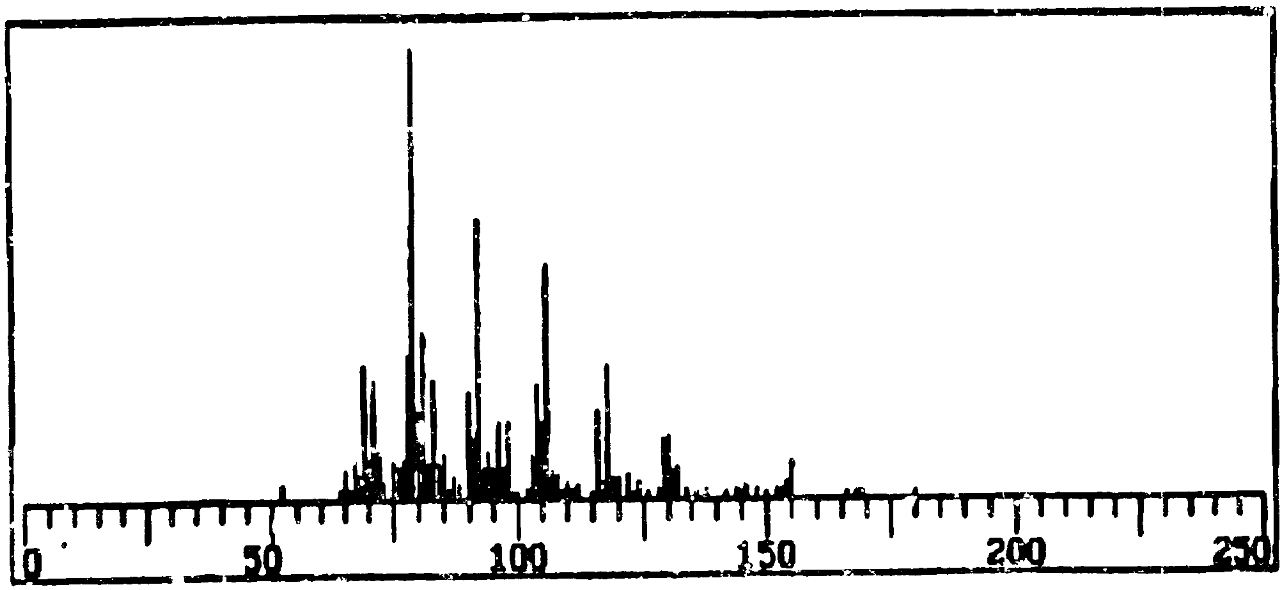


Bovine serum albumin

Bruker-Franzen Analytik GmbH, Bremen - Software Dept.



Bovine serum albumin

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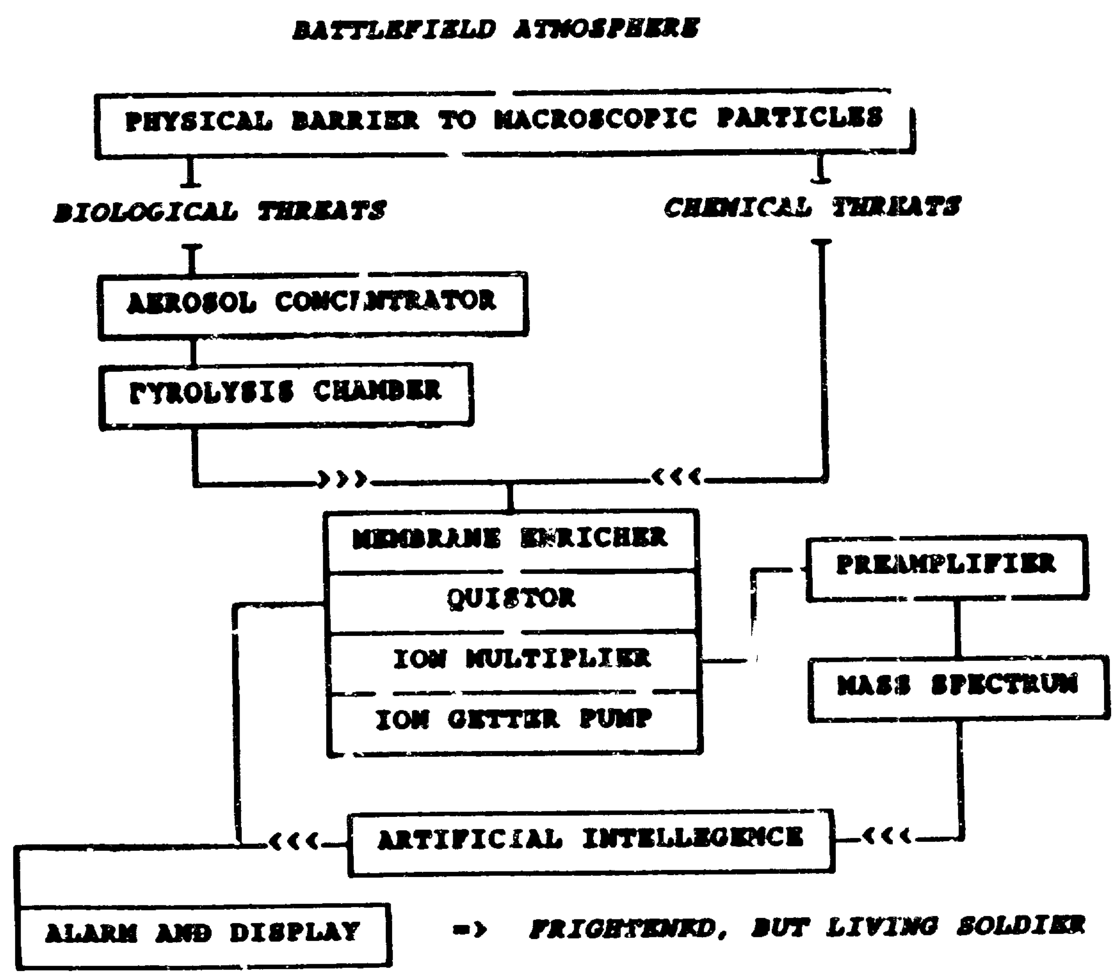

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GOAL COMPARISON

ARMY		NASA
	SMALL	
	MODULAR	
	LOW POWER	
	HIGH SENSITIVITY	
	AEROSOLS ARE IMPORTANT	
ARTIFICIAL INTELLIGENCE		HIGHLY SKILLED PROFESSIONAL

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APPLICATION OF FIBER OPTICS TECHNOLOGY FOR CHEMICAL CONTAMINANT DETECTION

by

Dr. James E. Smith, Jr.
Associate Professor and Director
Chemical Engineering Program

and

Kathleen M. Leonard
Graduate Assistant
Civil Engineering Program

The University of Alabama in Huntsville
Huntsville, Alabama 35899

SPECTROSCOPY OVER FIBER OPTICS MAY EMPLOY SEVERAL APPROACHES

THE FOLLOWING ARE A FEW EXAMPLES

DIRECT SPECTROSCOPY
- FLUORESCENCE
- TRANSMISSION
- RAMAN SCATTERING

INDIRECT SPECTROSCOPY
- IMMOBILIZED INTERMEDIATES
- CHEMICAL REACTIONS

SURFACE TECHNIQUES
- SURFACE IMMOBILIZED INTERMEDIATES
- SURFACE ENHANCED RAMAN (SERS)

The University Of Alabama In Huntsville

SCATTERED RADIATIONS CLASSIFICATION

$E_1 = E_2$; $(\nu_1 = \nu_2)$ RAYLEIGH SCATTERING

$$\left.\begin{array}{l} E_1 > E_2 \;;\; (\nu_1 < \nu_2) \\ \\ E_1 < E_2 \;;\; (\nu_1 > \nu_2) \end{array}\right\} \text{RAMAN SCATTERING}$$

IF $(\nu_1 < \nu_2)$ STOKES LINES.

IF $(\nu_1 > \nu_2)$ ANTI-STOKES LINES.

IN GENERAL INTENSITY FOLLOWS:

RAYLEIGH >> STOKES >> ANTI-STOKES

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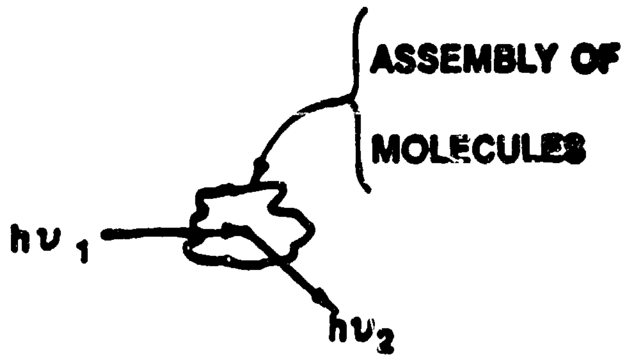
RAMAN SCATTERING

THIS SPECTROSCOPIC TECHNIQUE MAY BE EXPLAINED USING ASPECTS OF THE QUANTUM THEORY OF LIGHT SCATTERING.



a). IF THE COLLISION IS ELASTIC, THEN THE SCATTERED RADIATION HAS THE SAME ENERGY AS THE INCIDENT PHOTONS.

b). IF THE COLLISION IS INELASTIC, THEN THE DEFLECTED PHOTONS WILL HAVE EITHER HIGHER OR LOWER ENERGY THAN THE INCIDENT PHOTONS.

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Of Alabama
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FIBER OPTIC CHEMICAL SENSORS: HISTORICAL OVERVIEW

GENERALLY, FIBER OPTIC CHEMICAL SENSOR DEVELOPMENTS TO DATE HAVE CENTERED ON SINGLE COMPONENT IDENTIFICATION AND MINIATURIZATION OF THE PROBES THEMSELVES. SENSING PROBES AVERAGE ABOUT 2MM IN DIAMETER. HOWEVER, PROBE DIAMETER IS NOT A DRIVING FACTOR IN WATER SYSTEMS. A FEW OF THE SPECIFIC CLASSES OF PROBES WILL NOW BE CONSIDERED[1].

* DIRECT SPECTROSCOPIC MEASUREMENTS.
  - BALL OPTRODE.
  - CAPILLARY OPTRODE.
  - HIGH GRAIN OPTRODE.
* CHEMICALLY SPECIFIC MEASUREMENTS.
  - ABSORBANCE BASED pH OPTRODE.
  - HUMIDITY (COBALT CHLORIDE IN GELATIN).
  - AMMONIA (OXAZINE PERCHLORATE DYE).
  - HYDROGEN (PALLADIUM BASED INTERFEROMETER).

* FLUORESCENCE BASED OPTRODES.
    - NATURAL FLUORESCENCE.
        - ABOUT 10% OF ALL MOLECULES FLUORESCE.
        - EXCITATION SPECTRUM.
        - EMISSION SPECTRUM.
    - ORGANOCHLORIDE.
    - URANYL ION SENSING.
* ENERGY TRANSFER OPTRODES.
    - MULTI INDICATING CHEMICAL APPROACH.
        - ABSORPTION-EMISSION OPTRODE.
* EVANESCENT SENSORS.
    - ANTIGEN-ANTIBODY COMPETITIVE BONDING REACTIONS.
    - ANTIBODIES IMMOBILIZED ON THE UNCLADED OPTIC FIBER SURFACE.

1. Angel, S.M.,"Optrodes:Chemically Selective Fiber-Optic Sensors," Spectroscopy, Vol 2, No.4, (1987).

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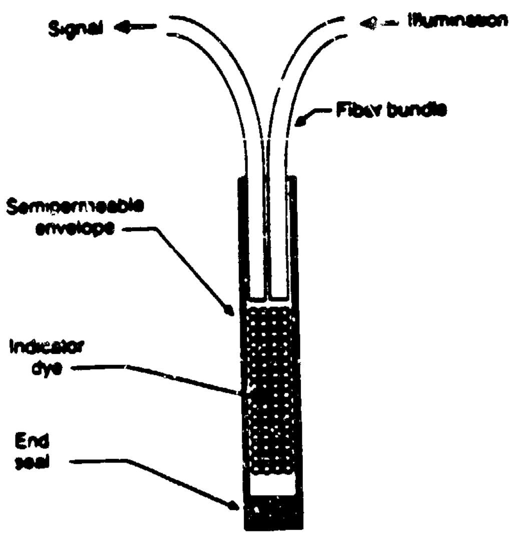

Absorbance-based pH sensor.

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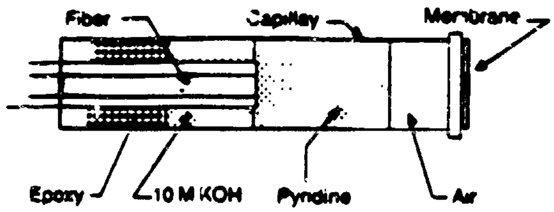

Configuration of the organochloride optrode.

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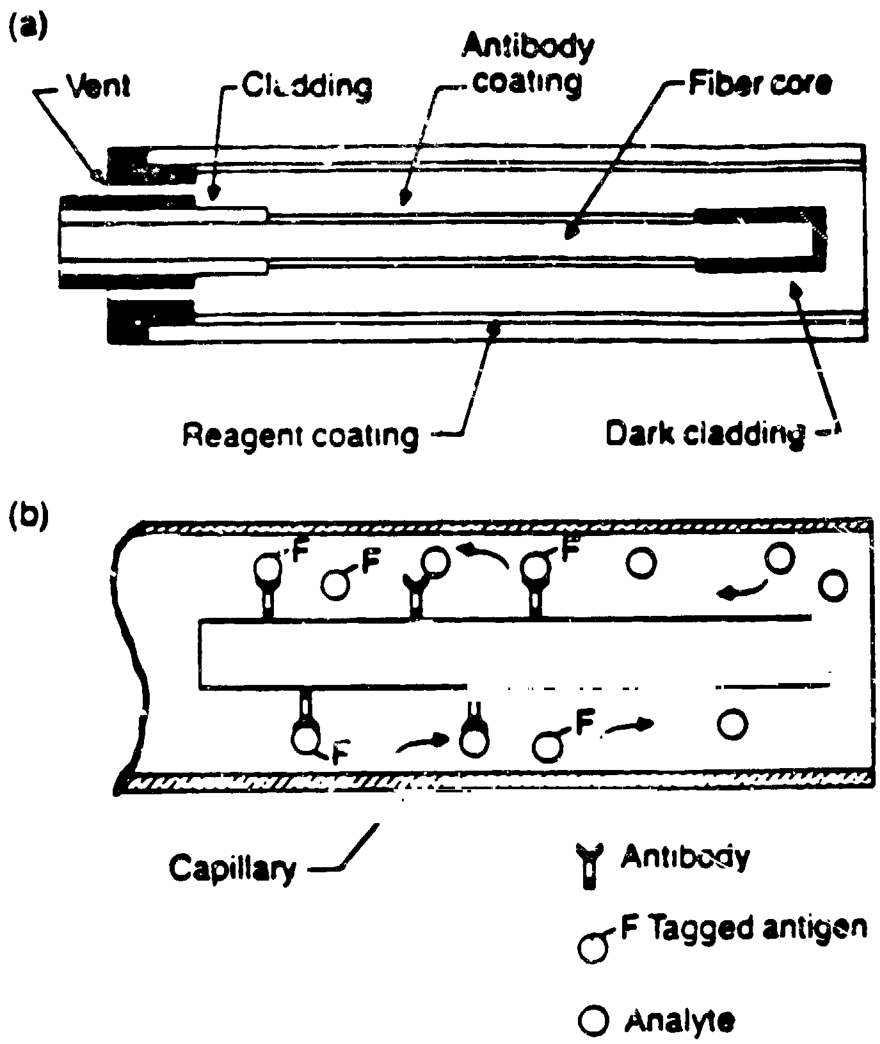

(a) Configuration of the fiber fluoroimmunoassay sensor. (b) Illustration of free antigen displacement tagged antigen, which causes a decrease in fiber fluorescence.

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REMOTE FIBER OPTIC SPECTROSCOPY

OVERVIEW OF SYSTEM COMPONENTS

- LIGHT SOURCE
- COUPLER
- FIBER OPTIC
- TRADITIONAL OPTICS
- SPECTROMETER
- FIBER OPTIC CHEMICAL SENSOR

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ATTENUATION PROBLEMS IN SILICA OPTICAL FIBERS

- Absorption from Impurities
- Power Leakage (Tunneling Effects)
- Loss at Connectors
- Microbending
- Pure Bending

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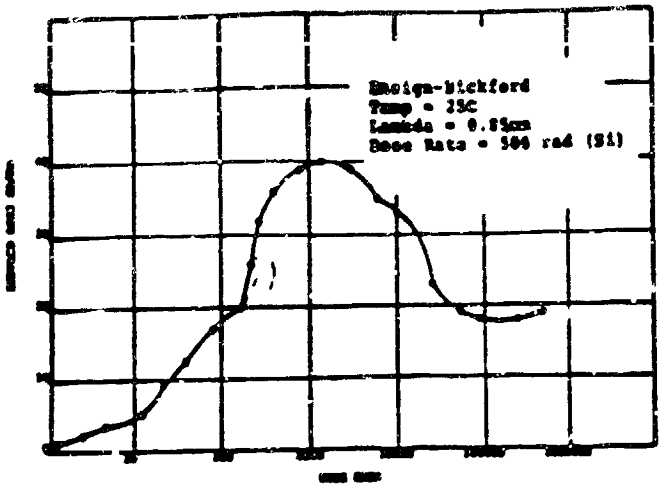
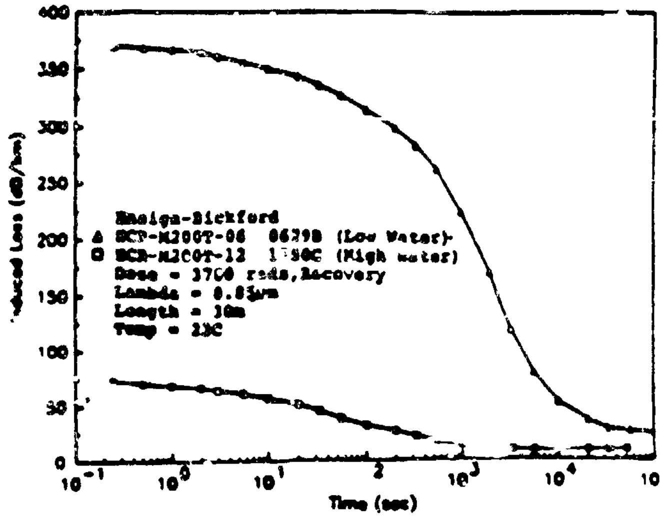
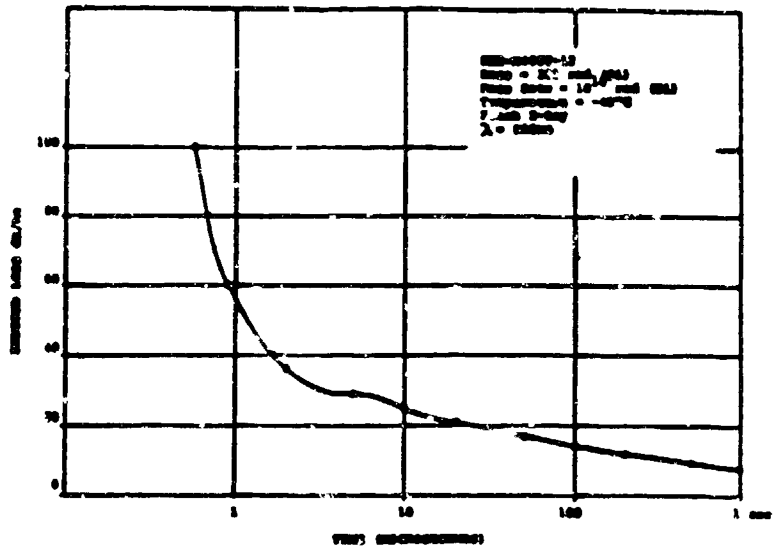


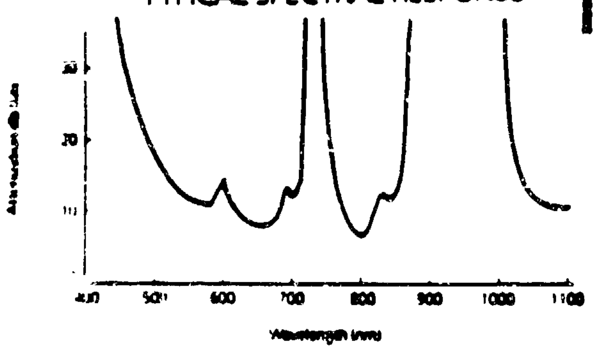


NRL Data (Gamma)



SPERRY Data (Flash X-Ray)

TYPICAL SPECTRAL RESPONSE



NUMERICAL APERTURE VS. LENGTH

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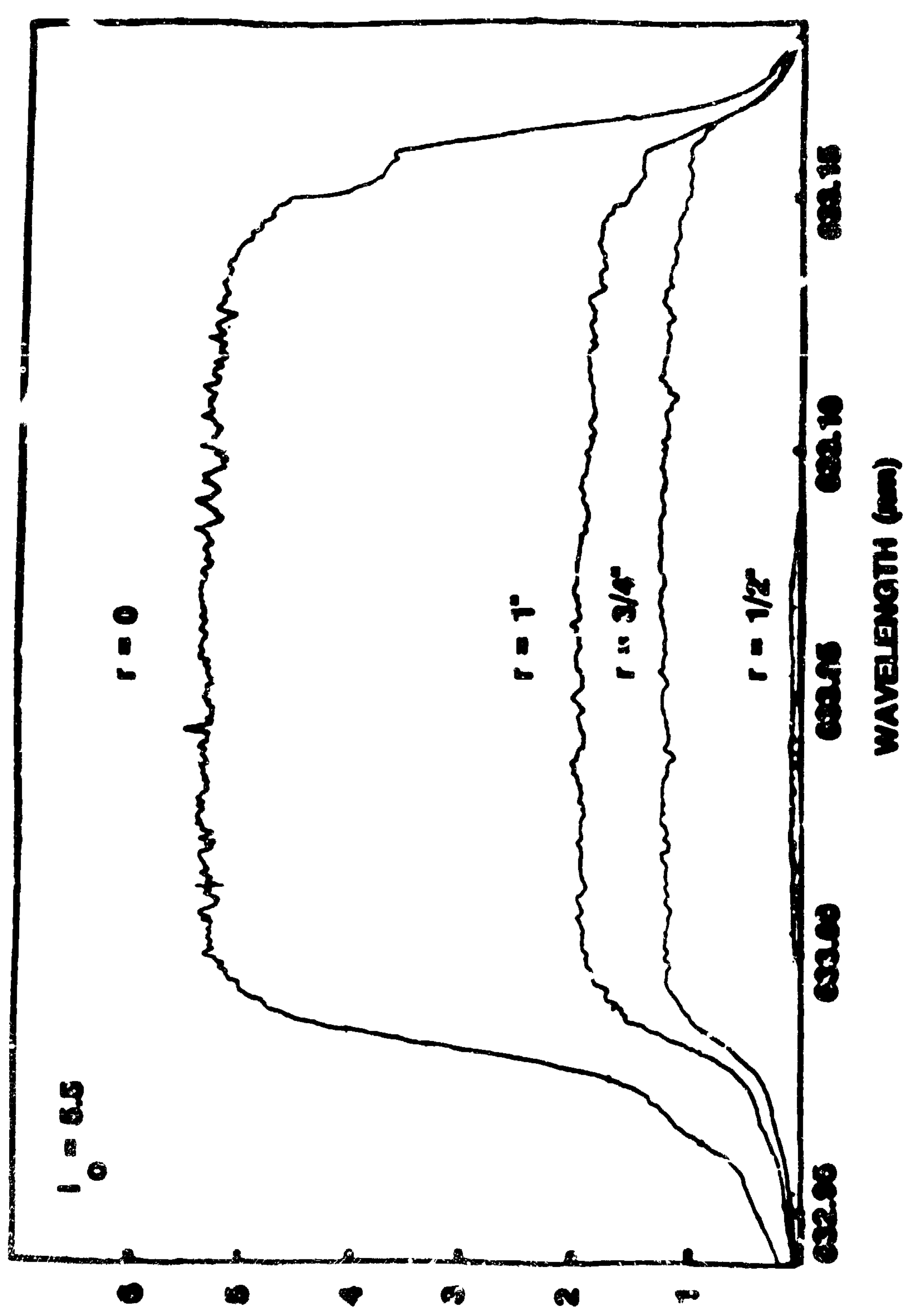

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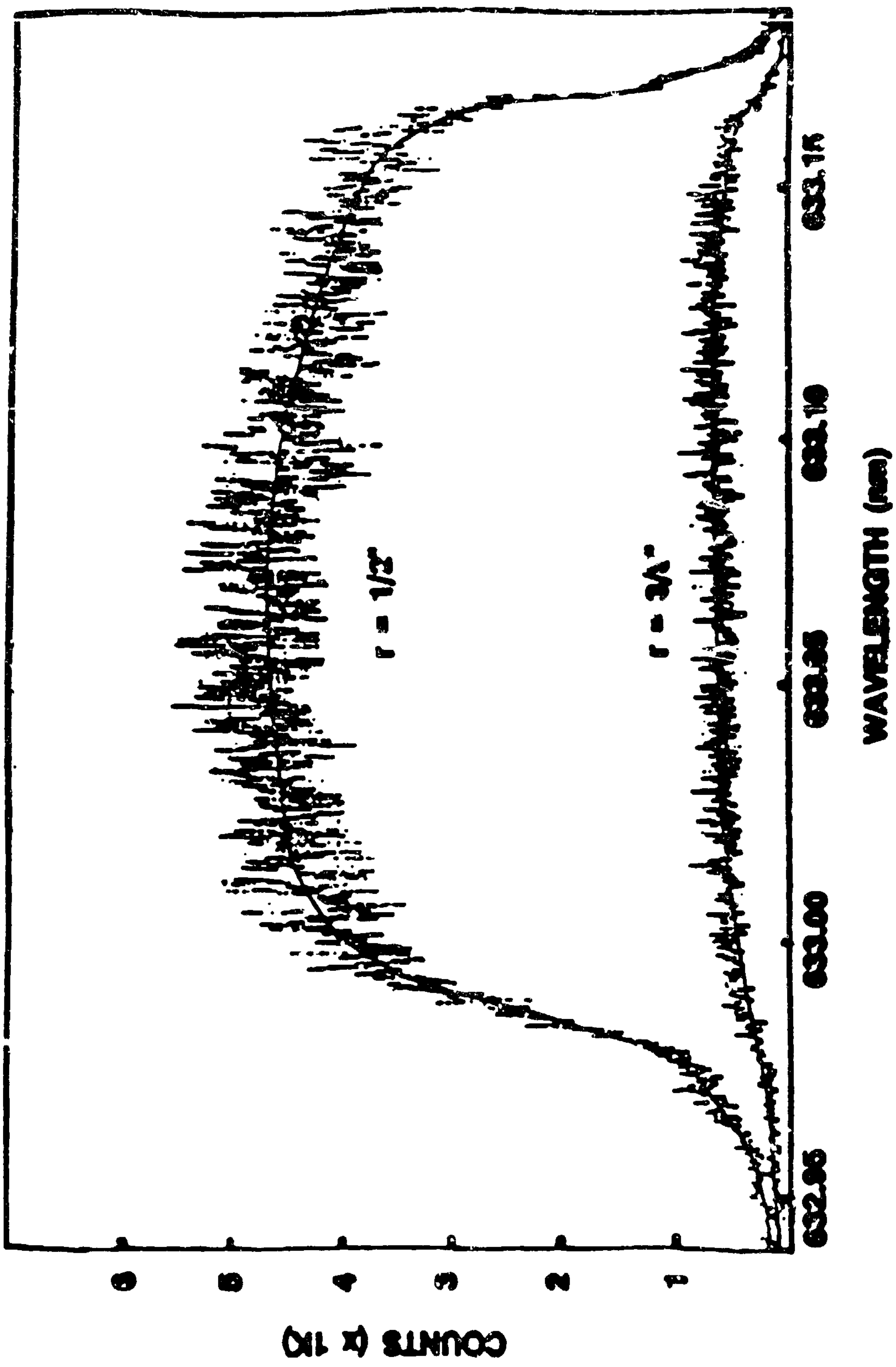

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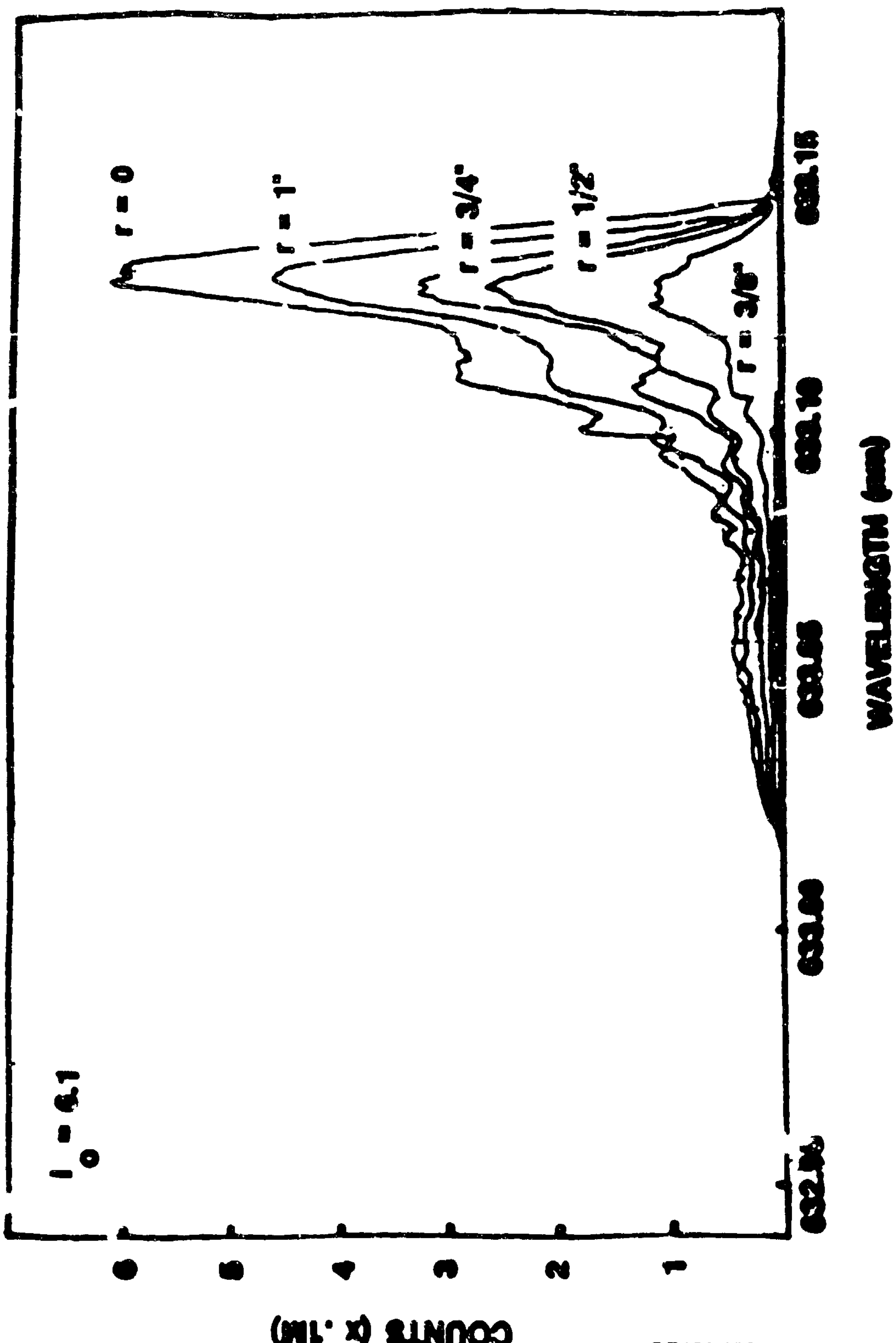

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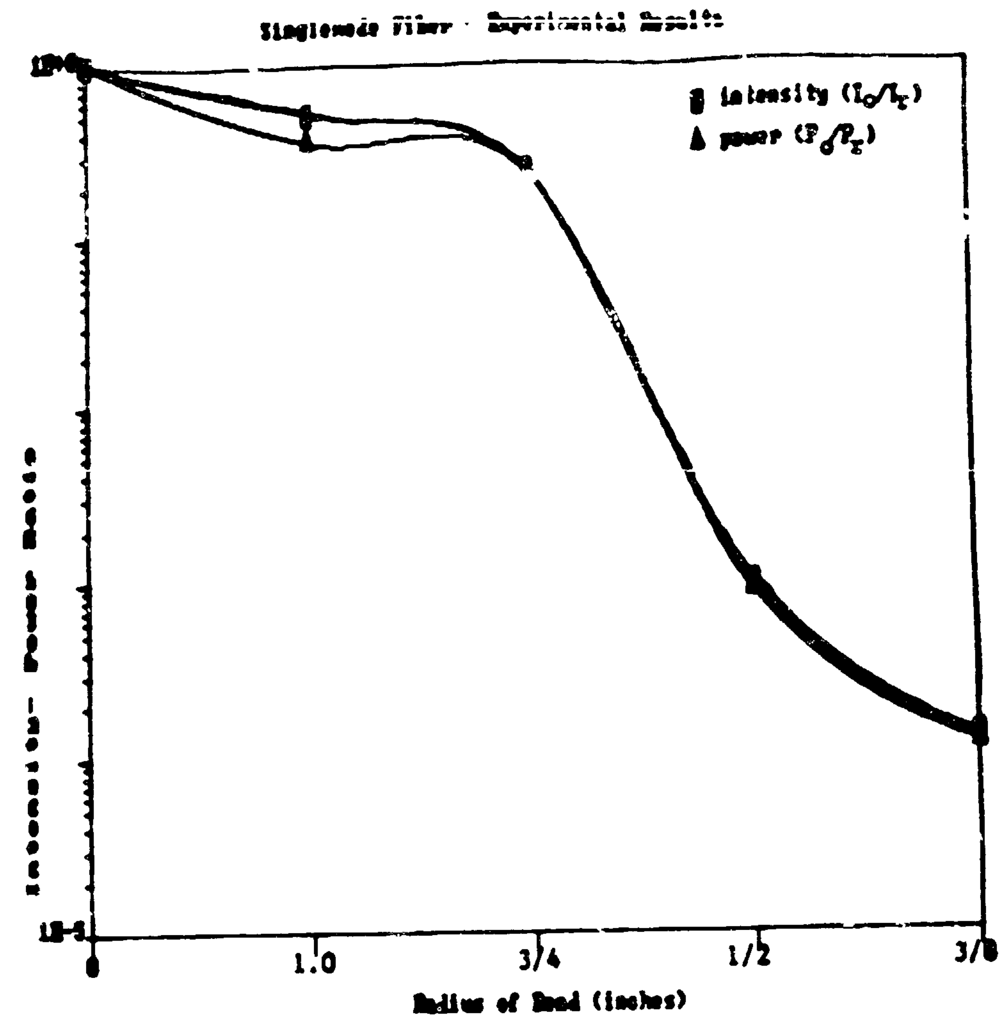

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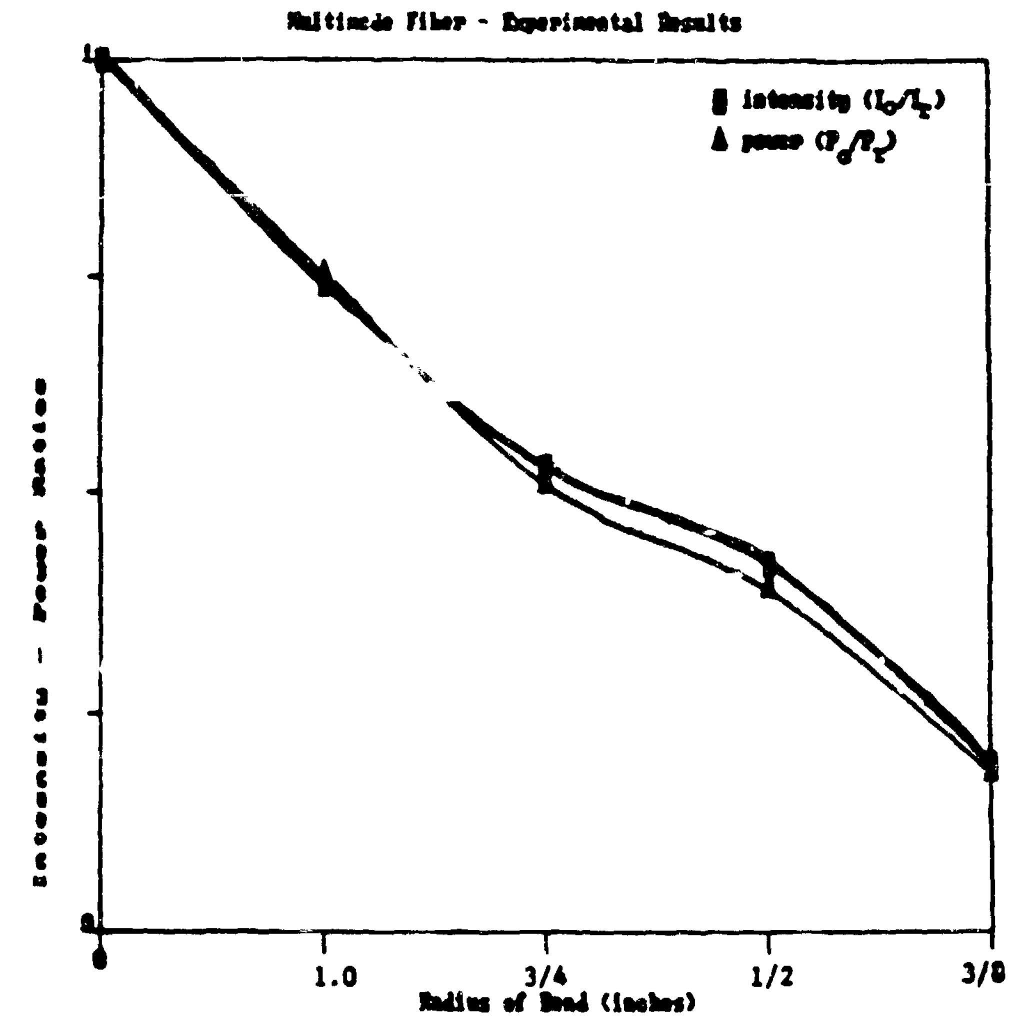

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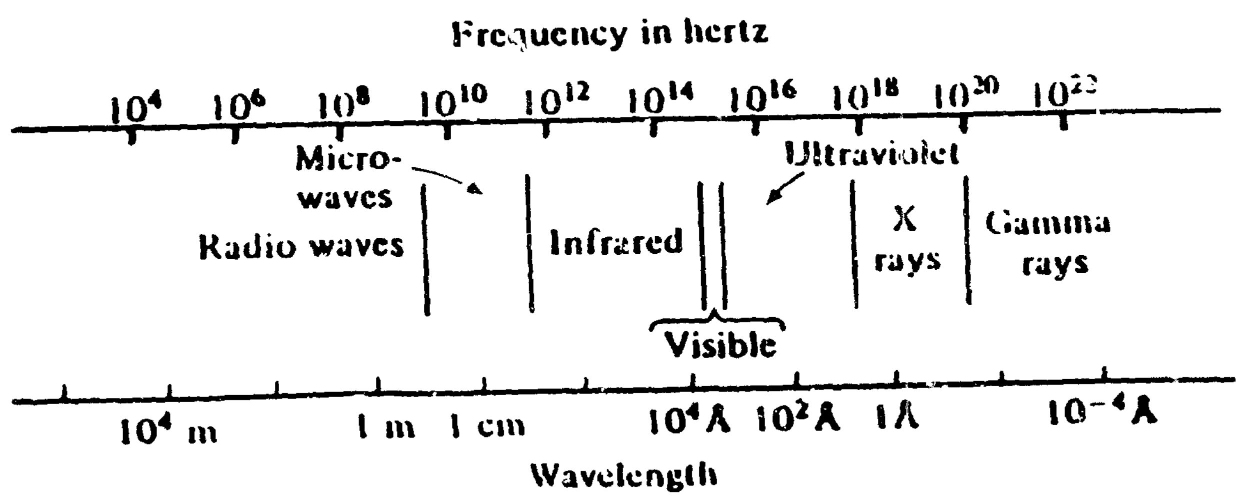

THE ELECTROMAGNETIC SPECTRUM WITH LOGARITHMIC SCALE.

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ADDITIONAL LIMITATION

FIBER OPTIC SPECTRAL BANDPASS

UV	VIS	NEAR IR	IR >
FAIR	GOOD	EXCELLENT	POOR

Infrared spectroscopy using fiber optic technology is limited by the current status of fiber optic development. Some IR fiber optics do exist by they are manufactured from materials that are hydroscopic and therefore not applicable to aqueous systems.

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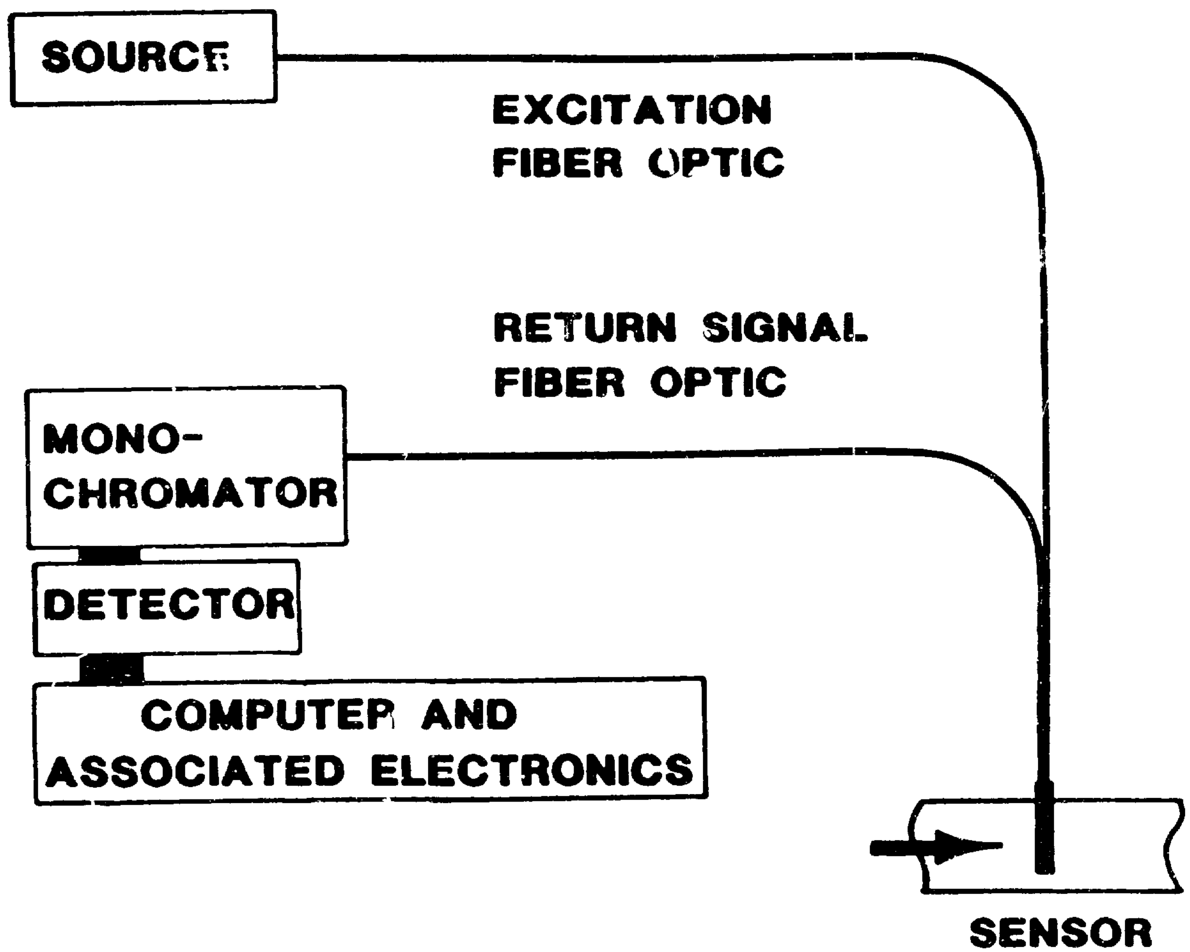
COMPONENTS OF A FIBER OPTIC CHEMICAL DETECTION SYSTEM



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CURRENT CAPABILITY

SOURCE

- 8 W ARGON-ION LASER
- 200 MW HELIUM-NEON LASER
- 200 W XENON ARC LAMP

MONOCHROMATORS

- ORIEL 1/4 METER
- SPEX'S 1877B TRIPLEMATE

SENSORS RECEIVING ATTENTION

- DIRECT FLUORESCENCE
- SURFACE ENHANCED RAMAN
- DIRECT ABSORBANCE
- SURFACE IMMOBILIZED INTERMEDIATES

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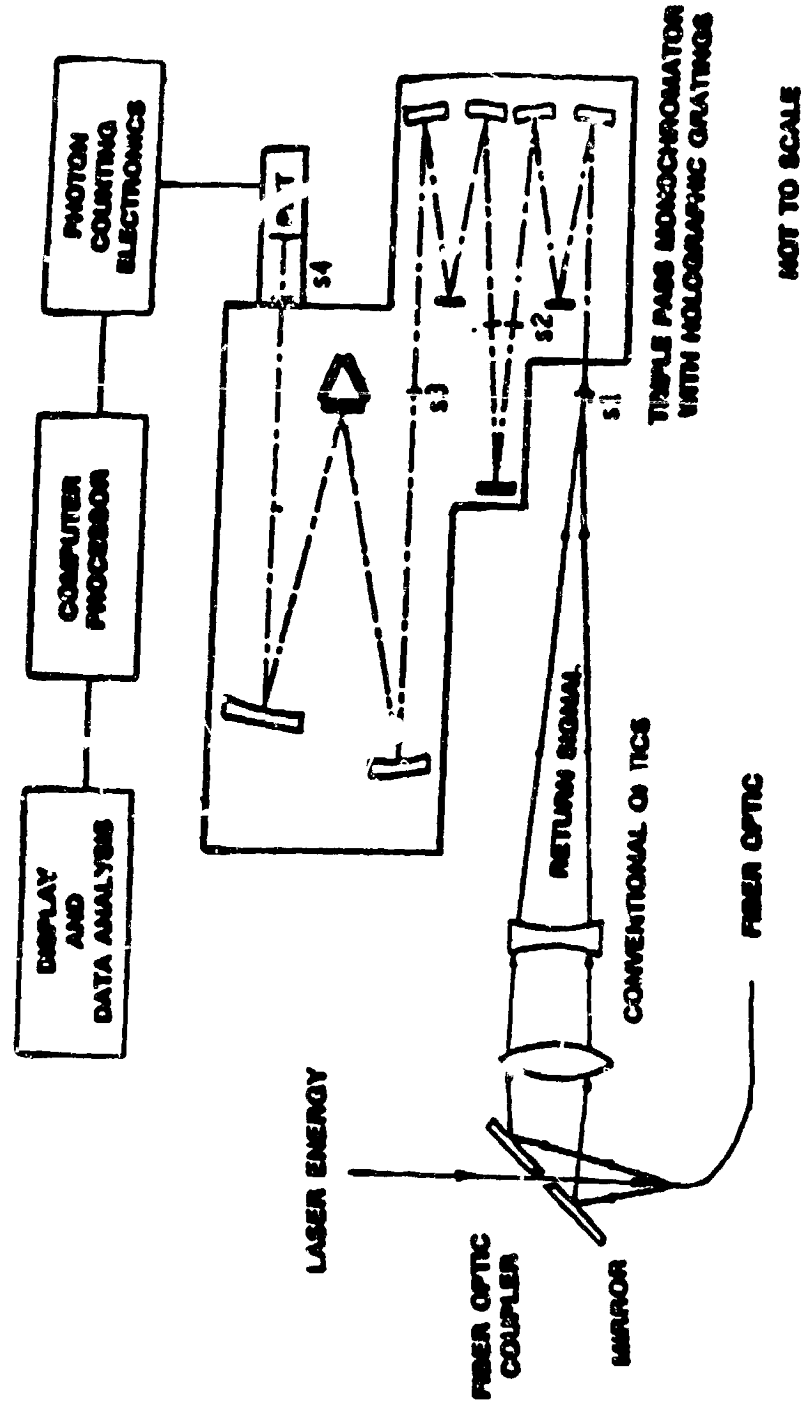

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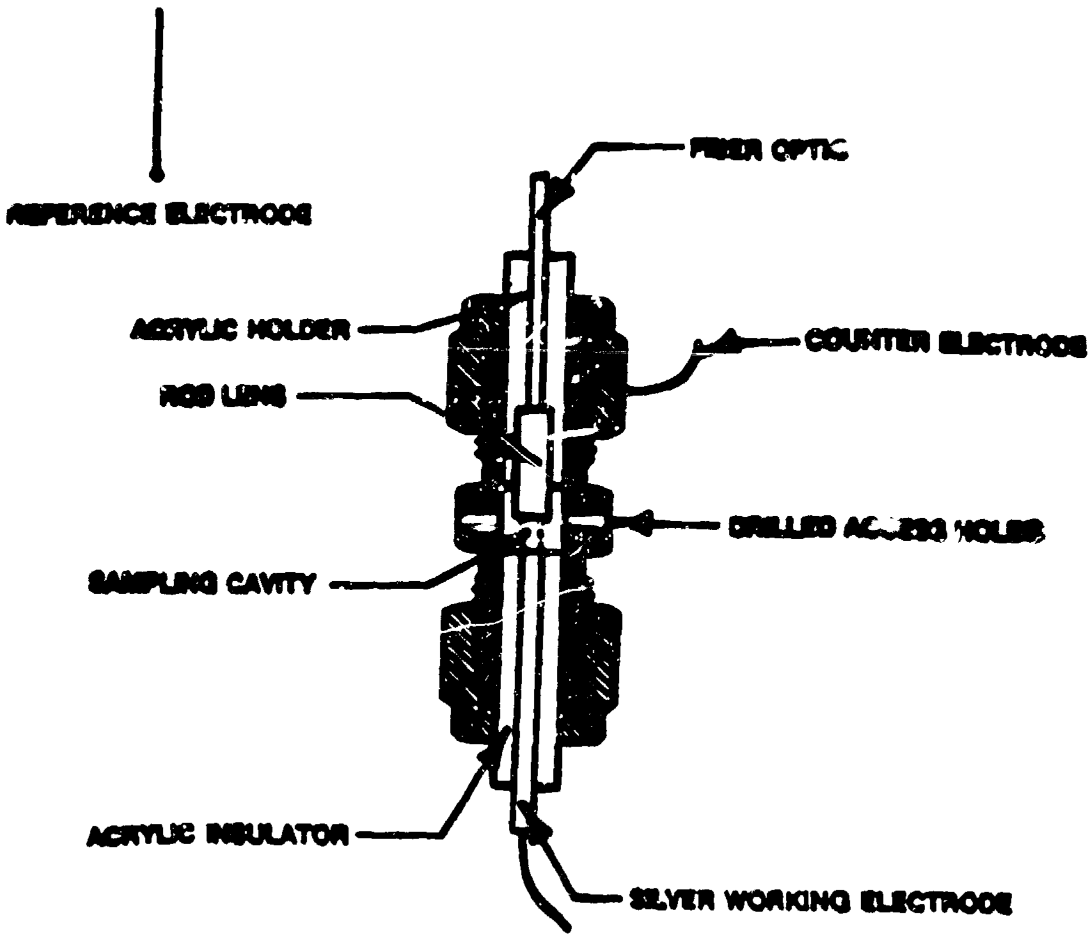

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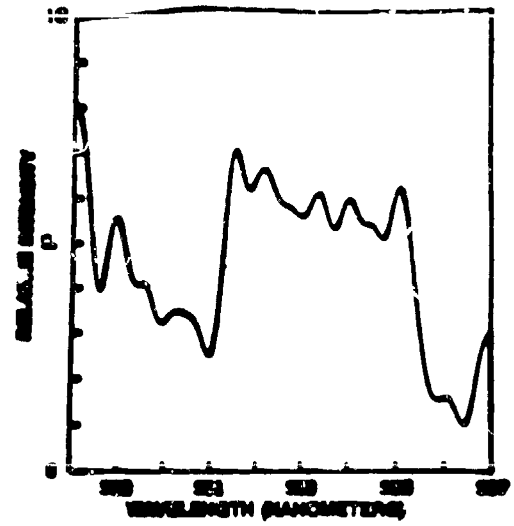

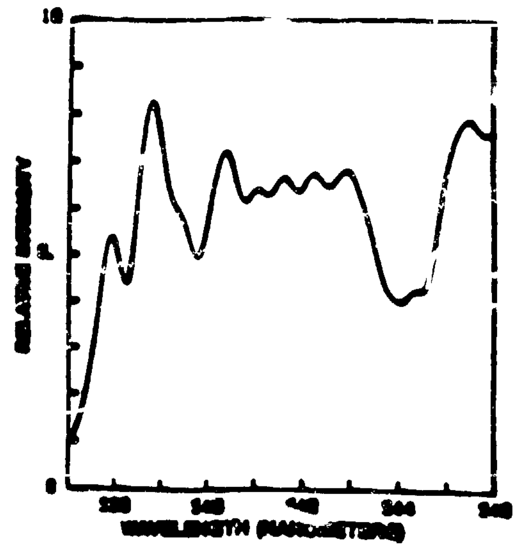

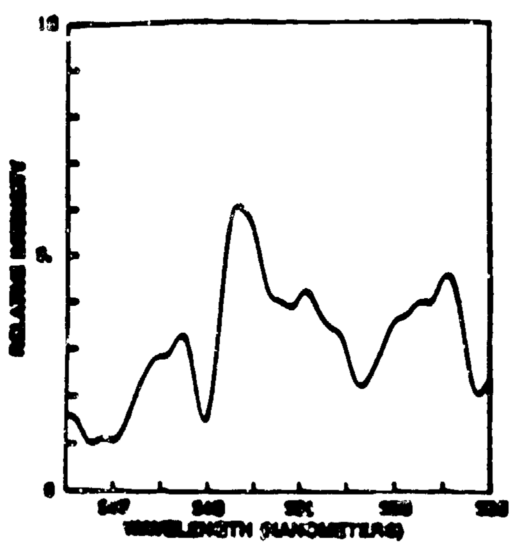

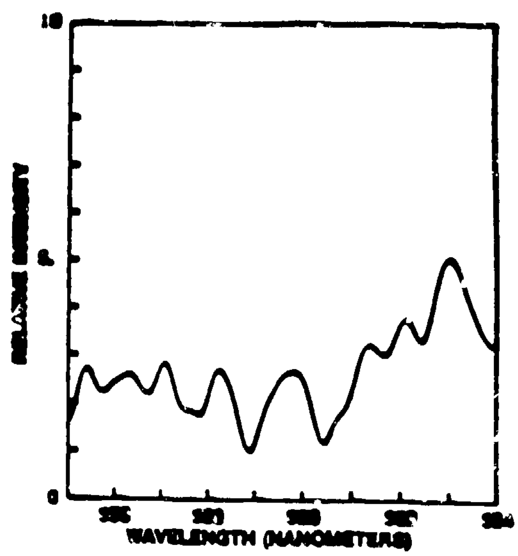

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COMPARISON OF PEAK POSITIONS FOR 10 PPM PYRIDINE IN WATER AT -0.6 VDC

•Peak Location Wavenumber	•Peak Location Wavelength	Fiber Optics Study Wavelength
622	531.5093	531.558
650	532.3015	532.186
752	535.2074	535.1[illegible]0
764	535.5513	536.06[illegible]
1004	542.3245	542.23[illegible]
1032	543.3499	542.94[illegible]
1064	544.2963	[illegible]5.430
1140	546.5573	547.980
1212	548.7186	548.40[illegible]
1370	553.5154	554.160
1477	556.8132	557.090
1584	559.52[illegible]	558.240
1593	560.433[illegible]	5[illegible]0.810
1620	561.2823	561.380

• Data from Carrabba, Edmonds, and Rauh, Anal. Chem., 59, 25[illegible]-25[illegible], ([illegible]987).

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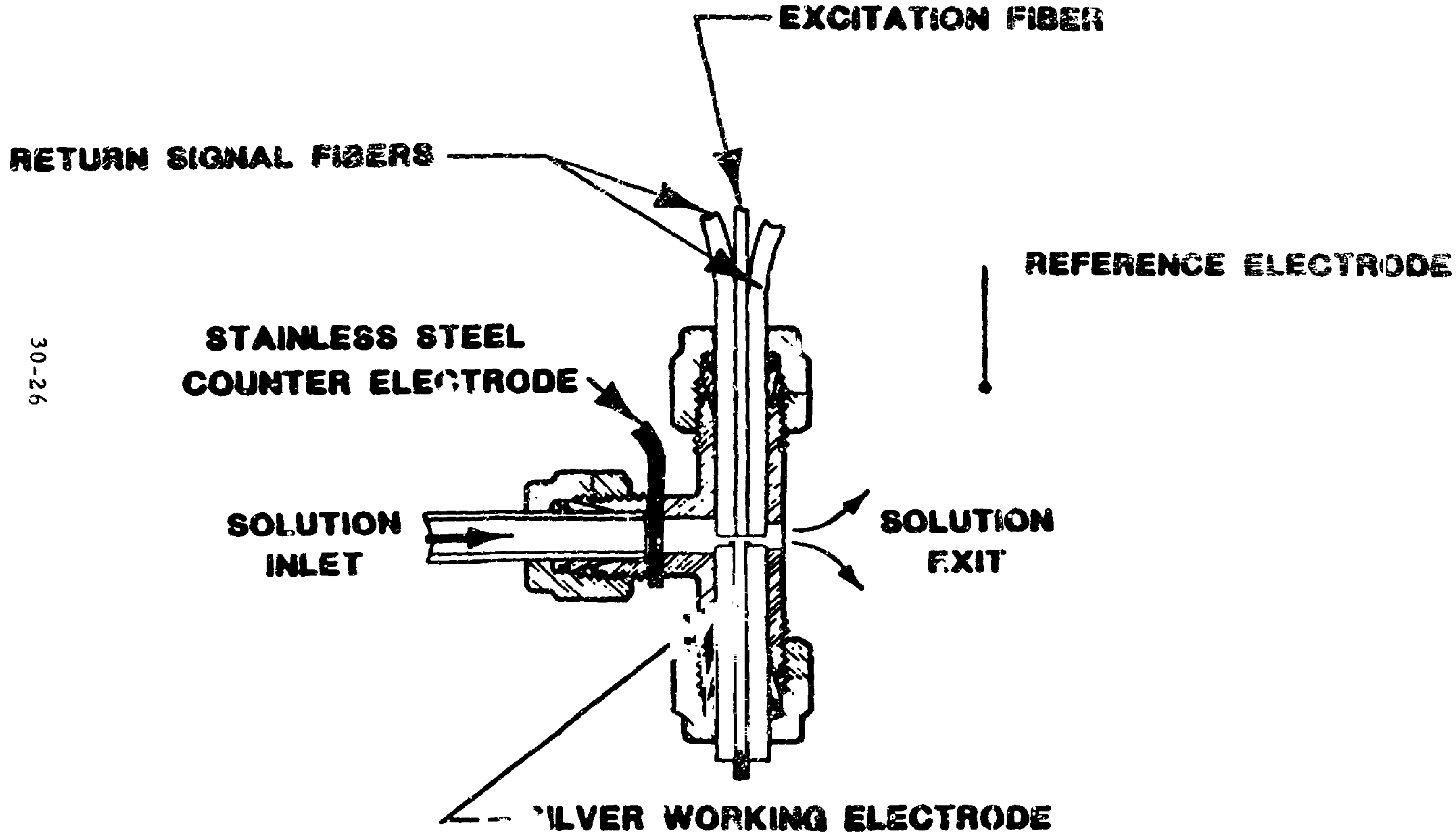
SERS PROTOTYPE



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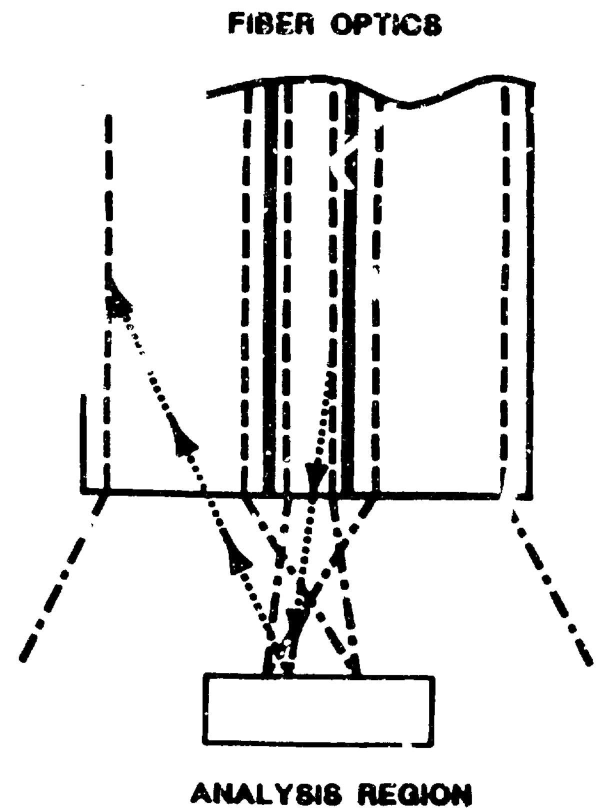
TECHNIQUE FOR EXPLOITING FIBER OPTIC NUMERICAL APERTURES FOR ILLUMINATION AND COLLECTION OF SCATTERED RADIATION



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CONCLUSIONS

- FIBER OPTIC CHARACTERIZATIONS AS A FUNCTION OF FREQUENCY AND EXTERNAL FORCES NEED FURTHER CONSIDERATION

- SERS HAS BEEN DEMONSTRATED AND SHOWS POTENTIAL FOR FURTHER DEVELOPMENT

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FUTURE RESEARCH

- IMPROVING THE OPTIC DESIGN OF THE SENSOR
- EXAMINING THE INFLUENCE OF LASER EXCITATION ENERGY LEVELS
- QUANTIFYING PYRIDINE MIXTURES AS A FUNCTION OF CONCENTRATION AND ELECTROCHEMICAL POTENTIAL
- STUDYING THE INFLUENCE OF ELECTROLYTE ADDITION
- SOLUTE/SOLVENT INTERACTIONS IN DRINKING AND GROUND WATER

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"Particulate Detection Technology"

Robert Caldow, Applications Engineer
TSI, Incorporated, St. Paul, MN

For presentation at:
Space Station Toxic and Reactive Materials Handling Workshop, 11/29/88 - 12/1/88, Huntsville, Alabama.

ABSTRACT

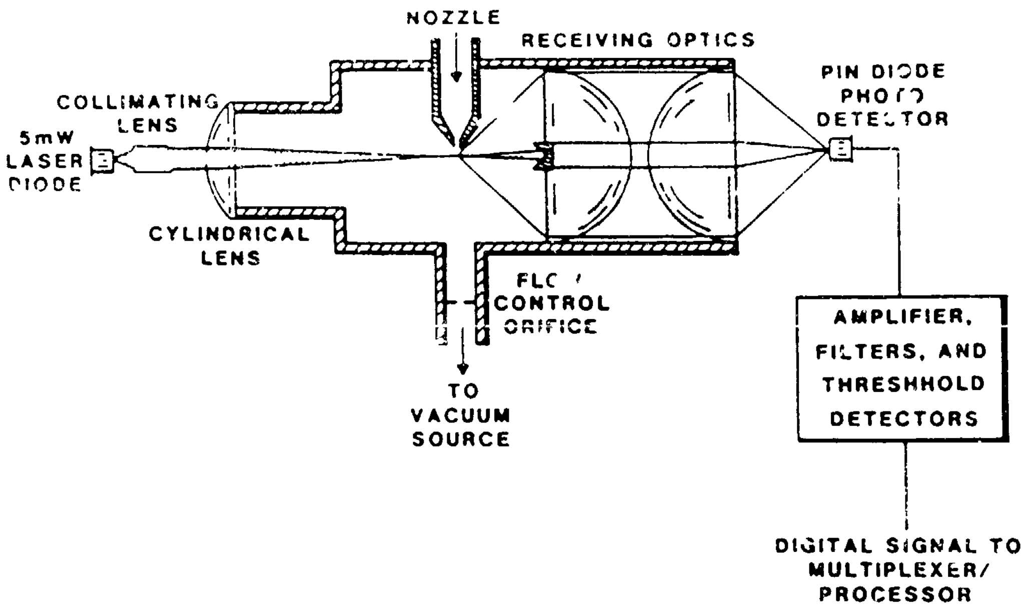
This talk will cover an overview of the major types of particulate contamination detection and monitoring instruments available which would be useful in a space station environment. The instruments can be grouped according to measurement method. These methods consist of optical, electrical and mechanical. The optical instruments which will be discussed are the Condensation Nucleus Counter (CNC), and the Laser Particle Counter (LPC). Electrical instruments include the Differential Mobility Analyzer (DMA), and Electrical Aerosol Analyzer (EAA). Mechanical instruments include the Aerodynamic Particle Sizer (APS), the Diffusion Battery, and the Impactor.

Outline

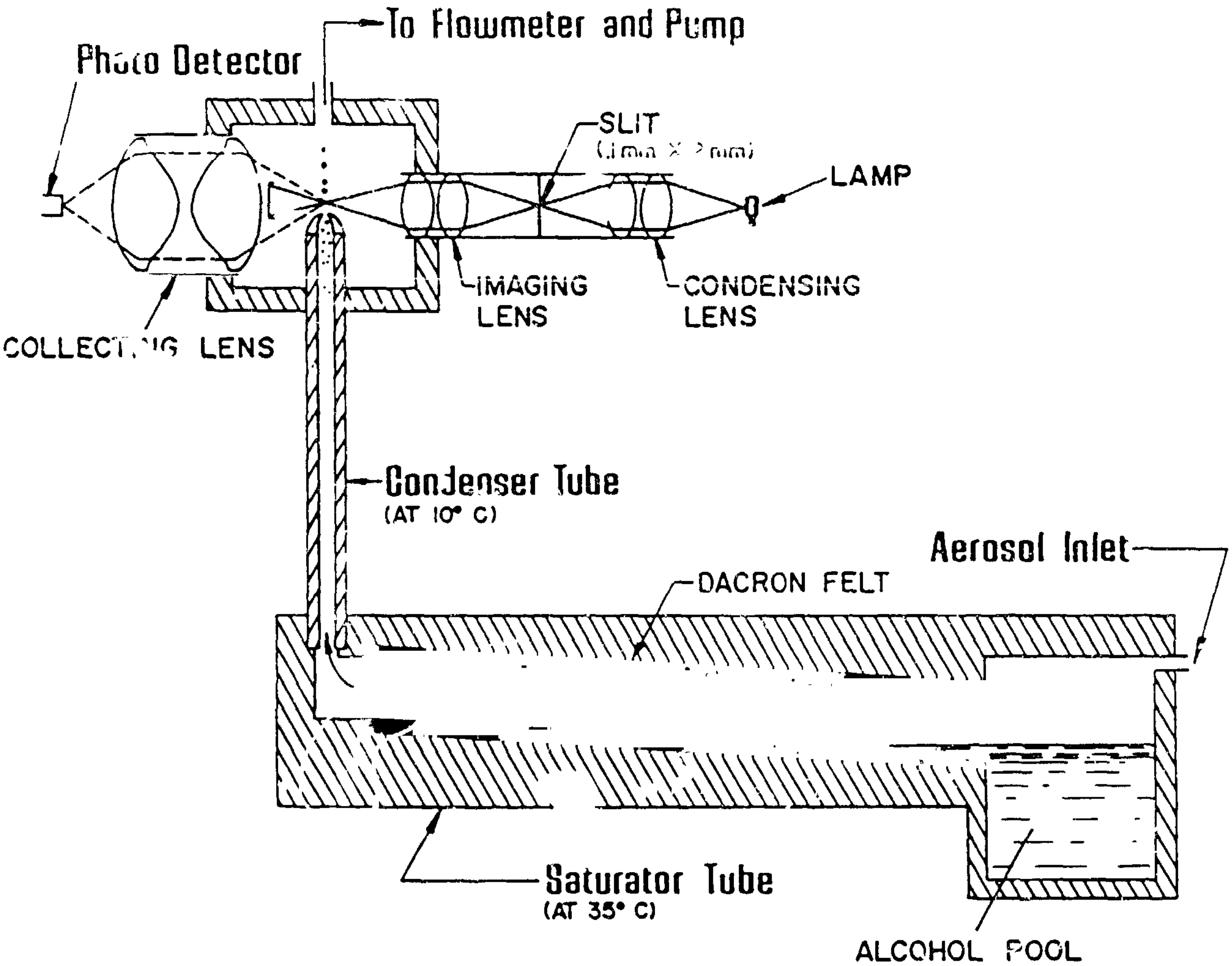
1. Optical Methods
    a. Optical Particle Counter
    b. Condensation Nucleus Counter

2. Electrical Methods
    a. Electrical Aerosol Analyzer
    b. Differential Mobility Analyzer
    c. ElectroStatic Precipitator

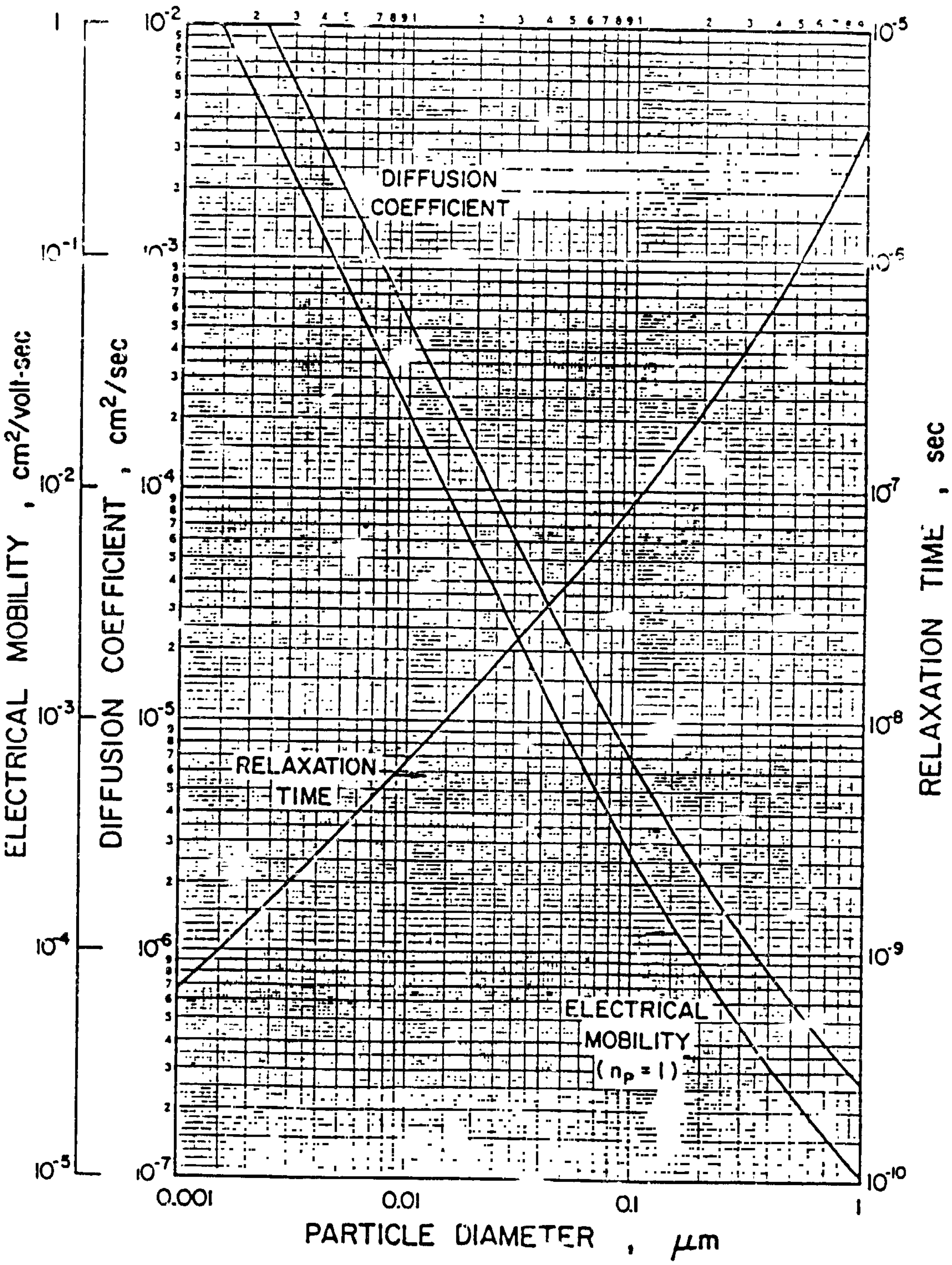
3. Mechanical Methods
    a. Cascade Impactor
    b. Diffusion Battery
    c. Aerodynamic Particle Sizer



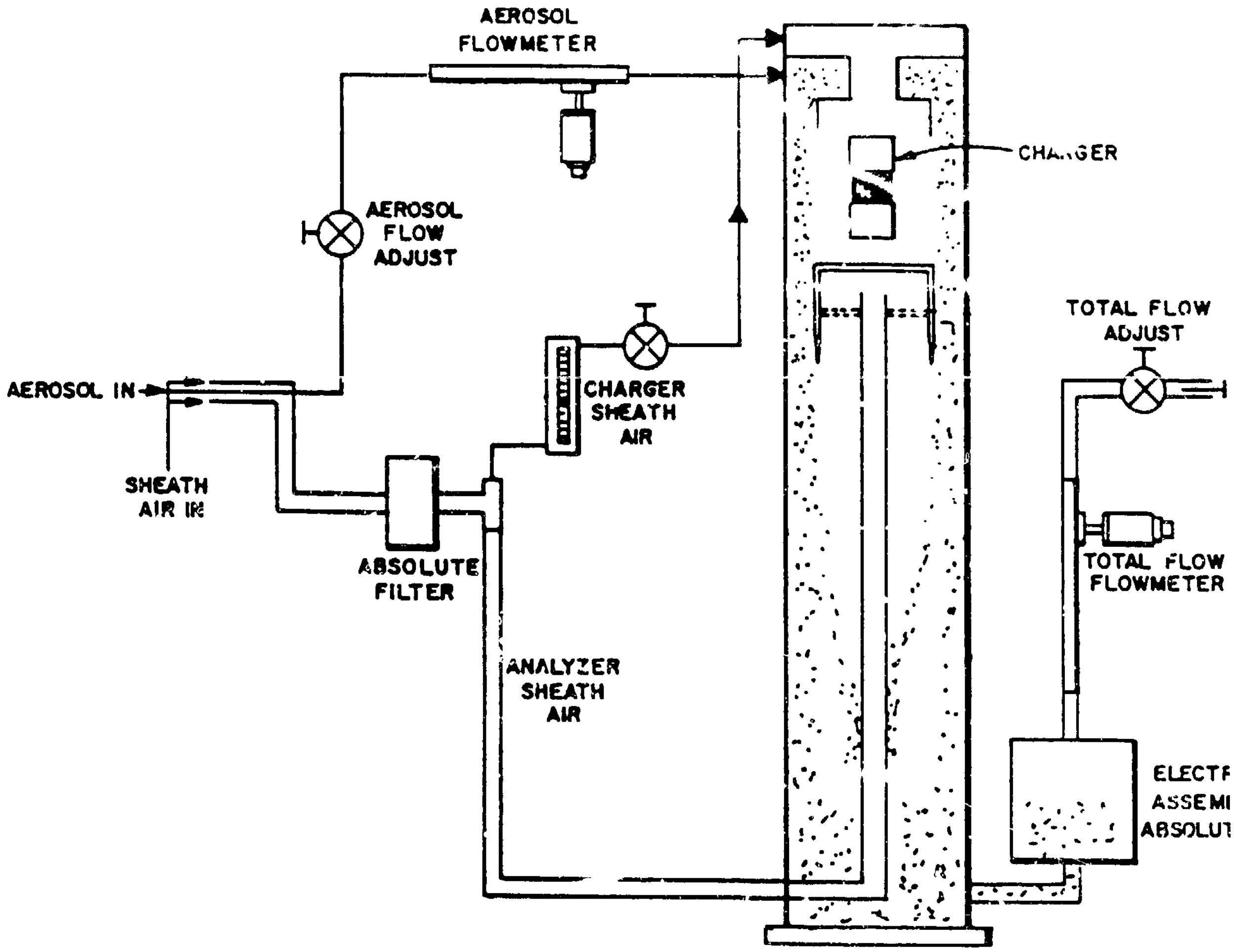
Laser Particle Counter (LPC)



Condensation Nucleus Counter (CNC)



Properties Chart



Electrical Aerosol Analyzer (EAA)

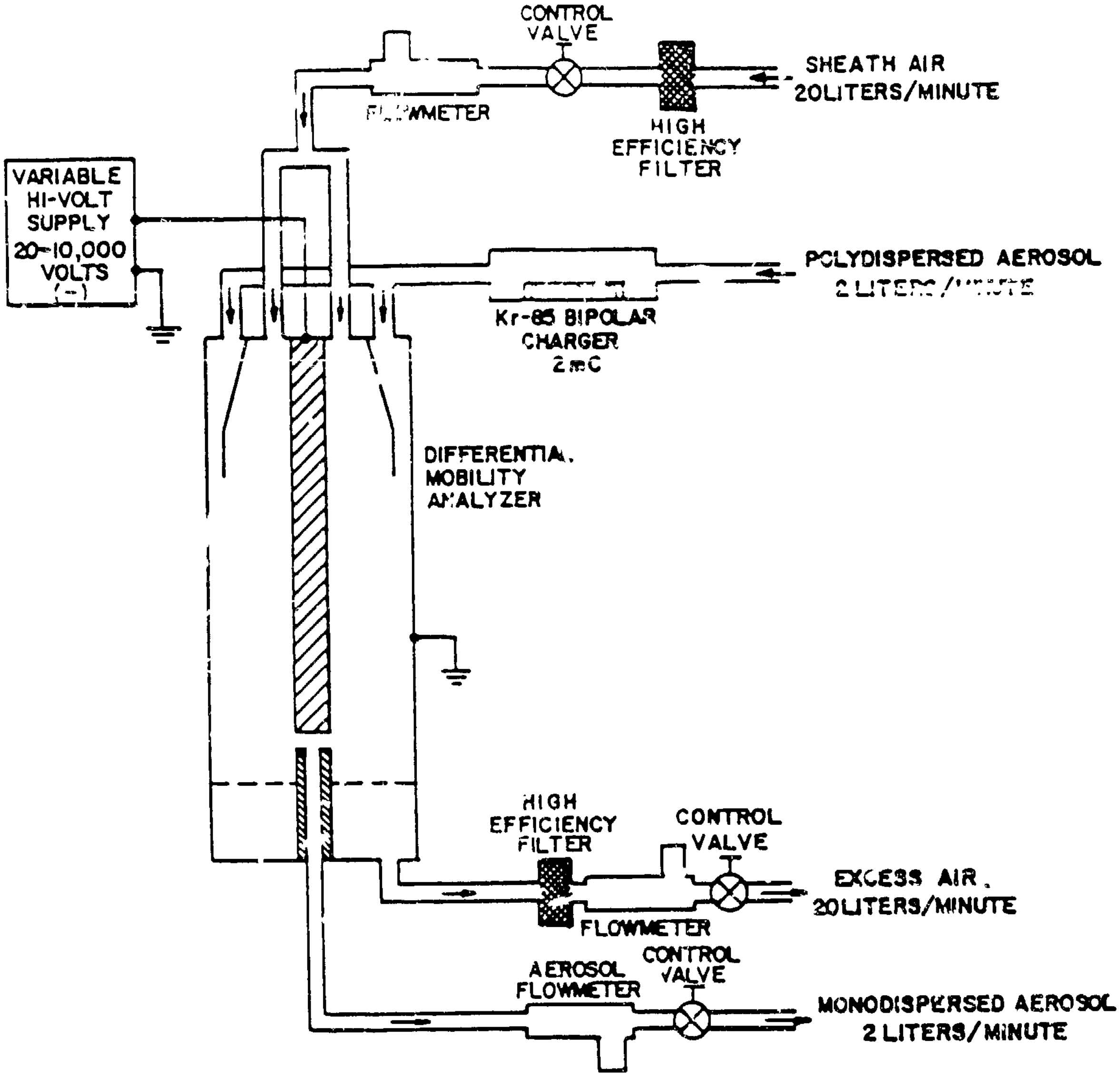


FIGURE 4.2. MODEL 3071 AIR FLOW SCHEMATIC DIAGRAM

Differential Mobility Particle Sizer (DMPS)

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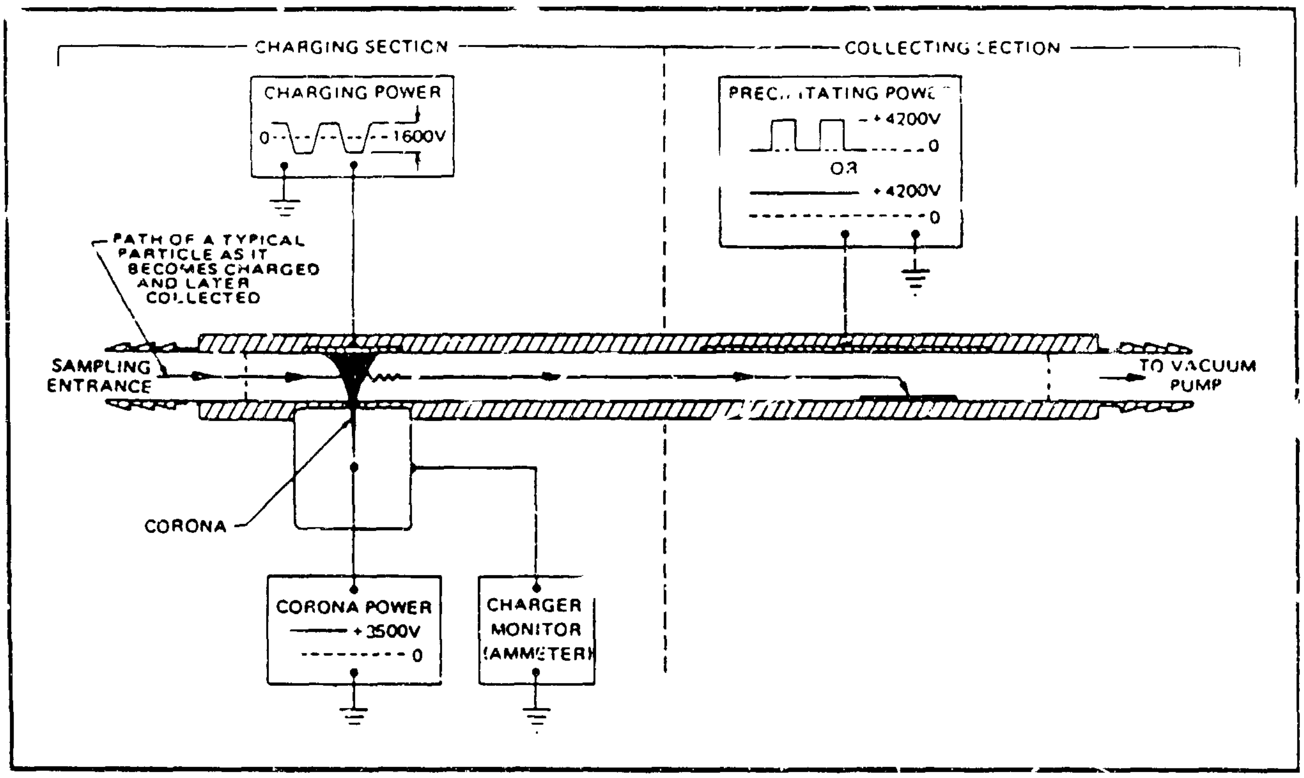

Electrostatic Precipitator (EP)

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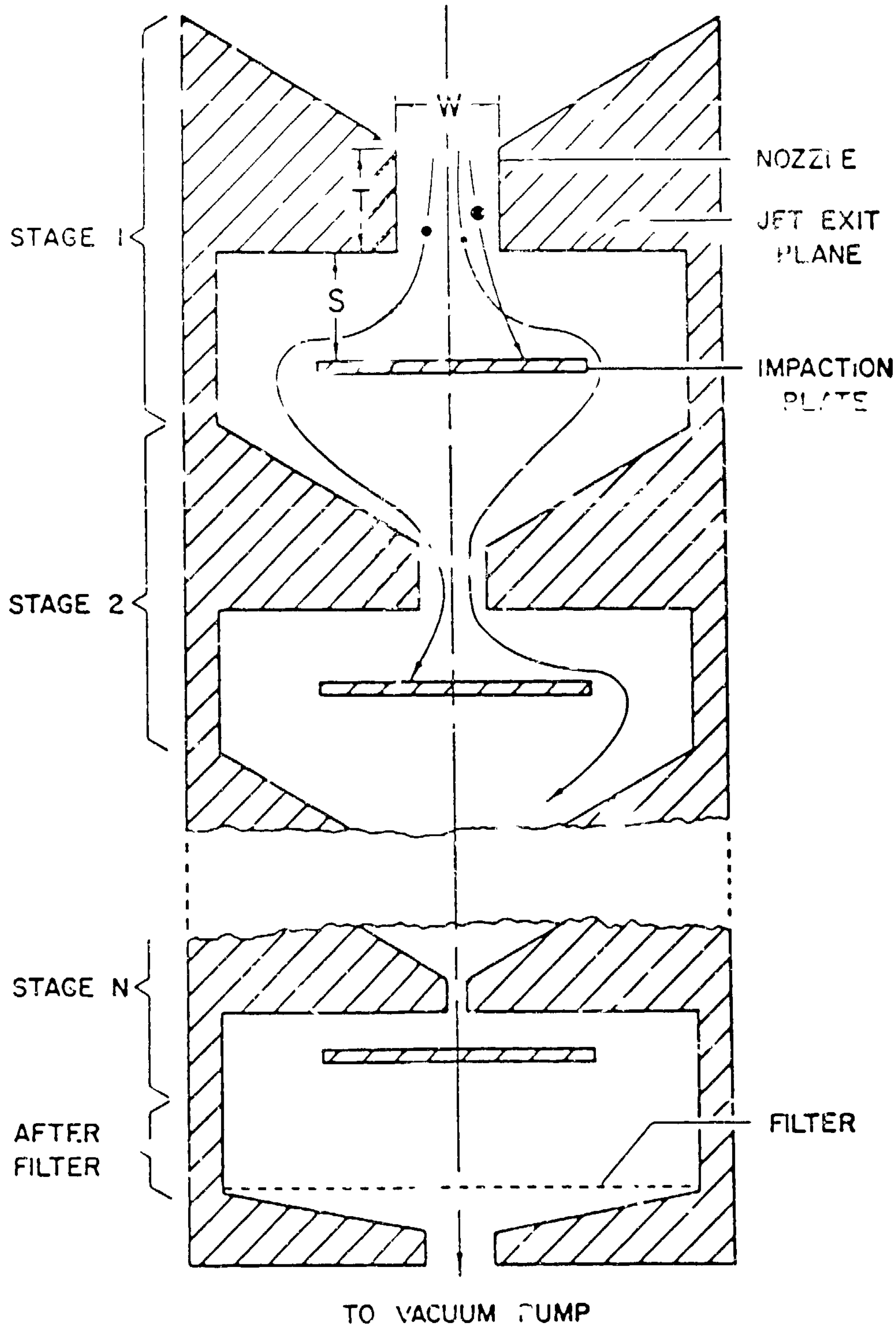

Cascade Impactor (CI)

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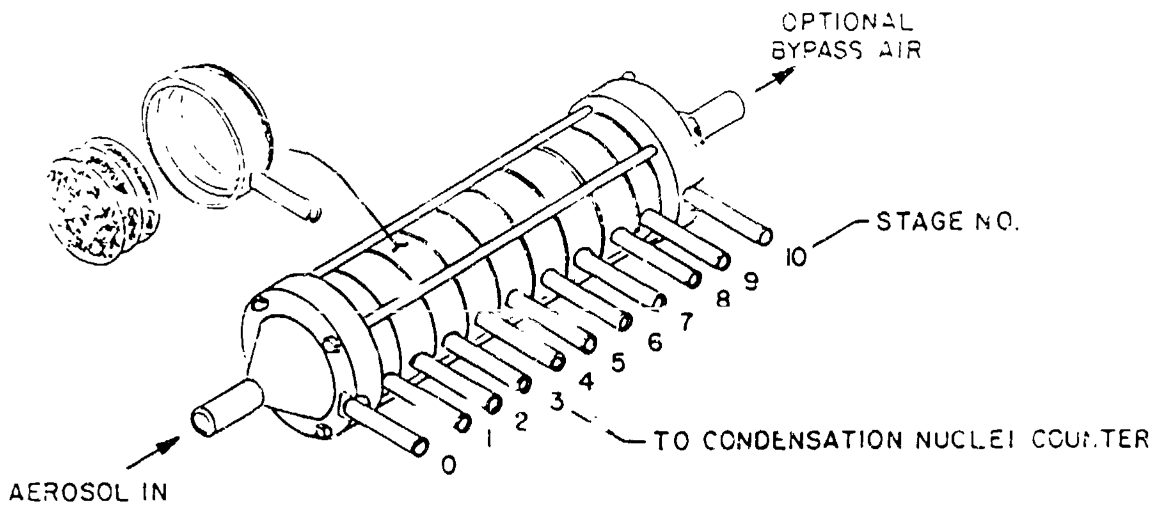
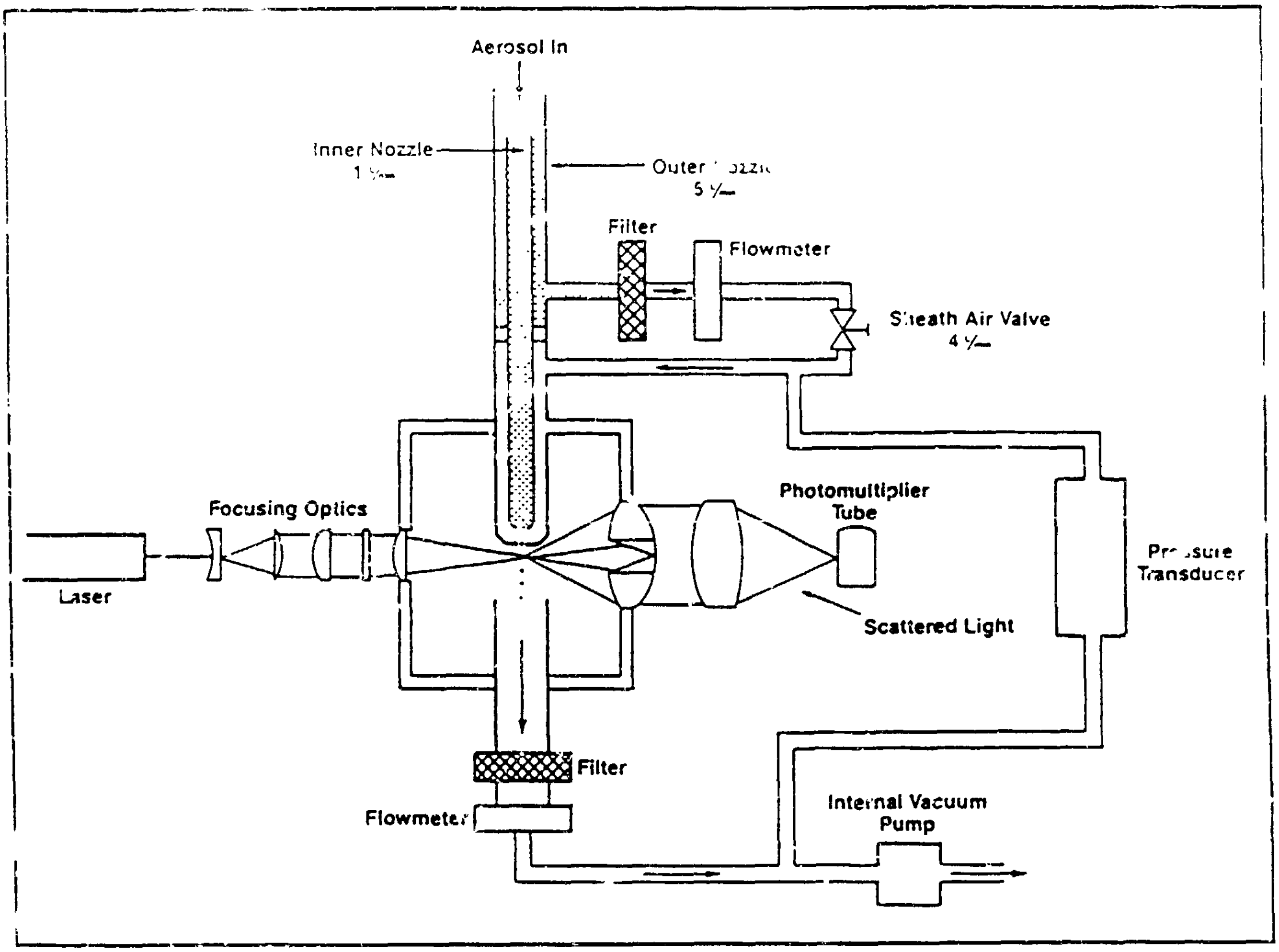


Figure 1. Schematic diagram of Model 3040 Diffusion Battery

Diffusion Battery (DB)



Aerodynamic Particle Sizer (APS)

Optical Method Summary

	Advantage	Disadvantage
	very fast, inexpensive versatile, compact, lightweight.	may not be accurate for non-spherical particles, coincidence problems.
OPC	high flow, multimode.	unstable, short life.
LPC	compact, very stable, rugged.	lower power, single-mode.
CNC	very high sensitivity.	no sizing capability, uses a working fluid.

Electrical Method Summary

	Advantage	Disadvantage
	can collect sample, very rugged, versatile.	long sampling time, large, heavy, high power consumption.
EAA	rugged, short sample time, self-contained.	large, heavy, requires error correction.
DMPS	versatile, accurate, very high resolution.	large, heavy, requires particle sensor, hard to set up, slow sample time.
EP	collects representative sample, self contained.	no sizing capabilities.

Mechanical Method Summary

	Advantage	Disadvantage
	uses aerodynamic properties.	
CI	very rugged, collects sample, steep size cut, compact.	very labor intensive, slow response time, hard to sample very small particles.
DB	very rugged, compact, measures to CNC limits.	slow response, requires a CNC or counter, requires data reduction.
APS	very fast response, steep size cut-off, very high resolution, computerized, repeatable.	expensive, less rugged, measures only low concentrations.

N91 15941

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Workstations and Gloveboxes for Space Station

Lockheed Missiles and Space Company is responsible for designing, developing, and building the Life Sciences Glovebox, the Laboratory Sciences Workbench, and the Maintenance Workstation plus 16 other pieces of equipment for the U.S. Laboratory Module of the Space Station Freedom. The Laboratory Sciences Workbench and the Maintenance Workstation have been functionally combined into a double structure to save weight and volume which are important commodities on the Space Station Freedom. The total volume of these items is approximately 180 cubic feet. These workstations and the glovebox will be delivered to NASA in 1994 and will be launched in 1995. The requirement for all equipment on board the Space Station Freedom to have a very long lifetime of 30 years presents numerous technical challenges in the areas of design and reliability. The equipment must be easy to use by international crew members and also easy to maintain on-orbit. For example, seals must be capable of on-orbit changeout and reverification. The stringent contamination requirements established for Space Station Freedom equipment also complicate the zero gravity glovebox design. The current contamination control system for the Life Sciences Glovebox and the Maintenance Workstation will be presented. The requirement for the Life Sciences Glovebox to safely contain toxic, reactive, and radioactive materials presents unique challenges. Trade studies, CAD simulation techniques and design challenges will be discussed to illustrate the current baseline conceptual designs. Areas which need input from the user community will be identified.

SPACE STATION FREEDOM

BOEING
Lockheed

SPACE STATION

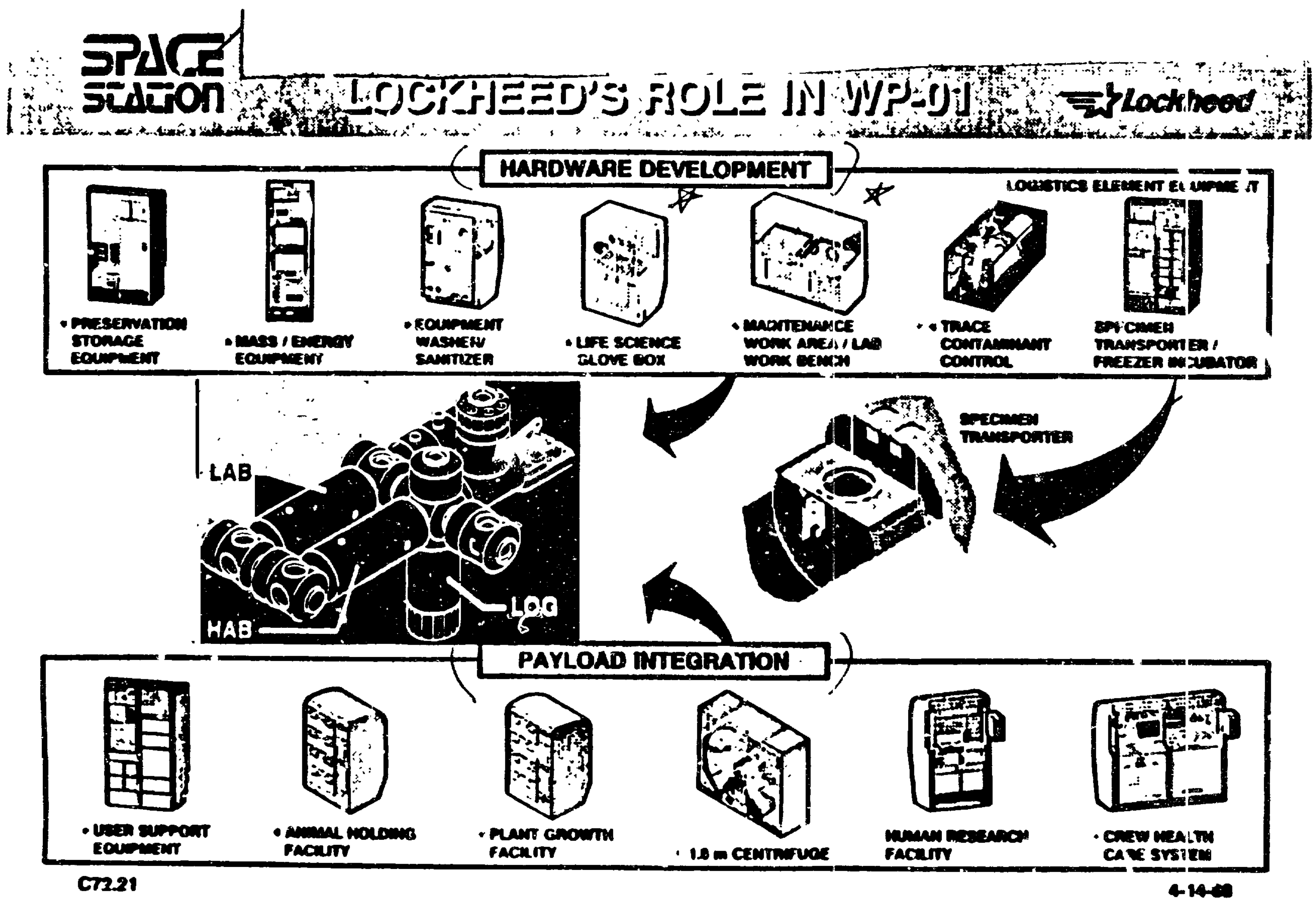
TOXIC AND REACTIVE MATERIALS HANDLING

GLOVEBOXES AND WORKSTATIONS

LIFE SCIENCES GLOVEBOX

MARIA JUNGE

DECEMBER 1, 1988



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SPACE STATION

WP-01 HARDWARE ELEMENTS LIFE SCIENCES GLOVE BOX

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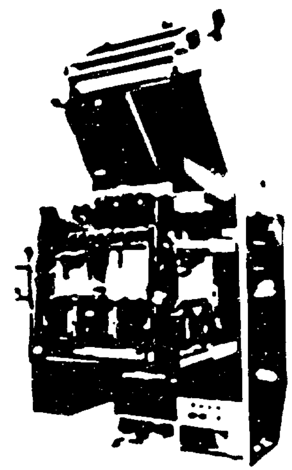
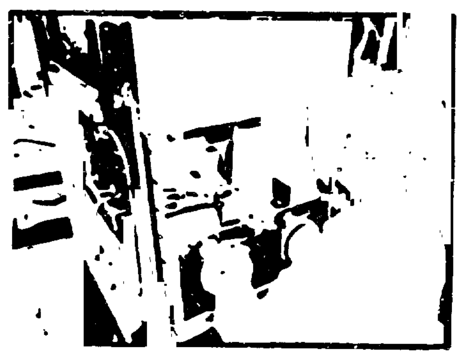


SPACELAB GENERAL PURPOSE WORKSTATION



GENERAL PURPOSE WORKSTATION GLOVE PORTS

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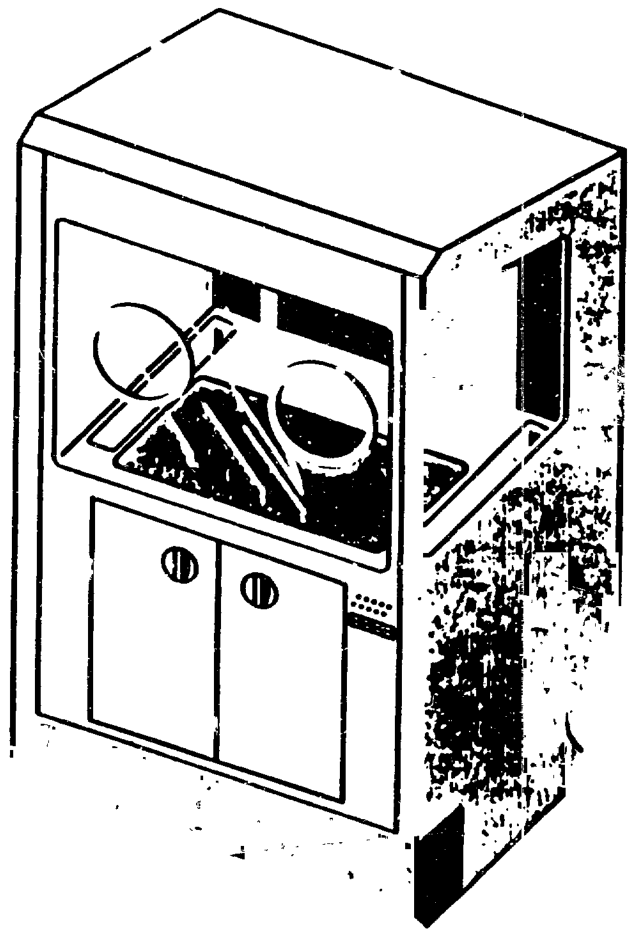
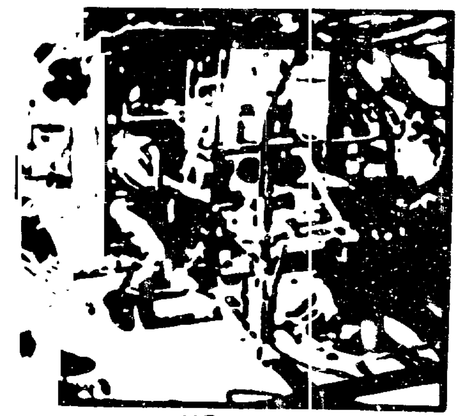
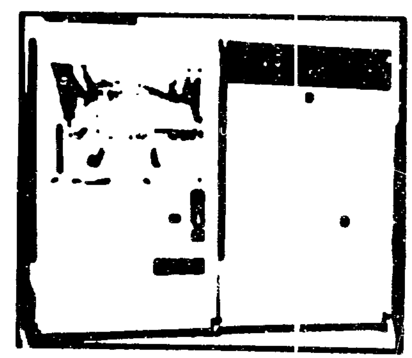


LIFE SCIENCES GLOVE BOX



KC-135 DEVELOPMENT TEST



GLOVE BOX AND EQUIPMENT WASHER SANITIZER METAL MOCK-UP

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SPACE STATION

WP-01 HARDWARE ELEMENTS MAINTENANCE WORKSTATION / LABORATORY SCIENCE WORKBENCH

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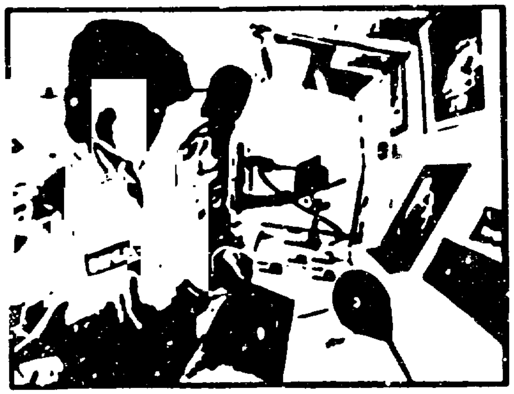
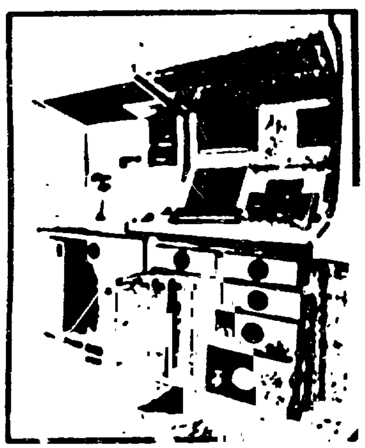
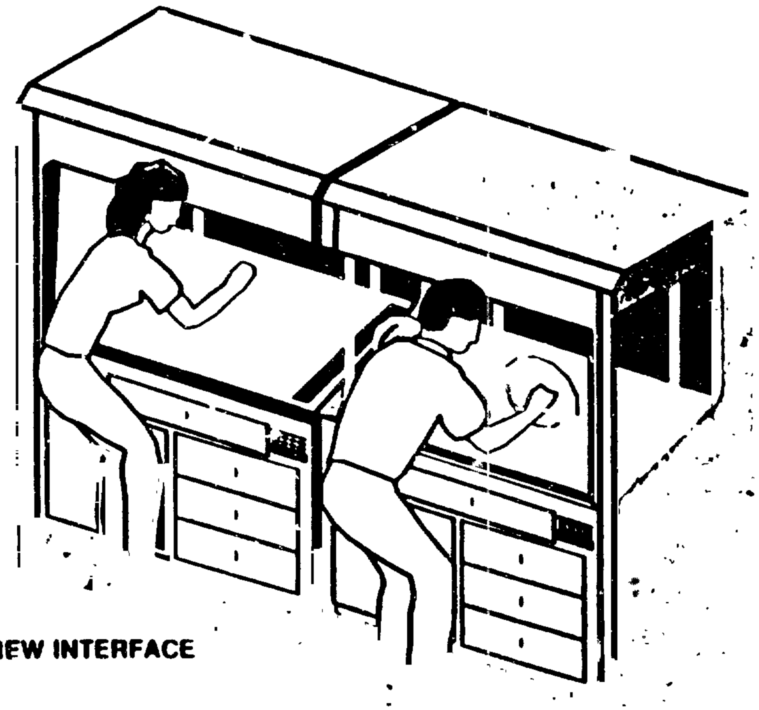


EQUIPMENT CALIBRATION AND REPAIR



MAINTENANCE WORKSTATION MOCK-UP



CREW INTERFACE

SPACELAB WORKBENCH

MAINTENANCE WORKSTATION LABORATORY SCIENCE WORKBENCH

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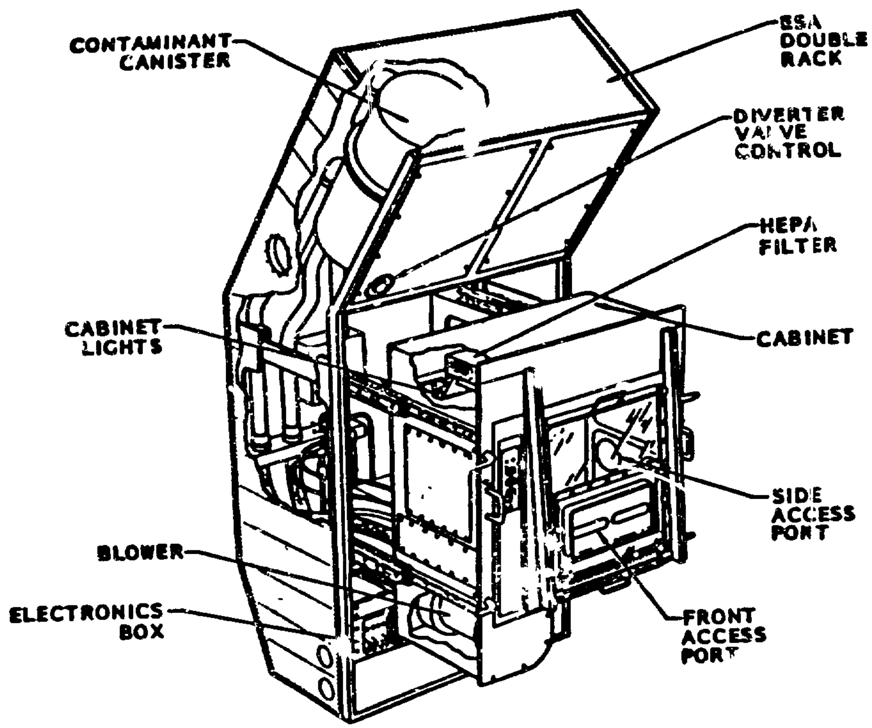
GENERAL PURPOSE WORK STATION



SPACELAB GPWS PROVIDES HERITAGE FOR SPACE STATION WORK STATIONS

SPACE STATION FREEDOM

GLOVEBOXES AND WORKSTATIONS

BOEING Lockheed

LIFE SCIENCES GLOVEBOX

KEY REQUIREMENTS

LIFE SCIENCES GLOVEBOX SHALL:

- PROVIDE BIOISOLATION
- PREVENT ANIMAL ESCAPE
- CONTAIN AND COLLECT LIQUID, SOLID AND GAS WASTES
- CONTINUOUSLY CLEAN AND RECYCLE INTERNAL ATMOSPHERE
- PROVIDE A STERILE ENVIRONMENT (CLASS III BIOLOGICAL CABINET)
- PROVIDE 99.99% (FOR 0.3μ PARTICLES) EFFICIENT HEPA FILTRATION
- PROVIDE FOR DETERMINATION OF INTERNAL CLEANLINESS LEVELS
- PROVIDE ACCESS TO PROCEDURES FOR GLOVEBOX OPERATION
- PROVIDE VIDEO OBSERVATION CAPABILITY

GLOVEBOXES AND WORKSTATIONS

LIFE SCIENCES GLOVEBOX

KEY REQUIREMENTS

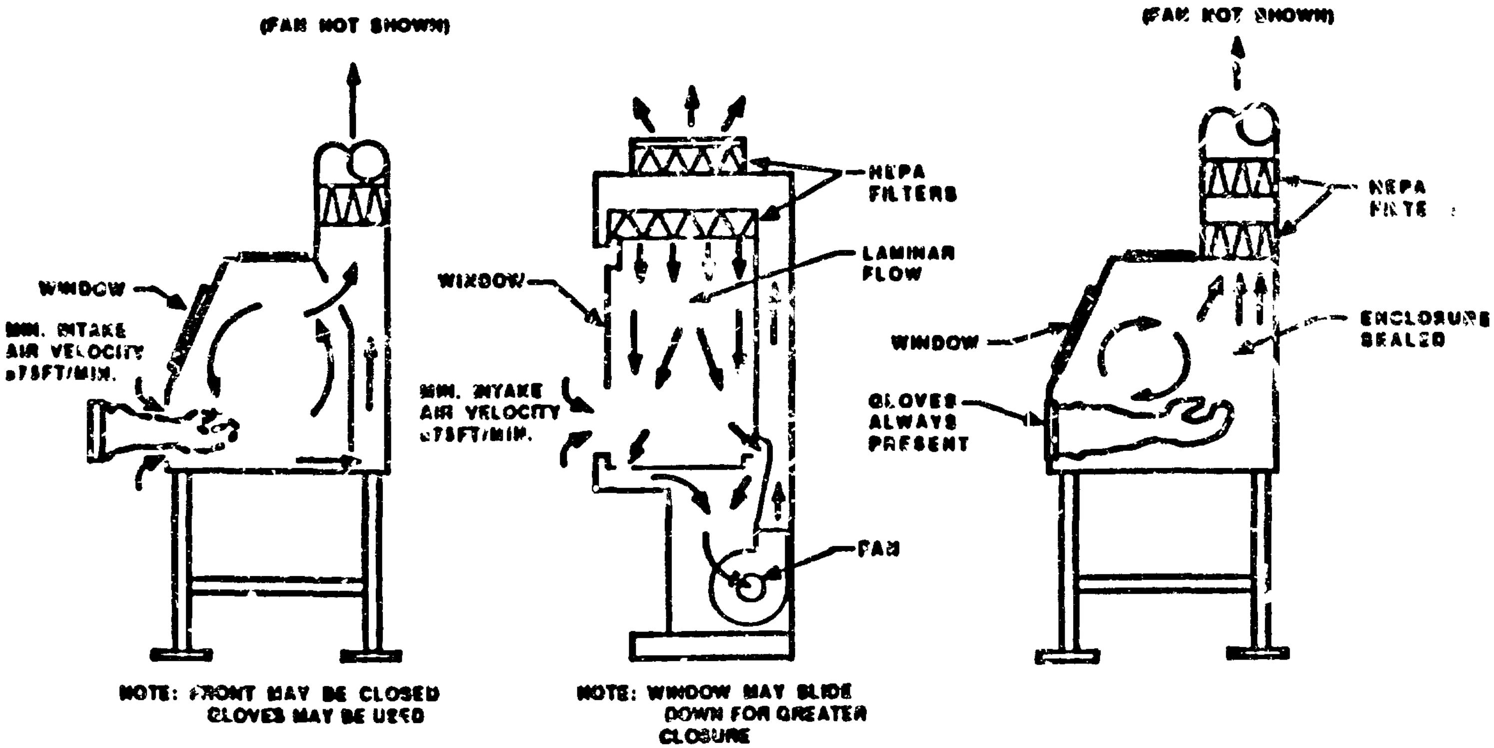
LIFE SCIENCES GLOVEBOX SHALL ACCOMMODATE:

- MASS MEASUREMENT DEVICES
- FLUID HANDLING TOOLS
- SPECIMEN LABELING DEVICE
- MODULAR HABITATS
- COMMONLY USED FLUIDS (AIR, WATER, ETC.)
- CRYOGENIC FREEZING OF SPECIMENS
- UTILITY INTERFACES TO SPECIFIED EQUIPMENT
- DATA ANALYSIS AND STORAGE DEVICES
- ROUTINE CLEANING AND PERIODIC DISINFECTION AND STERILIZATION

LIFE SCIENCES GLOVEBOX SHALL SUPPORT THE FOLLOWING OPERATIONS:

- GENERAL SPECIMEN HANDLING
- SURGERY, MICROSCOPY, DISSECTION, SAMPLE ACQUISITION, FIXATION
- CAGE AND CUVETTE MAINTENANCE
- CONSUMABLES RESUPPLY
- MAINTENANCE AND REPAIR
- IMAGING
- RECORDING AND HANDLING OF RADIOISOTPES, TOXIC, REACTIVE, AND INFECTIOUS MATERIALS

GLOVEBOX CLASSIFICATION



CLASS I CABINET

CLASS II CABINET

CLASS III CABINET

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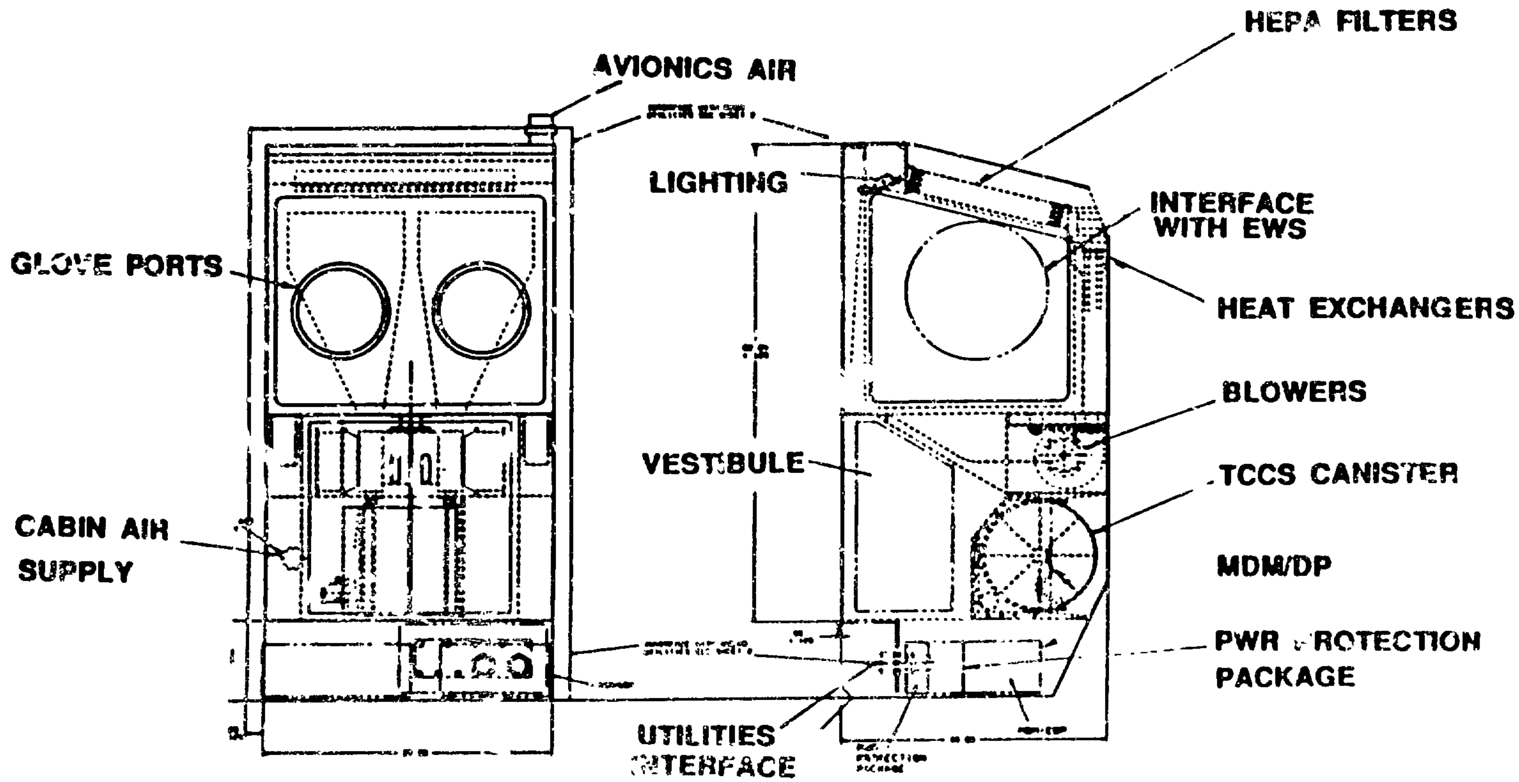
SPACE STATION FREEDOM

LIFE SCIENCES GLOVEBOX KEY FEATURES AND FUNCTIONS

BOEING Lockheed

- SUPPORT LIFE SCIENCES EXPERIMENTS IN BIOISOLATED CLEAN AREA
- ACCOMMODATES FULL CREW ANTHROPOMETRIC RANGE
- CLASS III BIOHAZARD CABINET WITH CONTAMINANT REMOVAL CAPABILITY
- TEMPERATURE CONTROLLED WORK VOLUME = 17.4 CU. FT.
- WORK SURFACE = 6 SQ. FT.
- GENERAL AND TASK LIGHTING
- ACCESS TO DMS, POWER, A/V, PMMS



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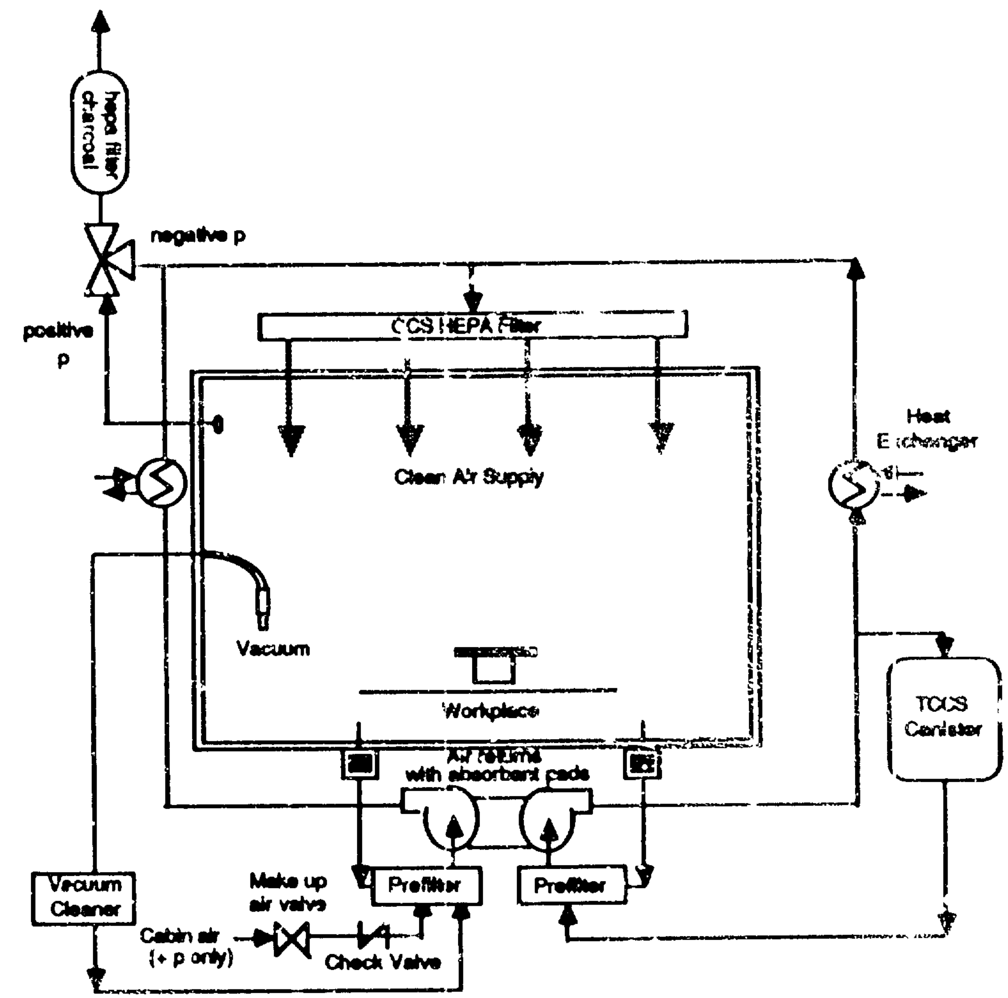
SPACE STATION FREEDOM

LIFE SCIENCES GLOVEBOX CONTAMINATION CONTROL SYSTEM

BOEING
Lockheed

- PROVIDES BOTH PARTICULATE AND GASEOUS CONTAMINATION CONTROL
- PROVIDES POSITIVE PRESSURE IN THE WORK VOLUME FOR ULTRACLEAN OPERATIONS
- PROVIDES NEGATIVE PRESSURE IN THE WORK VOLUME FOR CONTAMINANT PRODUCING TASKS
- PROVIDES VACUUM CLEANER FOR LOCALIZED WET/DRY PARTICULATE CONTAINMENT



TRACE CONTAMINANT CONTROL CANISTER

CAPABILITIES

- STANDARD BED CONFIGURATION WILL ACCOMMODATE MOST CONTAMINANTS
- CUSTOMIZATION OF BED CONTENTS OPTIMIZES PERFORMANCE FOR A PARTICULAR MISSION
- COMPUTER MODEL AVAILABLE TO DETERMINE OPTIMUM BED CONFIGURATION
- POTENTIAL BED COMPONENTS:
  - ACTIVATED CARBON - MEDIUM TO HIGH MOLECULAR WEIGHT HYDROCARBONS (INCLUDING GLUTARALDEHYDE AND ETHANOL)
  - PHOSPHORIC ACID TREATED SECTION - AMMONIA
  - BASIC TREATED SECTION - ACID GASES (SUCH AS HYDROCHOLORIC AND PHOSPHC
  - CATALYST COATED SECTION - CO OXIDATION
  - SPECIAL SORBENT LAYERS - SELECTED MATERIALS SUCH AS FORMALDEHYDE
- COMPONENTS NOT EFFECTIVE FOR LOW MOLECULAR WEIGHT HYDROCARBONS AND HALOCARBONS + RADIOACTIVE COMPOUNDS WHICH FORM GASES NOT EASILY ABSORBED

POTENTIAL USER HAZARDOUS MATERIALS WITH PROPOSED ALTERNATIVES

SOURCE: ANIMAL AND PLANT RADIOISOTOPE EXPERIMENTS (GREEN BOOK)

- CALCIUM HOMEOSTASIS EXPERIMENT (^{47}Ca).

  - **ALTERNATIVE:** USE STABLE (NON-RADIOACTIVE) ISOTOPES, E.G., ^{40}Ca, ^{46}Ca, ^{48}Ca. COLLECT SAMPLES, FREEZE, ANALYZE BY MASS SPECTROMETER AFTER RETURN. STABLE ISOTOPES FREQUENTLY USED IN Ca STUDIES.

- CARDIOVASCULAR SYSTEM EXPERIMENT (RADIOACTIVE MICROSPHERES).

  - **ALTERNATIVE:** DETERMINE CARDIAC OUTPUT BY DYE DILUTION. WELL-ESTABLISHED, ACCURATE PROCEDURES. IF ISOTOPES REQUIRED, USE STABLE ^{58}Fe OR ^{50}Cr.

- HEMATOLOGY EXPERIMENTS (ISOTOPE NOT SPECIFIED. COUNTED WITH GAMMA COUNTER.).

  - **ALTERNATIVE:** USE STABLE ^{58}Fe, AS SPECIFIED IN EXPERIMENT. SAMPLES ANALYZED AFTER RETURN BY NEUTRON ACTIVATION.

SPACE STATION FREEDOM

BOEING Lockheed

POTENTIAL USER HAZARDOUS MATERIALS WITH PROPOSED ALTERNATIVES

SOURCE: ANIMAL AND PLANT RADIOISOTOPE EXPERIMENTS (GREEN BOOK)

- PLANT PHYSIOLOGY EXPERIMENT (UNSPECIFIED ISOTOPE. POSTFLIGHT: RADIOACTIVE COUNTING).

  - **ALTERNATIVE:** USE STABLE ISOTOPES (^{13}C, DEUTERIUM, ETC.) POSTFLIGHT: DETERMINE ISOTOPE CONCENTRATION.

- REPRODUCTION AND DEVELOPMENT EXPERIMENTS. (LABEL INFLIGHT WITH, E.G., ^{14}C-LEUCINE, ^{35}S-METHIONINE. METABOLIC PRODUCT: RADIOACTIVE $^{14}CO_2$).

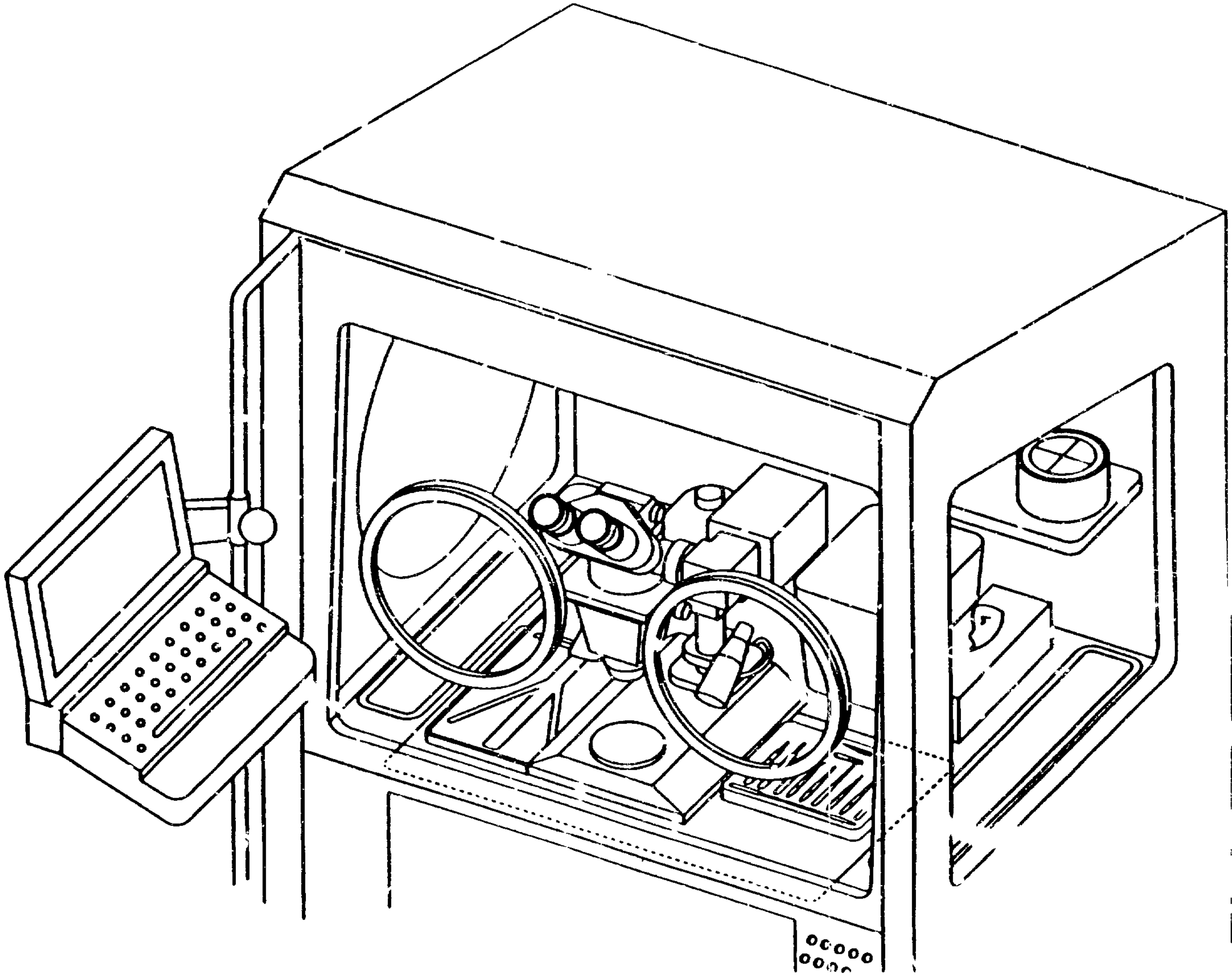
  - **ALTERNATIVE:** USE STABLE ISOTOPES (^{13}C, DEUTERIUM, ETC.). POSTFLIGHT: DETERMINE ISOTOPE CONCENTRATION.

SPACE STATION

LSG - DISSECTION MICROSCOPE

INSTALLATION

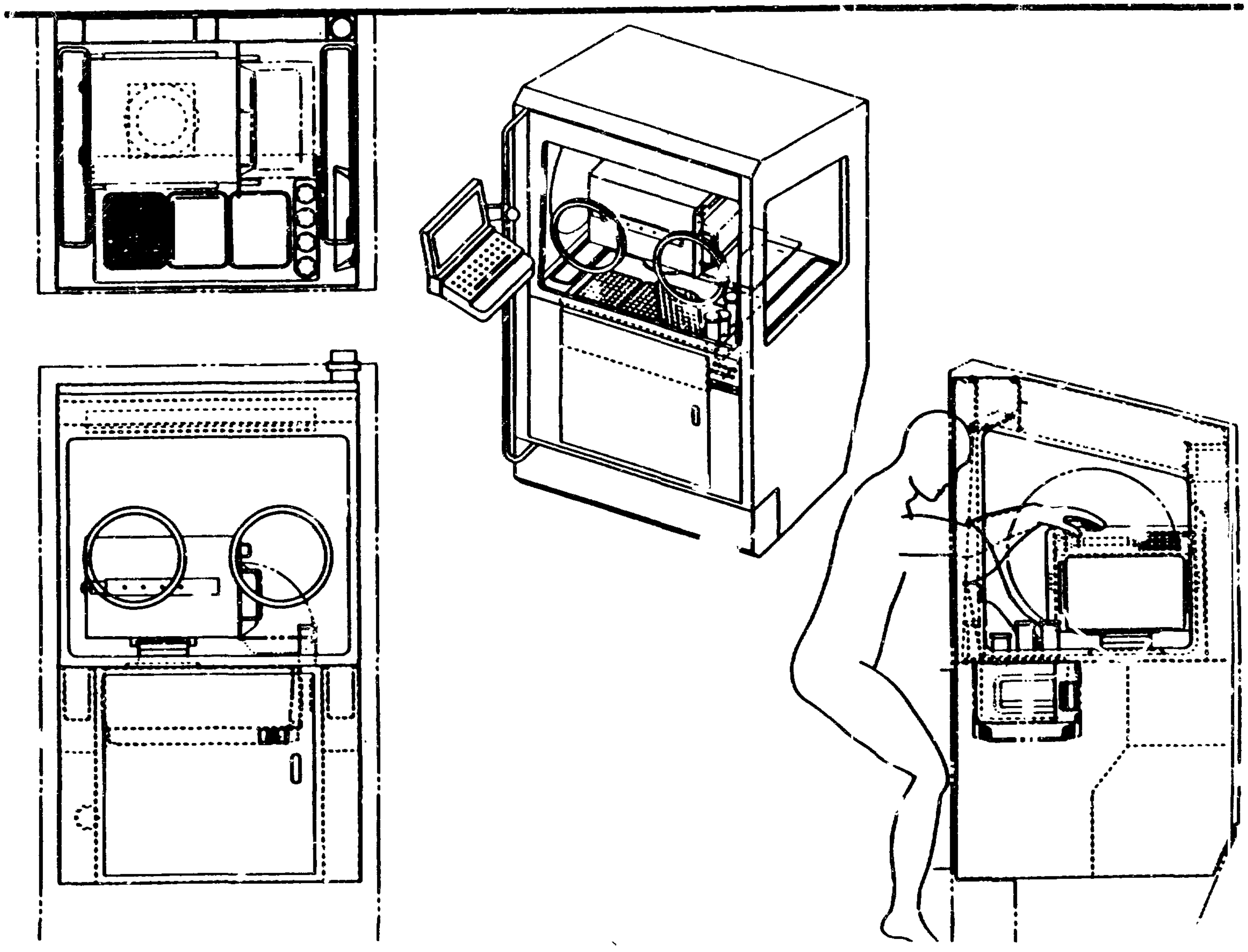
Lockheed



SPACE STATION

LSG - SMMD SCENARIO

Lockheed



KEY ISSUES AND CONCERNS

ISSUE:

- DEFINITION AND ACCOMMODATION OF USER NEEDS

SOLUTIONS:

- LSG ACCOMMODATION OF MODULAR HABITAT AND SUPPORT EQUIPMENT
- DEVELOPMENT OF A TYPICAL WEEK IN THE LIFE OF LSG
  - TYPICAL EXPERIMENT SCENARIOS
  - TYPE OF CONTAMINANTS AND GENERATION RATES
  - USE LMSC/MSFC COMPUTERIZED CHEMICAL LOAD MODEL

ISSUE:

- HANDLING WIDEST VARIETY OF EXPERIMENTS

SOLUTIONS:

- DESIGN FOR MAXIMUM SYSTEM FLEXIBILITY
- PREFLIGHT SCREENING AND APPROVAL OF EXPERIMENTS
- CUSTOMIZE TCCS CANISTER AND OTHER COMPONENTS BY MISSION

LIFE SCIENCES GLOVEBOX

SUMMARY

- LIFE SCIENCES GLOVEBOX PROVIDES CONTAMINATION CONTROLLED WORK ENVIRONMENT
- LIFE SCIENCES GLOVEBOX MODULAR DESIGN ALLOWS MAXIMUM SYSTEM FLEXIBILITY
- LIFE SCIENCES GLOVEBOX ACCOMMODATES WIDE RANGE OF USER REQUIREMENTS
- NEXT STEP: INTEGRATE USER INPUTS ON THE TYPES AND QUANTITIES OF CONTAMINANTS INTO THE DESIGN PROCESS
- SYSTEM DESIGN INCLUDES HERITAGE OF SPACELAB GENERAL PURPOSE WORKSTATION

N91-15942

11/22/88

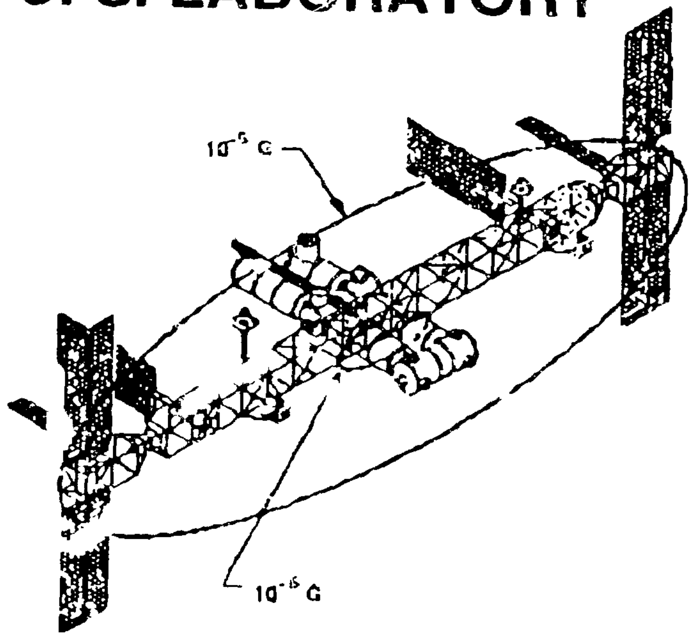
Space Station Toxic and Reactive Materials Handling Workshop

Summary of Presentation Entitled :
The Materials Processing Sciences Glovebox
Date of Presentation: 10:55 am , 12/1/88
Presenter: Larry Traweek

Summary:
The Materials Processing Sciences Glovebox is a rack mounted workstation which allows on orbit sample preparation and characterization of specimens from various experiment facilities. It provides an isolated safe, clean and sterile environment for the crew member to work with potentially hazardous materials. It has to handle a range of chemicals broader than even PMMS. The theme of the presentation is that **The Space Station Laboratory Experiment Preparation and Characterization Operations Provide The Fundamental Glovebox Design Characteristics** . The presentation discusses Glovebox subsystem concepts and how internal material handling operations affect the design.

Current Estimated Cost: $5M

SPACE STATION
U. S. LABORATORY



MATERIALS PROCESSING SCIENCES GLOVEBOX

Larry S. Traweek
December 1, 1988

TELEDYNE
BROWN ENGINEERING

L TRAWEEK

SPACE STATION TOXIC AND REACTIVE MATERIALS HANDLING WORKSHOP

SPACE STATION

MATERIALS PROCESSING SCIENCES GLOVEBOX

OVERVIEW

- DEFINITION AND REQUIREMENTS
- SUBSYSTEMS AND FUNCTIONAL SCHEMATIC
- SUBSYSTEM DESIGN AND PERFORMANCE FEATURES
- MATERIAL HANDLING ISSUES AFFECTING DESIGN
- CONCLUSIONS

THEME: SPACE STATION EXPERIMENT PREPARATION AND CHARACTERIZATION OPERATIONAL DEFINITION PROVIDES FUNDAMENTAL DESIGN GOALS FOR ALL GLOVEBOX SUBSYSTEMS

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SPACE STATION

MATERIALS PROCESSING SCIENCES GLOVEBOX

DEFINITION

- Rack Mounted, Crew Accessible but Isolated Work Area for Sample Preparation and Characterization Operations
- Provides User Protection to Handle Potentially Hazardous Materials

Therefore

- Provides an Internal Waste Handling Capability
- Airlock Isolation Entry of Specimens and Equipment
- Fluid Handling and Cleaning Tool Interfaces and Other Needed LSE Characterization Equipment Interfaces

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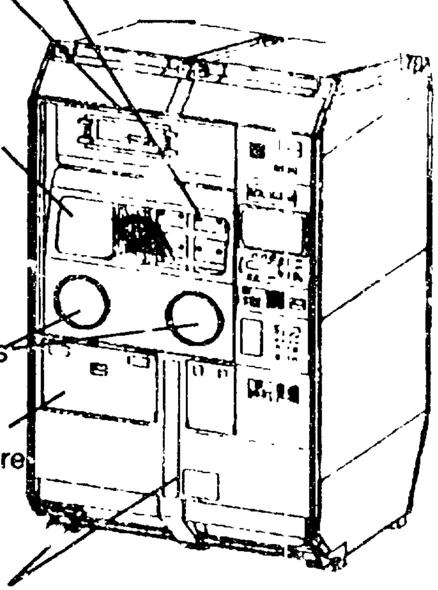
12/1/88

GLOVEBOX REQUIREMENTS

ACCOMODATIONS
Cleaning Fluids and Tools, etching and encapsulation equipment, access to subsystem and required LSE utilites, sample characterization and observation, biological preparation of media, pH meter, small mass measurement device, microscopic supplies, macroscopic inspection,device for analysis and results of data, separate and dispose of waste materials



PROVISIONS
Class 100 to Class 100k (continuous) cleanliness, determination of cleanliness levels, 0.5"ΔP steady state pressure operation below cabin, 10 air exchanges per hour, 1E-03 atm cc/sec helium inleakage at steady state ambient conditions, sterilization, prevention of crew contamination, glove removal and replacement, surface restraints in work area, video observation of internal operations, DMS interface, access to operational, maintenance and diagnostic data, lighting and illumination, imaging

TELEDYNE
BROWN ENGINEERING

L. Trawick
12/1/88

Usage

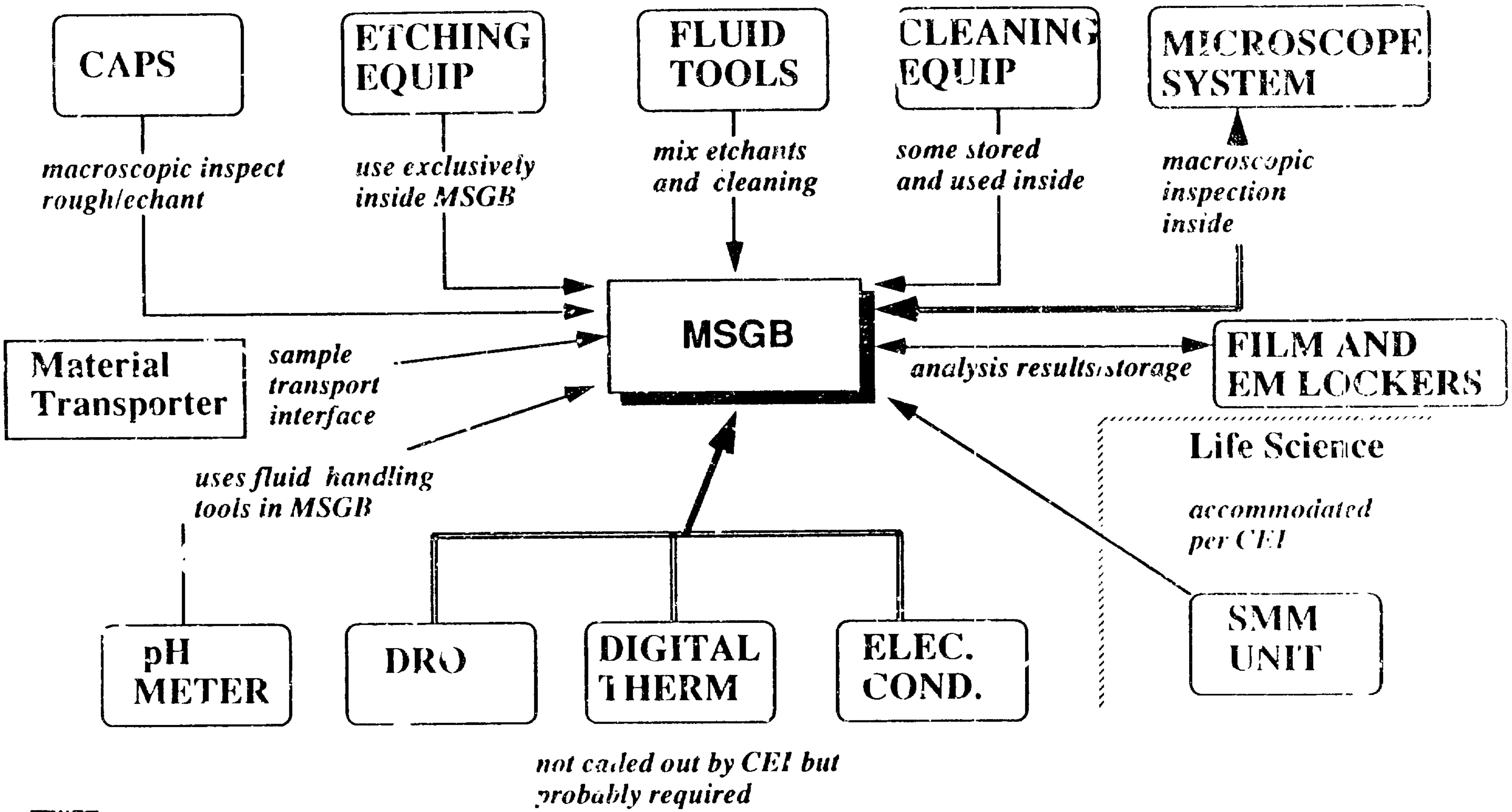
- Integrated Glovebox Systems Are Used For Realizing Users Characterization Needs By:
  - Interfacing with Experiment Facilities (via Material Transporter)
  - Accomodating Supporting LSE, Services(video, power etc..)
  - Being Operator Friendly
- Design of Glovebox is Determined by How It is Used

SPACE STATION TOXIC AND REACTIVE MATERIALS HANDLING WORKSHOP

SPACE STATION

MATERIALS PROCESSING SCIENCES GLOVEBOX

Glovebox- LSE Relationships



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MATERIALS PROCESSING SCIENCES GLOVEBOX

Subsystems

- 6 Subsystems Defined:
  - Cabinet (Work Area)
  - Accomodation Volumes (Storage, Access to Utilities)
  - Data Management System (Crew Access to Procedures, Maintenance, Video, Diagnostic Information)
  - Air System (Filtration/Cleansing of Internal Environment)
  - Waste Management (Storage, Treatment, Prep for PMMS)
  - Airlock (sterile/clean entry of specimens/equipment)

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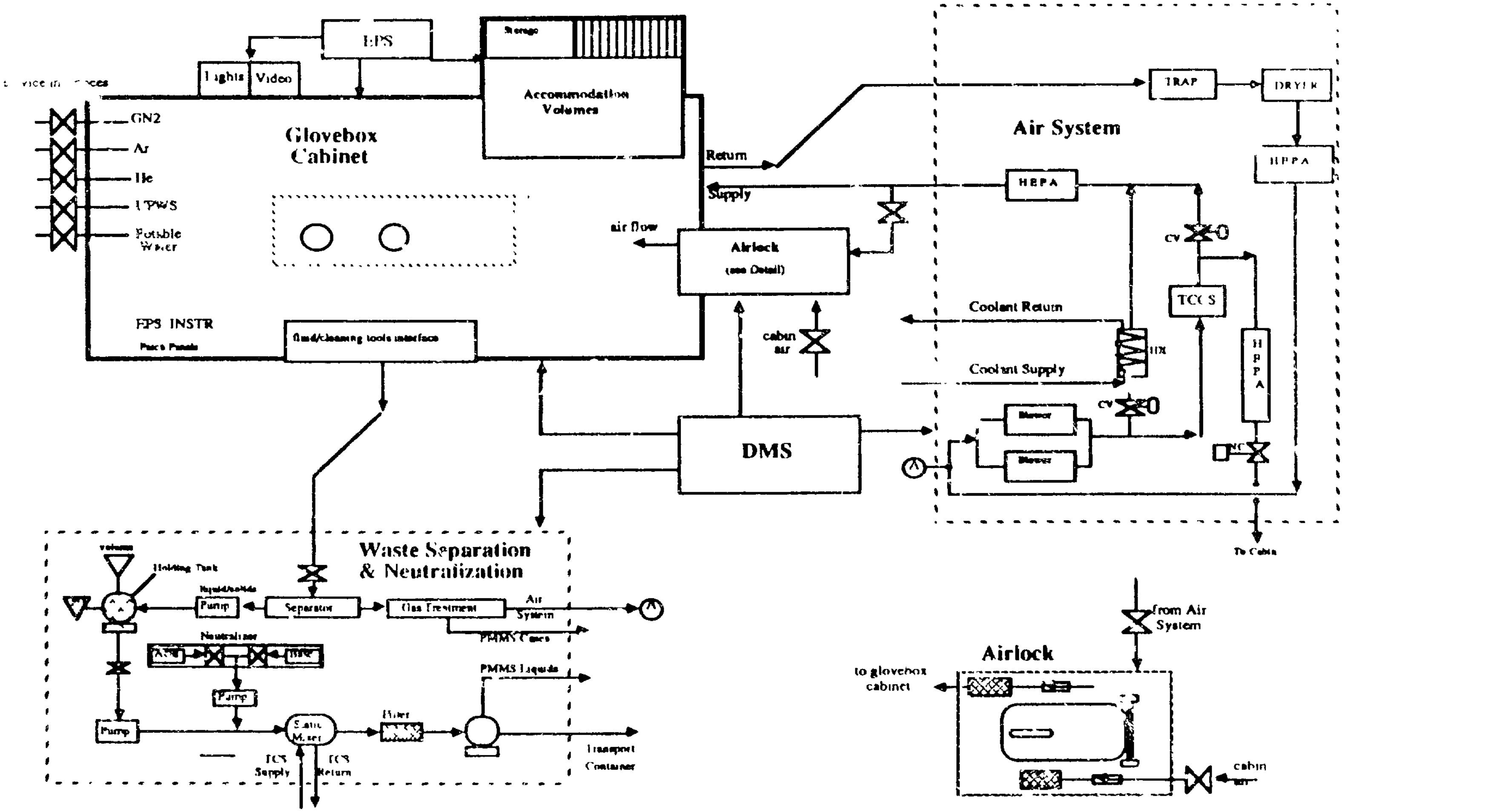
TRAW K

SPACE STATION

FUNCTIONAL SCHEMATIC

MATERIALS PROCESSING SCIENCES GLOVEBOX



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MATERIALS PROCESSING SCIENCES GLOVEBOX

CABINET

Design Features

- Work Volume Accessed Via Gloveports
- Interfaces Other Subsystems (Air, Waste Airlock, Storage/Service etc.)
- Human Factors of Operation a Major Design Consideration
- Dependent Upon Equipment Complement Needs For Characterization (other LSE)
- Materials of Construction Dependent on Chemical Compounds, Quantities, Mixtures and Possible Reactions

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MATERIALS PROCESSING SCIENCES GLOVEBOX

Accomodation Volumes

Design Features

- Ease of Access to Stored Supplies
- Service/Storage Access Panels (for protection)
- Adequate Storage Volume to Support Operations
- Instrumentation Access to Rack Mounted LSE for Measurement

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MATERIALS PROCESSING SCIENCES GLOVEBOX

DMS

Design Features

- Computer Access to User Operational Procedures
- Computer Access to Internal Diagnostic and Repair/Maintenance Procedures
- Instrumentation Access for Leak Detection and Cleanliness (particulate/chemical) State Measurement and Validation
- Safety Interlocks (Normal, Transient Conditions)
- Video Observation of Internal Operations

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MATERIALS PROCESSING SCIENCES GLOVEBOX

Air System

Design Features

- Filtration and Trapping of Floating Fluid and Particulate Matter
- Removal of Organic and Inorganics Via TCCS
- Filtration from Class 100K to Class 100
- Closed Loop System Design Similar to GPWS and Biorack

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MATERIALS PROCESSING
SCIENCES GLOVEBOX

Waste Management System

Design Features

- Interfaced to Work Volume Via Fluid Tools and Cleaning Tools
- Chemcial Level Monitoring Instrumentation
- Separates Fluid and Solid Waste Materials
- Treats, Stores or Diverts to PMMS
- Multiple Use States: Startup/Shutdown/Cleaning/Validation

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MATERIALS PROCESSING SCIENCES GLOVEBOX

Airlock

Design Features

- Interfaces with Material Transporter/Portable Glovebox
- Preserves Environmental Integrity of Samples
- Large Enough to Import LSE and Specimen Containers
- Leak Integrity/Detection/Validation
- Human Factors Consideration for Operation

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SPACE STATION TOXIC AND REACTIVE MATERIALS HANDLING WORKSHOP

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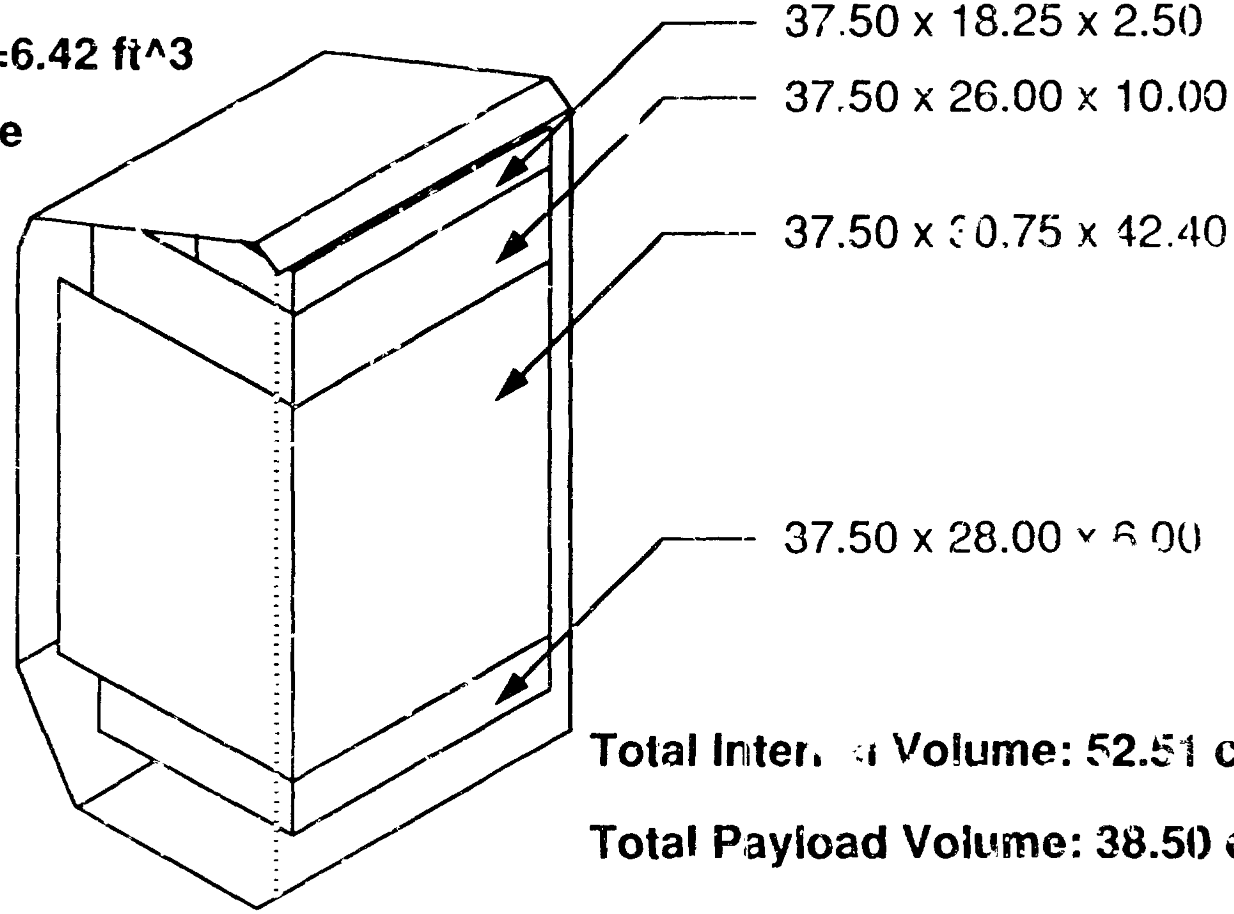
MATERIALS PROCESSING SCIENCES GLOVEBOX

Materials Handling Issues Affecting Design
Rack Packaging

- Avg Vol/Subsys=6.42 ft^3
- Adequate Volume For Meeting Design Goals



Total Internal Volume: 52.51 cu. ft.

Total Payload Volume: 38.50 cu.ft.

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SPACE STATION | *MATERIALS PROCESSING SCIENCES GLOVEBOX*

Materials Handling Issues Affecting Design

- SPECIMEN PREPARATION OPERATIONS
  - Fluid and Wet Chemistry Operations
    spill sets, chemical mixtures, quantities and state
  - Solids Particulate Generation
    quantitiy, size, chemical composition
  - Handling Operations
    tools needed, stored supplies, services
  - Visual or Video Observations

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Materials Handling Issues Affecting Design

- CHARACTERIZATION OR REPAIR OPERATIONS
  - Measurements Required for Given Operations establish LSE complement baseline and thus volume, service accommodations etc..

DESIGN OF GLOVEBOX IS DETERMINED BY HOW IT IS TO BE USED

SPACE STATION

MATERIALS PROCESSING SCIENCES GLOVEBOX

CONCLUSIONS

- Packaging Subsystems Within Volume Constraints May Not Be Possible Unless:
  - Re-interpretation of Use and Functional Limitations examples:
    - Waste Processing vs Total Storage
    - Internal Transport of LSE vs Feedthrough Accommodation
    - Self Contained Chemical and Cleanliness Monitoring System
    - Self Contained Leak Detection Validation System

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SPACE STATION TOXIC AND REACTIVE MATERIALS HANDLING WORKSHOP

SPACE STATION — *MATERIALS PROCESSING SCIENCES GLOVEBOX*

CONCLUSIONS (continued)

- A Baselined Set of Mission Operation Scenarios Should be Developed to Establish Design

ie.. sets of materials to be handled, tools, LSE etc..

-Chemical Levels/Cleanliness Monitoring May Be Accomplished By a Shared Effort With PMMS

- Trade Study Recommedations Using Basline Set May Simplfy Unit

  - based upon User interviews followed by development of concepts and procedures to accommodate

example: compartmentalization of work area to achieve class 100 cleanliness from class 100k

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I. TRAVILEK
12/1/88

National Aeronautics and
Space Administration

George C. Marshall Space Flight Center
Science and Engineering Directorate/ED62

NASA

U. S. Laboratory Chemical Hazard Remediation

Presented by
J. L. Perry

George C. Marshall Space Flight Center
Structures and Dynamics Laboratory/ED62

Space Station Toxic and Reactive Materials Handling Workshop

November 29, 30 & December 1, 1988

Space Station Project PMMS Objectives

Process Fluid Supply

Process Material Transport

Waste Dispensation

Chemical Storage and Leak Detection

PMMS Subsystems

Basic Subsystems

- Process Fluid Supply
- Waste Processing
- Water Recovery and Processing
- Chemical Storage and Transport

Peripheral Subsystems

- Portable Glovebox
- Emergency Shower and Eye Wash
- Vacuum Maintenance System

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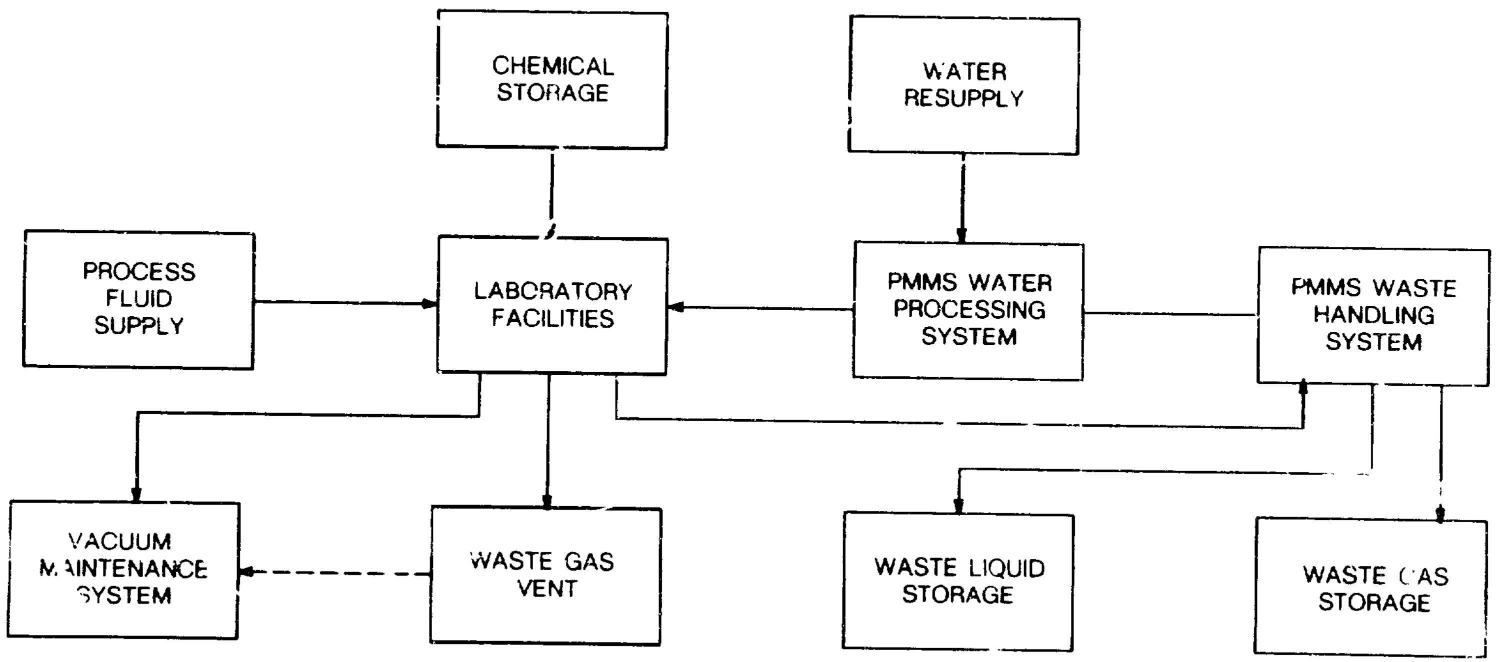
Process Material Management System



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USL Chemical Storage, Handling, and Isolation

Transport while maintaining isolation from the USL atmosphere

Containment levels
Portable glovebox

Ambient, safe storage for 90 day mission set

PMMS-supplied
User-supplied

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Science and Engineering Directorate/ED62

NASA

USL Waste Handling Requirements

Process and reclaim waste water as appropriate

Accommodate contaminated effluent

Handle leaks and spills within USL facilities

Separate and condition phases for storage or periodic venting as appropriate

Potentially Hazardous Operations on the USL

Chemical and waste storage

Chemical and waste transportation

Chemical and waste processing

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NASA

USL Hazard Remediation Approach

Survey past experience on Skylab, Spacelab, and Shuttle

Gather data on each material candidate

Screen materials based on criteria and limits established by the Space Station Project

USL Material Database Development

Database includes the following information:

1. Chemical name and formula
2. Physical properties
3. Phases used
4. Hazard classification
5. Amount used or generated per cycle and the location in the USL
6. Total amount used or generated
7. Recommended treatment methods and location
8. Spacecraft maximum allowable concentration
9. Funtional classification
10. Major incompatibilities
11. Comments

Aid for matching USL and user requirements to reach the optimum design

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Space Administration

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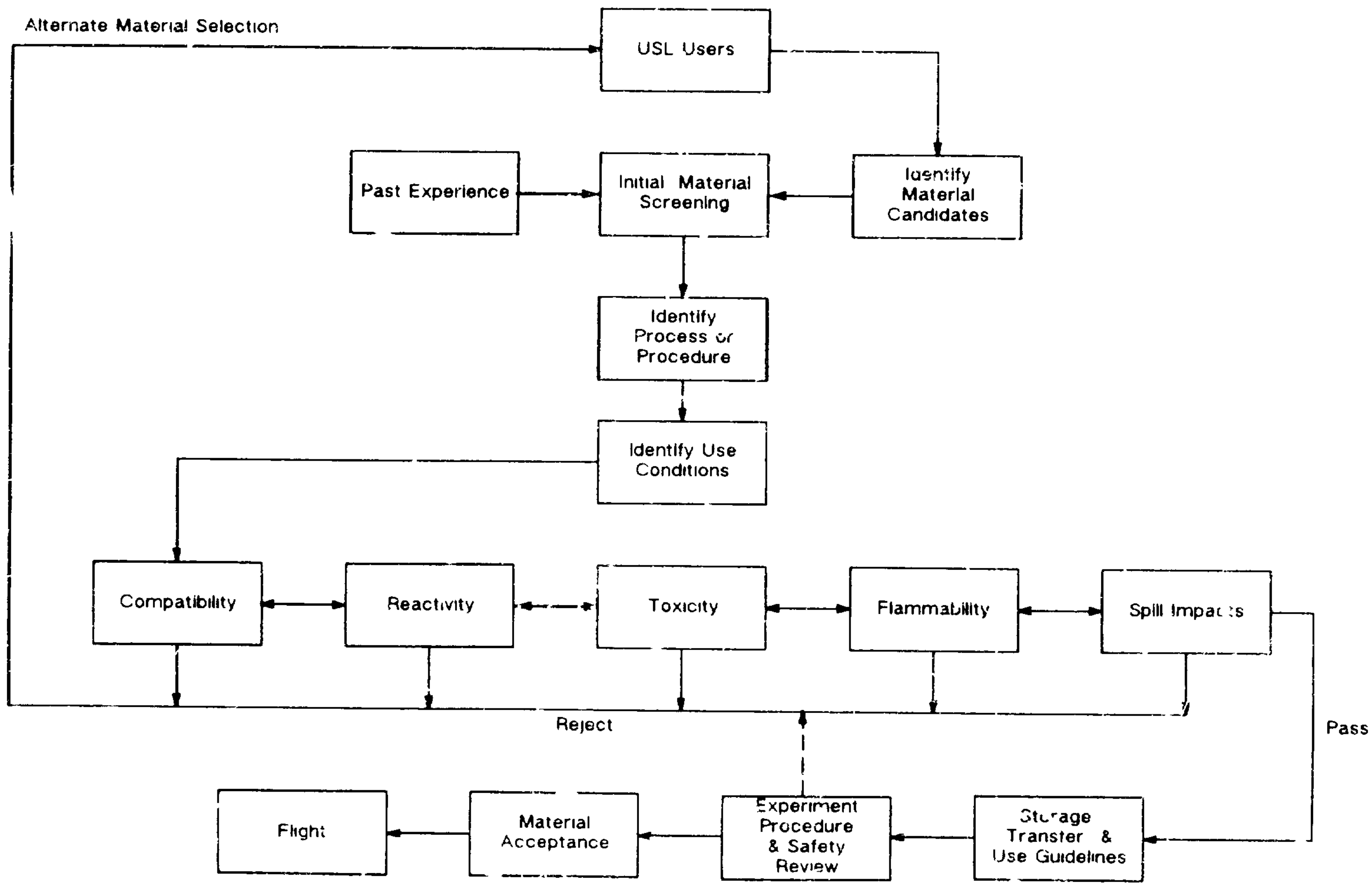
NASA

Criteria for USL Experiment Material Screening

Accommodation levels for storage, containment, and processing for sample, reagent and waste materials will be determined according to the following:

1. Concentration
2. Reactivity
3. Toxicity
4. Flammability limits
5. Chemical compatibility
6. Corrosiveness
7. Quantity
8. Use rate
9. pH
10. Solubility
11. Phase
12. Flash point
13. Latent heat of neutralization
14. Reaction and degradation products
15. Spacecraft maximum allowable concentration (SMAC)
16. Cleanup techniques
17. Detectable limits and detection techniques
18. Temperature and pressure conditions of use
19. Additional substances used in the same volume
20. Process or procedure performed
21. Storage, transfer, and use guidelines
22. Spill impacts on the ECLSS

Space Station USL Hazardous Material Control Procedure



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Develop USL Material Classifications and Waste Remediation Techniques

Segregate separately and store for further use or return to earth

Treat locally before central disposal

Treat locally before local disposal

Recover water from selected experiment operations

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PMMS Approach to Handling Chemical Classes

Local Treatment and Storage

Filter
Separate phases
Liquid storage
Segregate hazardous chemicals and return to proper storage *after* verifying containment

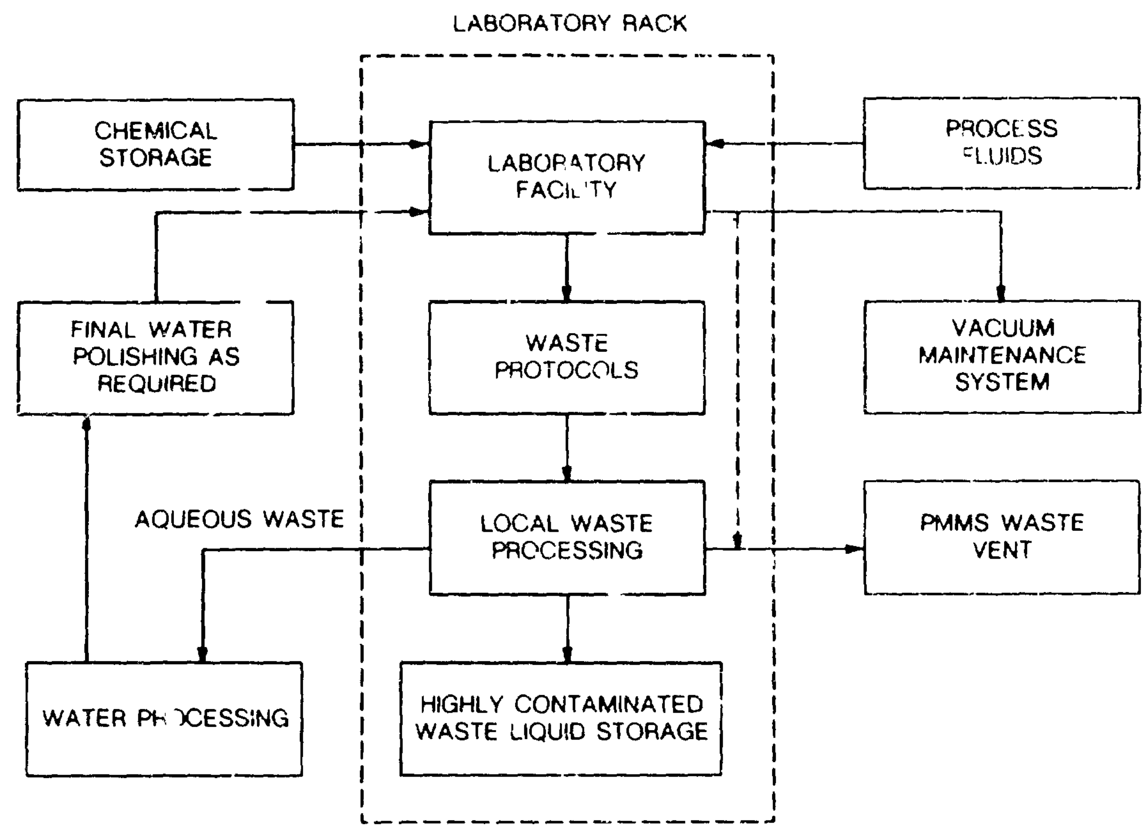
Transportation

Appropriate containment
Appropriate subsystem interfaces

Central Treatment and Storage

Filter
Separate phases
Reclaim water from candidate wastes
Inert gas purge potential for recycle

Rack-Level Waste Handling Methodology



Personal Protective Equipment

Goggles, face protection, or both

Gloves or proper material

Protective coat or suit as appropriate

General laboratory safety equipment

Summary

Requirements review

Hazard handling strategy

Hazard remediation strategy

Meet objectives and requirements of USL

DONALD E. STAFFORD

Principal
Compliance Consulting Services
Scottsdale, Arizona

Don is the founder and principal engineer of this service dedicated to assisting businesses, large or small, in meeting the demands of numerous local, state, and federal regulations pertaining to safety, health, and environmental issues.

Don received his BS in engineering at Arizona State University and has over twenty years of experience with the design and construction of semiconductor facilities and process equipment. A major effort at Motorola in the project management of a new GaAs crystal growth business followed by a major contribution in establishing a GaAs epitaxy business for Epitronics lead to a heavy involvement in hazardous materials issues.

Speaker and participant at numerous SEMI seminars on hazardous materials as well as participation with the Institute of Environmental Science and American Electronics Association.

GROUND BASED ELECTRONIC CRYSTAL GROWTH
SAFETY PRACTICES

- o KEY CONSIDERATIONS
  - * FACILITY SELECTION
  - * EQUIPMENT SELECTION
  - * PERSONNEL SELECTION AND TRAINING

- o DESIGN FOR SAFETY
  - * FACILITY
  - * EQUIPMENT
  - * PERSONNEL PROTECTION

- o TRAINING
  - * FACILITIES OPERATION
  - * EQUIPMENT OPERATION
  - * EMPLOYEE SAFETY

- o SUMMARY - Q&A

GROUND BASED ELECTRONIC CRYSTAL GROWTH SAFETY PRACTICES

A. FACILITY SELECTION

1. ASSESS HAZARDS PARAMETERS

   o TOXICITY

   o QUANTITY

   o SITE LOCATION

2. DEDICATE SPACE AND SERVICES

3. COMPARTMENTALIZE

   o SMALLEST CUBIC FOOT OF SPACE REQUIRED FOR PROCESS

   o MINIMIZE POSSIBLE CLEANUP AREA

GROUND BASED ELECTRONIC CRYSTAL GROWTH
SAFETY PRACTICES

B. EQUIPMENT SELECTION

1. IDENTIFY POSSIBILITIES FOR A CATASTROPHE

   o PRESENCE OF TOXIC SOLIDS OR GASES

   o FIRE POTENTIAL

   o CHEMICAL CONTAINMENT

2. DESIGN "IN" SAFETY FEATURES VS. ADD-AS-YOU-GO

3. EVALUATE VENDORS KNOWLEDGE OF HAZARDS

C. PERSONNEL SELECTION AND TRAINING

1. ESTABLISH BASELINE MEDICAL RECORDS

- o HEAVY METALS BASELINE
- o PULMONARY FUNCTIONS BASELINE

2. HAZARDS TRAINING

- o CLASSROOM BEFORE PRODUCTION AREA
- o EMERGENCY PROCEDURES
- o OSHA RIGHT-TO-KNOW
- o SPECIAL NOTES ON HANDLING HAZMAT

GROUND BASED ELECTRONIC CRYSTAL GROWTH
SAFETY PRACTICES

D. FACILITY SAFETY

1. FIRE PROTECTION

2. DETECTORS

   - SMOKE
   - TOXIC GAS
   - COMBUSTIBLE GAS

3. CENTRAL ALARM CENTER

   - MONITOR FIRE SYSTEM
   - MONITOR DETECTORS
   - EVACUATION ALARM
   - 24-HOUR MONITORING, ON OR OFF-SITE

4. CONTAMINATION SURVEILLANCE

   - WIPE SAMPLES
   - GAS/VAPOR DETECTOR PUMPS

E. EQUIPMENT SAFETY

1. DESIGN FOR SAFE OPERATION AND SHUTDOWN
   - REMOTE MONITORS OF CRITICAL PARAMETERS
   - REMOTE SHUTDOWN AT CENTRAL ALARM CENTER

2. DESIGN FOR CONTAINMENT OF TOXIC MATERIAL
   - HIGH VELOCITY EXHAUST HOODS
   - EXTENSIVE USE OF GLOVE BOX APPARATUS
   - NEGATE NEED FOR FULL-TIME RESPIPATORS

3. DESIGN FOR EXPEDIENT CLEANUP
   - ISOLATE AREA/EQUIPMENT
   - EASY BREAKDOWN OF EQUIPMENT

GROUND BASED ELECTRONIC CRYSTAL GROWTH
SAFETY PRACTICES

F. PERSONNEL PROTECTION

1. PROTECTIVE CLOTHING

   - DUAL USEAGE-CLEANROOM AND HAZMAT PROTECTION
   - CONSIDER DISPOSABLE GARMENTS, GLOVES

2. RESPIRATORY PROTECTION (OSHA 1910.134)

   - ROUTINE DUTIES VS. NON-ROUTINE DUTIES
   - AIR SUPPLIED VS. CHEMICAL CARTRIDGE
   - MASK MUST BE FITTED TO THE INDIVIDUAL
   - MEDICAL SURVEILLANCE REQUIRED
   - REQUIRES WRITTEN PROCEDURES

3. EYE/FACE PROTECTION

   - CHEMICAL SPLASH
   - FRAGMENTS

4. SPECIAL PROTECTION

   - HAZARDOUS MATERIAL CLEANUP
   - MAJOR FACILITY MODIFICATIONS

GROUND BASED ELECTRONIC CRYSTAL GROWTH
SAFETY PRACTICES

G. TRAINING

1. FACILITIES OPERATIONS

   - REVIEW WRITTEN PROCEDURES
   - HAZARDOUS MATERIALS MANAGEMENT
   - EMERGENCY RESPONSE

2. EQUIPMENT OPERATIONS

   - COMMUNICATE CHANGES
   - REVIEW WRITTEN PROCEDURES

3. EMPLOYEE SAFETY

   - SCHEDULED SAFETY MEETINGS
   - SEEK EMPLOYEE INPUTS
   - CONTINUAL REVIEW OF HAZARDOUS MATERIALS

N91-15943

IMPORTANCE OF BIOLOGICAL SYSTEMS IN INDUSTRIAL WASTE TREATMENT

POTENTIAL APPLIC'TION TO THE SPA'E STATION

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INTRODUCTION

Hazardous chemicals in the environment are a global concern and in recent years this subject has received considerable attention. The Congressional Office of Technology Assessment (OTA) (Hirschhorn et al. 1983) estimates that the costs for cleaning up existing sites containing hazardous chemicals could range from 80 to 300 billion dollars using conventional technology. These projected costs have stimulated several federal agencies to support research into the development of less expensive methods for treating hazardous chemicals. In recent years, with the support of the Federal Government, several such technologies have been developed, including incineration and vitrification. Although these technologies are effective in treating hazardous waste they are expensive.

An additional technology which is currently being developed is the use of microbial systems for the degradation and/or immobilization of hazardous waste. This latter technology has been shown to be effective in the treatment of some hazardous chemicals at costs that are less than conventional technologies.

Microbial degradation of waste is perhaps one of the oldest waste management system known to man. This system has been used for centuries to treat human waste (e.g., sewage). In fact, the majority of organic waste products, both natural and synthetic, are probable degraded by microorganisms (Alexander, 1981). Since many hazardous organics are related chemically to naturally occurring chemicals it is not surprising that microorganisms capable of degrading hazardous organic chemicals have been isolated from the environment (Cook et al., 1983; Ahmed and Focht, 1973; Fedorak and Westlake, 1984; Johnson and Talbot, 1983). Microorganisms capable of immobilizing hazardous chemicals through biological processes which facilitate adsorption, absorption and/or conversion of the chemicals have also been identified in the environment (Revis et al., 1988; Postgate, 1984).

Although several microorganisms isolated from the environment have been shown to degrade and/or immobilize hazardous chemicals the rates at which some chemicals are degraded and immobilized is very slow. For example, Brown et al. (1988) estimates that it would take approximately 300 years for microbial systems in the sediment from the Hudson River to completely dechlorinate existing concentrations of polychlorinated biphenyls (PCBs). Such slow rates would reduce the cost advantages of industrial application of microbial systems.

In an attempt to increase the rates of microbial degradation of organic chemicals, several investigators are exploring biochemicals pathways in microorganisms capable of degrading the organics (albeit at slow rates) with the hope of amplifying these pathways through genetics engineering. Since many of the degrading pathways require enzymes to metabolize the organics scientists are investigating methods for increasing the rate of synthesis of the degrading enzymes. In a recent study Rojo et al. (1988) engineered a Pseudomonas species capable of degrading chloro- and methylaromatics. This organism, prior to genetic engineering, was only capable of degrading chloroaromatics at relatively slow rates. However, after engineering, this strain the bacteria was capable of degrading both the chloro and methylaromatics at signicantly increased rates. Thus, genetic engineering may provide a method for increasing the rate at which microorganisms degrade hazardous organics. Because microbial systems used in waste treatment are generally less expensive than the conventional chemical and physical methods, further development of engineered organisms may prove to be the method of choice for treating hazardous chemicals in the environment.

In addition to having applications for waste management issues on planet earth, microbial systems may have application in reducing waste volumes aboard space craft. A candidate for such an application is the space station. The National Aeronautics and Space Administration plans to launch a space station by the year 2000. The station will serve to support the space research efforts of the United States and several western counties. Many of the planned experiments will generate aqueous waste. Because of space and weight limitations in the space station a need exists for: 1) minimizing the amount of aqueous waste generated, 2) reclycling of air and 3) recycling water. To recycle air and water the contaminants from previous experiments must be removed before the air and water can be used for other experiments. This goal may be achieved using microorganisms in a bioreactor.

Contaminants in the air and water may be removed via degradation, adsorption, absorption and/or precipitation by microorganisms. The microorganisms and contaminants are then both removed from the aqueous phase using ultra filtration. The air and water are recycled and the sludge is solidified by heating. It is of interest to note that water vapor from the heated sludge can also be collected if the contaminants in the sludge do not volatilize.

Potential Bioreactors for the Space Station

a) Inorganics

_ Described in Table 1 is a list of potential contaminants that may be found in air and aqueous waste generated from experiments planned for the space station. For the inorganics, several microbial systems have been shown to be effective in precipitating metals from solution. These metals include mercury, silver, cadmium, nickel copper, iron, and aluminum. However systems have not been identified, to the author's knowledge that precipitate gallium, tellurium, germanium, niobium, and indium. For arsenic, beryllium, silicon, and tungsten, microbial systems have been identified which adsorb and/or abso these metals.

b) Organics

Several microbial systems have shown to degrade the organics methanol, ethanol, acetone, benzene, trichloroethylene, xylene, and toluene (Table 1). Systems can also absorb and/or absorb the organics dimethyl sulfoxide, acetonitrile, trichloroethylene, carbon tetrachloride and sodium azide. To the authors knowledge microbial systems which degrade the organics glutaraldehyde, chlorodifluoromethane, trichlorotrifloroethane, and methyl ethyl ketone remain to be reported. However based on reports in the literature which describe microbes which can degrade chloroorganics, it is likely that microbes will eventually be found that can degrade chloro and fluoro compounds.

c) Etchants

A sulfate-reducing bacterium that metabolizes nitric and sulfuric acid to nitrogen and sulfide, respectively, would be an appropriate microbial system for reducing the levels of these acids in the aqueous waste. Furthermore, sulfuric acid could be used as a sulfate source in a bioreactor designed for the precipitation of metals through the formation of metal sulfides.

It is thus possible to reduce the concentration of many of the contaminants shown in Table 1 using microorganisms in a bioreactor. The microbial systems identified above for the organics, inorganics and etchants include both aerobes and anaerobes. Thus it may be necessary to maintain two bioreactors (e.g. an aerobic and anaerobic reactor).

ANTICIPATED WASTE FROM EXPERIMENTS PROPOSED FOR THE SPACE STATION

ORGANICS	INORGANICS	ETCHANTS
Acetonitrile,	Gallium,Iron	Acids
Ethanol, Methanol,	Arsenic,	Nitric
Acetone, Benzene,	Cadmium,	Hydrofluoric
Toluene, Xylene,	Germanium,	Sulfuric
Dimethyl sulfoxide	Tantalum,	
Dimethyl formamide	Beryllium,	Bases
Trichloroethylene,	Copper,	Sodium
Carbon tetra-	Aluminum,	Potassium
chloride, Na azide	Silver,	
Glutaraldehyde,	Indium,	Hydrogen
Chlorodifluoro-	Tungsten,	Bromide
methane,Trichloro-	Mercury,	Chloride
trifluoroethane, &	Tellurium, &	
Methyl ethylketone	Niobium	

RESULTS AND CONCLUSIONS

Sulfate-reducing bacteria reduce sulfate to sulfide under anaerobic conditions and in this process they derive energy. The sulfide is release from the bacteria as hydrogen sulfide (Figure 1). Following the displacement of hydrogen the sulfide will react with a variety of metals to give a metal sulfide. Since metal sulfides are relatively insoluble (Table 2) in aqueous solution they precipitate and the metals can be recovered through ultra filtration of the solution.

These bacteria will grow in solution containing metals at concentrations ranging from 0 to 10,000 ppm. An example of the effect of sulfate-reducing bacteria on metals is shown in Table 3. In this experiment bacteria were added to a solution containing sulfate, lead, cadmiun, mercury, nickel, copper, and zinc. After incubation at 32 °C for 14 h., the mixture was filtered and analyzed for the above metals. As shown, the filtration process reduced the concentration of all of the added metals. That these metals were not filterable suggests that they are in the sulfide form. Thus, metals which form metal sulfides are potential candidates for treatment with the sulfate-reducing bacteria. Since the metals gallium, tellurium, germanium, tantalum and indium can exist in the sulfide form they would be candidates for sulfide precipitation by sulfate-reducing bacteria. However experiments would be necessary to confirm this suggestion.

Sulfate-Reducing Bacteria Effect:
Toxic metals in soil, sediment, sludge

SULFATE-REDUCING BACTERIA
\+ sulfate and nutrients

|

|

HYDROGEN SULFIDE

\+

IONIC METALS
in soil, sediment or sludge

|

|

METAL SULFIDE

Metals, Cd, Hg, Pb, Cu, Ag, Ni, Sn

Solubility of Metal Sulfides
in aqueous solution

Metal	Metal Sulfide	Solubility ug/liter
Cadmium	CdS	.00000087
Cobalt	CoS	.000016
Copper	CuS	.0000000000000088
Lead	PbS	.0000043
Mercury	HgS	.0000000000000000011
Nickel	NiS	.00011
Silver	Ag_2S	.0000000084
Tin	SnS	.00004[illegible]

Precipitation Heavy Metals by Sulfate-Reducing Bacteria

Metal	Permit Level ppb	Concentration after filtration ppb Starting	Final
Cadmium	1000 *	500	2.5
Mercury	200 *	100	0.5
Nickel	3980 **	10,000	2,400
Zinc	300 **	1,000	100
Copper	22 **	780	130
Lead	5000 *	10,000	620

* Discharge permit levels under RCRA
** Discharge permit levels for DOE-ORO as specified by region 4 EPA

Incubation 14 h. at 32 degrees

Sulfate-reducing bacteria have also been associated with the degradation of ethanol, methanol, acetone and toluene (Postgate, 1984). The degradation of these organics appear to occur when sulfate levels in the medium is low. The rates of degradation for these organics remains to be determined. Thus experiments would be necessary to determine the degradation rate and whether this bacteria can degrade some of the other organics shown in Table 1.

For the removal of metals from solution, an aerobic bacteria has recently been identified which will reduce ionic metals to the elemental form. This bacteria has been shown to reduce mercury, silver, selenium, copper, lead, gold, platinum, and cadmium to the elemental form (Figure 2). Results from experiments showing the effects of this bacteria on the above metals are shown in Table 4. The above metals in the chloride form (except for selenium which added as Na_2SeO_3) were added to medium containing the bacteria <u>Psuedomonas maltiphila</u> (O2) and incubated at 32 °C for 14 h.. After incubation, the samples were filtered through an 0.45 u filter and the filtrate was analyzed for the above metals. As shown, the soluble concentration of most of these metals were reduced by 10-fold. This bacterium has also been used to treat photographic fixer waste with results showing that silver in the fixer could be reduced to 0.005 ppm (the initial silver concentration was 10,000 ppm). The bacterium has been shown to grow on either methanol and ethanol alone, which suggests that it can degrade these organics.

Microbial Reduction of Metals to the Elemental Form

Reaction:

++Hg + BACTERIA (2 electrons) ->

oHg + BACTERIA

oHg in aqueous solution is removed by cross flow filtration (0.45 u filter)

OTHER METALS

Lead	(2+)
Csdmium	(2+)
Silver	(1+)
Tin	(2+)
Selenium	(2+)
Gold	(1+)
Copper	(2+)

Effective in Aqueous Solution

BACTERIAL REDUCTION OF Pb^{++}, Hg^{++}, Se^{+} Ag^{++}, Pt^{++}, and Cu^{++} to ELEMENTAL METAL

METAL	INITIAL ppm	FINAL ppm
Pb^{++}	922	50
Hg^{++}	3000	6.2
Se^{++}	4500	33
Ag^{++}	5800	1.8
Pt^{++}	1100	19
Cu^{++}	3600	80

BACTERIA INCUBATED IN MEDIUM WITH THESE METALS FOR 14 h. AT 32oC. THIS MIXTURE WAS FILTERED AND FILTRATE ANALYZED FOR THESE METALS

Several microbial systems have been investigated that reduce the solubility of inorganics in aqueous waste. These inorganics can be removed from the aqueous waste by ultra filtration. In contrast, only a few microorganisms have been identified that can degrade most of the organics shown in Table 1. Furthermore, results showing that microorganisms can degrade the organics glutaraldehyde, chlorodifluoromethane and trichlorotrifluoroethane remain to be reported. However, through genetic engineering one may develop an organism that can degrade these three organics. Thus it would seem highly plausible that microorganisms could be used to treat the aqueous waste generated in experiments abroad the space station.

Clearly, additional studies would be necessary to design a bioreactor for treating the aqueous waste. However, as discussed above, biological waste treatment systems are effective in reducing the concentration of hazardous waste and may be considerable less expensive than the chemical and physical technologies currently available for waste treatment. In summary, Tables 5, 6 and 7 describe the current technologies that may be applied to waste treatment, and provide examples of how biological systems may be used in treating waste on the space station.

POTENTIAL TREATMENT METHODS FOR WASTE ON THE SPACE STATION

TREATMENT METHODS:

1) Filtration
   a. ultra
   b. charcoal (organics)
   c. resins (inorganics)

2) Store and return to earth

3) Chemical and/or physical methods

3) Biological methods

BIOLOGICAL PROCESSES IN MICR.
FOR WASTE TREATMENT

PROCESSES

ADSORPTION	(Cell surface)
ABSORPTION	(internalize)
CONVERSION	(sulfide or elemental)
METABOLISM	(carbon dioxide and water or less toxic metabolite)

BIOREACTOR FOR THE REMOVAL OF CONTAMINANTS IN SPACE STATION AQUEOUS WASTE

BIOREACTORS

Anaerobic

1. Sulfate-reducing bacteria,
aqueous waste (metals + organics),
nutrients ---------->
2. Solution containing metal sulfides
3. Filtration of this solution ------>
metal sulfide sludge + degraded
organics + reusable water

Aerobic

1. Psuedomonas Maltiphilia (02),
aqueous waste (metals + organics),
nutrients ------------>
2. Solution containing elemental metals
3. Filtration of this solution ------>
sludge containing elemental metal +
degraded organics + reusable water

1. Psuedomonas (Putida B-13),
aqueous organic waste,
nutrients -------------->
2. Solution containing degraded organic
3. Filtration of this solution ----->
bacterial sludge

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CONTROLLED DECOMPOSITION AND OXIDATION -- A TREATMENT METHOD FOR GASEOUS PROCESS EFFLUENTS

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ABSTRACT

The safe disposal of effluent gases produced by the electronics industry deserves special attention. Due to the hazardous nature of many of the materials used, it is essential to control and treat the reactants and reactant by-products as they are exhausted from the process tool and prior to their release into the manufacturing facility's exhaust system and the atmosphere.

Controlled decomposition and oxidation (CDO) is one method of treating effluent gases from thin film deposition processes. This report discusses CDO equipment applications, field experience, and results of the use of CDO equipment and technological advances gained from field experiences.

INTRODUCTION

A number of extremely hazardous gases are routinely used by the semiconductor and photovoltaic industries to manufacture integrated circuits and other devices. Although the processes generally consume only small quantities of these gases, the nature of the gases is such that even small amounts of gas can do considerable damage to people and equipment in a very short time.

Effective controlled process exhaust gas conditioning has been and is becoming an issue of growing concern for specialty gas processors, process equipment manufacturers, users of process equipment various governmental agencies, insurance underwriters, and the general public.

CODES AND REGULATIONS

During the last few years, there has been and continues to be growing concern over finding safer methods of storing, dispensing, and monitoring these gases. More recently, the disposal of these gases has been receiving greater and greater attention.

In response to growing concern over toxic substance problems, Congress has enacted over two dozen regulatory statutes covering the routes by which certain chemicals or aspects of chemical use can threaten human health and the environment.

The laws are administrated by various federal regulatory agencies. The Occupational Safety and Health Administration (OSHA) has been given responsibility to insure a safe workplace. It sets mandatory job safety and health standards and provides reporting procedures for all industrial injuries and fatalities. The Environmental Protection Agency (EPA) attempts to prevent further poisoning of the environment by requiring industry to develop air quality control. The Federal Water Pollution Control Act dictates controls to improve water quality. The Toxic Substances Control Act regulates the use of certain toxic materials and establishes a toxic substance data base, while the Resource Conservation and Recovery Act gives EPA added authority over how waste materials are disposed.

The Department of Transportation sets standards for labeling (DOT Hazard System), packaging, testing, and handling compressed gases. Other agencies such as NIOSH (part of OSHA), the Uniform Building Code (UBC) and its companion document, the Uniform Fire Code (UFC), and other codes and state and local regulations have meaningful mandates that also deserve our attention.

The UBC published by the International Conference of Building Officials is the most widely used model building code in the country. It is the code for the western United States. The Basic/National Building Code is used primarily in the northeastern part of the country, and the Standard Building Code is used almost exclusively in the southeastern part of the country.

Occupancy is one of the primary regulatory criteria in the building code and is based on the use or occupancy in the proposed building. The seven major classes or Occupancy Groups are:

A - Assembly
B - Business
E - Educational
H - Hazardous
I - Institutional
M - Miscellaneous
R - Residential

Within each of these Occupancy Groups are sub-categories called Divisions. In Group H Occupancy, there are six Divisions; and Division 6 may be briefly defined as semiconductor fabrication facilities.(2)

"Division 6. Semiconductor fabrication facilities and comparable research and development areas when the facilities in which hazardous production materials are used and constructed in accordance with Section 911 and when storage, handling, and use of hazardous materials is in accordance with the Fire Code." (2)

The UFC, which is the product of the Western Fire Chiefs Association, is a companion document to the UBC. Many provisions of the codes are interrelated and cross referenced. Administratively, the fire code is organized into eight basic parts consisting of one or more articles in each part. (4)

Part I Administration
Part II Definitions and Abbreviations
Part III General Provisions for Fire Safety
Part IV Special Occupancy Use

Part V Special Processes
Part VI Special Equipment
Part VII Special Subjects
Part VIII Appendices

Article 51 of the UFC, which is companion to H-6 of the UBC, appears in part V of the fire code. Article 51 deals with controls required for the utilization of hazardous materials in the production of semiconductor devices and related research functions. The required controls relate to the nature of materials encountered, their physical state, and the condition in which they are found in the building, i.e., storage, handling, or use. Control over the materials is achieved by limiting the amount of material in use at any particular work station and applying engineering controls such as sprinklers, automatic leak detection, local exhaust, and warning systems. (4)

The purpose of the UBC and UFC is to protect the public by regulating the construction, alteration, and maintenance of structures and the storage, handling, and use of hazardous materials. The codes establish certain minimum criteria that define the code intent. The UBC and UFC are concerned with fire and related hazards. The codes may be adopted locally or on a statewide basis. The adoption may be made by ordinance or by a legislative act.

An excellent reference concerning H-6 Occupancy is available through Larry Fluer, Inc., P.O. Box 10386, San Jose, CA 95157.

Two new pieces of "legislation" confronting the semiconductor wafer fabrication industry and other institutions using hazardous materials are:

1. Uniform Fire Code - Article 80 Rewrite
2. California Assembly Bill #1021

Previously the codes primarily addressed the storage, dispensing, and monitoring of hazardous materials. With the addition of Article 80, the codes now address STORAGE, DISPENSING, MONITORING, and DISPOSAL.

CONTROLLED PROCESS EXHAUST GAS CONDITIONING

Effective controlled process exhaust gas conditioning has been and is becoming an issue of growing concern for specialty gas processors, process equipment manufacturers, users of process equipment, various governmental agencies, insurance underwriters, and the general public.

Exhaust gas conditioning or removing harmful substances from process exhaust gases is not necessarily needed for succesful device wafer fabrication; and perhaps since exhaust gas conditioning equipment is not revenue producing, its importance has not been previously fully acknowledged. However, Factory Mutual, a leading insurance company for semiconductor manufacturers, reports $60,000,000 in claims were paid for 112 incidents from 1974 through 1986. The $60,000,000 reported by Factory Mutual does not include claims covered by other underwriters, unreported losses, and self-insured claims. Fire was by far the most frequent cause of loss and the ignition of flammable and pyrophoric gases was the leading cause of fire. Hydrogen and silane gases were involved in approximately 90 percent of the reported incidents.

Table I: SEMICONDUCTOR PLANT LOSSES
1974 THROUGH 1986 $60,000,000

CAUSE	NUMBER OF INCIDENTS
Fire	72
Liquid Leakage or Spillage	29
Human Element	11
TOTAL	112

Table II: CAUSES OF FIRES AT SEMICONDUCTOR PLANTS

CAUSE	NUMBER OF INCIDENTS
Ignition of Flammable or Pyrophoric Gases (27 of the 29 or approximately 90% involved Hydrogen or Silane)	29
Electrical Origin	20
Immersion Heaters	13
Ignition of Flammable Liquids	6
Hot Plates	4
TOTAL	72

Although exhaust gas conditioning may not be essential for semiconductor wafer fabrication, it is important for the protection of personnel, protection of the environment, and, as stated above, the protection of the manufacturing facility.

The contaminants encountered in process exhasut gas streams are extremely varied. Rarely does an exhaust stream contain only one classification of contaminant -- whether it be particulate, gas, or vapor. While the gases introduced into almost all semiconductor wafer fabrication processing chambers are well defined, the composition of the gas mixture exiting the process chamber is generally not precisely defined. Furthermore, since the mid 1970's, there has been an ever increasing utilization of subatmospheric or reduced pressure (vacuum) processing in semiconductor wafer fabrication. This has introduced additional unknowns such as pump oil vapors into the process effluent.

For the most part, reactive gases are not released unreacted from a process chamber; and in most cases, the gases are present only in low concentrations. However, almost all are highly toxic (AsH_3, PH_3, B_2H_6), pyrophoric (SiH_4), flammable (H_2), or corrosive (HCl). Hydrogen (H_2) is a by-product of all hydride (SiH_4, AsH_3, B_2H_6, PH_3) reactions; and under controlled exhaust conditions, SiH_4 can be the ignition source for a serious H_2 reaction.

"THE PENINSULA TIMES TRIBUNE

DAMAGE MAY RUN HIGH IN FIRE A LOCAL PLANT
MOUNTAIN VIEW -
...The fire, ignited by gas and vaporized oil, spread through an air duct system in a fabrication room where valuable silicon chips are manufactured.
...The fire began in an air duct system where vaporized oil from a vacuum pump and gas from a malfunctioning reactor had collected."

No manufacturer wants a mishap due to improperly handled exhaust gases to end up in the morning paper.

In the past, dilution or simple water washing was employed to dispose of exhaust gases. Dilution to "safe" levels has long been an accepted practice, but public sentiment and new codes are diametrically opposed to any practice in which chemicals of any kind are released into the atmosphere untreated.

Conscientiously, we should address pounds per hour, not parts per million (ppm).

"DILUTION IS NO SOLUTION TO POLLUTION!"

Plain water scrubbing is ineffective for most of the hazardous gases encountered in wafer fabrication.

SOURCE VS. CENTRAL EXHAUST GAS CONDITIONING

Exhaust gas conditioning equipment may be divided into two broad categories -- source and central systems.

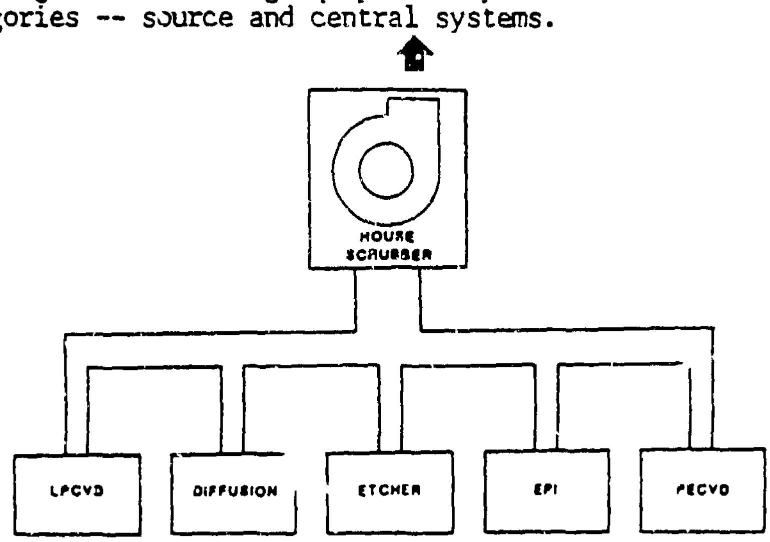

Fig. 1. Central Conditioning - Multi process tools with incompatible exhaust effluent entering common duct system and being transported to remotely located exhaust treatment system.

Because of the nature and low volume of effluent exiting most wafer fabrication systems, it is desirable and more effective to conditioning process exhaust gases as close to their source as is physically possible.

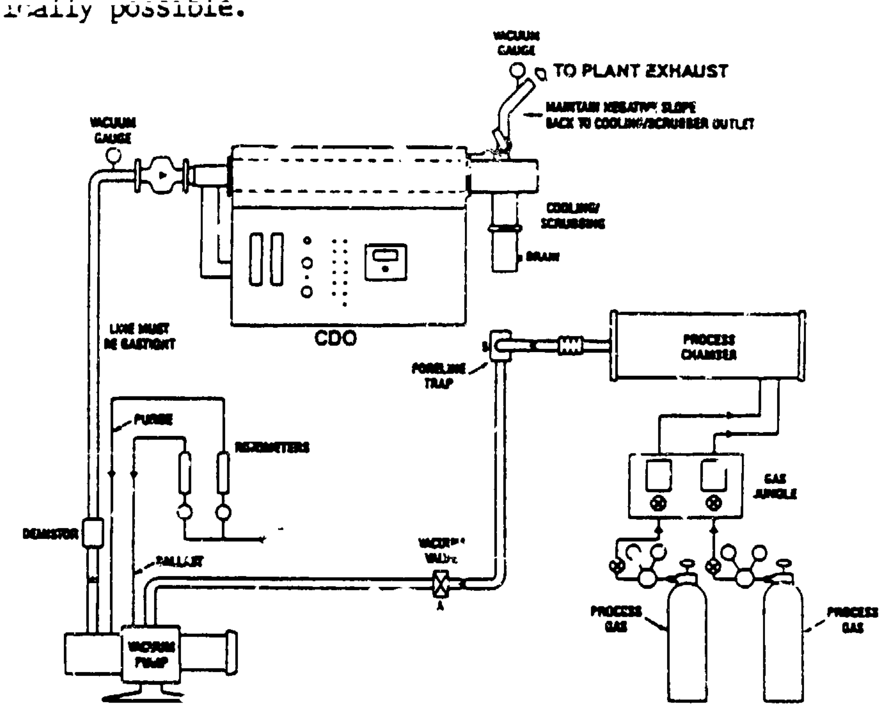

Fig. 2. Source Conditioning - Dedicated gas treatment system located as close to process tool exhaust as physically possible.

Because of the nature of the gases and vapors exiting most process systems and based on the interpretation of codes and regulations, source conditioning may be mandatory in the future. From UFC Article 51: "Duct Systems - Reactives. Two or more operations shall not be connected to the same exhaust system when either one or the combination of the substances may constitute a fire, explosion, or chemical reaction hazard within the duct system." (4)

Also, Section 1105 of the 1985 Edition of the Uniform Mechanical Code: "A mechanical ventilation or exhaust system shall be installed to control, capture, and remove emissions generated from product use or handling when required by the Building Code or Fire Code and when such emissions result in a hazard to life or property. The design of the system shall be such that the emissions are confined to the area in which they are generated by air currents, hoods, or enclosures, and shall be exhausted by a duct system to a safe location or treated by removing contaminants. Ducts conveying explosives or flammable vapors, fumes, or dusts shall extend directly to the exterior of the building without entering other spaces. Separate and distinct systems shall be provided for incompatible materials."

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CONTROLLED "SOURCE" PROCESS EXHAUST GAS CONDITIONING IS:

1. THE WAVE OF THE FUTURE
2. EVOLUTIONARY/EVOLVING
3. MORE EFFECTIVE
4. DESIRABLE
5. SAFER
6. ESSENTIAL TO COMPLY WITH CODES

PROCESS TOOL EXHAUST

Many of the process systems in use today and proposed for the future are sub-atmospheric pressure systems utilizing vacuum pumps.

The required pumping systems for sub-atmospheric processes are fairly well defined and for simplicity may be broken down into three areas (see Fig.1): foreline (inlet), pump, and exhaust.

That portion of the pumping system connecting the process chamber to the vacuum pump may be called the foreline or inlet. The foreline generally includes a flexible stainless steel interconnect line, a particulate trap, and a vacuum valve. Pumping precautions which should be taken include:

(a) preventing the condensation or trapping of chemicals in the pump rotor and stator area;
(b) preventing oxygen from entering the pump (i.e., through the ballast valve);
(c) preventing the accumulation of explosive, toxic, and/or corrosive gases in the dead volume of the pump oil reservoir.

Items (a) and (b) may be accomplished by injecting a 1 to 2 SLM dry nitrogen flow into the pump ballast inlet. Since most pumps are equipped with an inlet to the pump oil chamber, item (c) may be accomplished by flowing 2 to 3 SLM of dry nitrogen into this inlet. Another effective technique for the oil chamber purge is to bubble the dry nitrogen through the pump oil. This dry nitrogen flow will help to dilute and eject the explosive, toxic and/or corrosive gases from the pump oil chamber. Ideally, regulators, flow meters, and pressure gauges should be used to set and monitor the dry nitrogen gas flow.

It should be noted that large flows of purge gas through the oil chamber may result in an unreasonable loss of fluid from the pump due to rapid removal of fluid vapor. Excessive nitrogen purge may also dilute the exhaust gases to such a diluted concentration as to be detrimental to effective exhaust gas conditioning.

The effluent exiting the pump casing frequently contains pump fluid vapors and toxic and flammable or explosive gases. An uncontrolled mixing of the reactive gases (i.e., silane or hydrogen) with air can create explosive conditions. Uncontrolled discharge of toxic gases (i.e., arsine, diborane, and phosphine) can create environmental as well as personnel hazards. Unconditioned vacuum pump fluid vapors can condense in exhaust ducting causing maintenance and health and safety hazards.

The toxicity and flammability of vacuum pump effluent is hazardous enough that particular attention should be given to "gas-tightness" of the entire high pressure (exhaust) section and to the "conditioning" or treatment of the pump effluent prior to its release into the atmosphere.

The design of the gas exhaust line mounted on the discharge port of a mechanical pump should follow certain basic reules (see Fig.2):

a) Exhaust lines should be sized so as not to create pump discharge back pressure.
b) The exhaust line should be constructed of gas tight metal tubing. Stove pipe type 'jointed' ducting should not be used as it is not air tight. Air must not be allowed to mix with the gases prior to conditioning.
c) The line should have slightly sub-atmospheric pressure (½ inch to 1 inch of water below atmosphere) to assist in ejecting the effluent. However, this pressure should not be so low (i.e., 8 to 9 negative inches of water) that excessive pump oil vapors are sucked from the pump.
d) A pressure gauge should be installed on or just downstream of the pump exhaust port to monitor exhaust line pressure.
e) The exhaust line should incorporate a device to condense fluid vapors from the pump effluent.
f) "Conditioning" of the pump effluent is necessary for personnel safety, protection of property, and protection of the environment.
g) Pressure (vacuum) gauges should be mounted on the inlet and discharge sides of the conditioning equipment.

While the gases introduced into the process chamber are generally well known, the composition of the gax mixture exiting the process chamber, passing through, and exiting the pump is generally not precisely defined. However, the pump effluent generally contains enough toxic, explosive and combustible materials that effluent "conditioning" is essential

TABLE III: TYPICAL SUBATMOSPHERIC CVD GASS EFFLUENT

CVD PROCESS	PROCESS GASES	PROCESS EFFLUENT
Poly	SiH_4	Si, SiH_4, H_2, Pump Fluid Vapors
Doped Poly	SiH_4, PH_3	Si, SiH_4, PH_3, H_2 Pump Fluid Vapors
Low Temperature Oxide (400°C)	SiH_4, O_2, PH_3	SiO_2, SiH_4, O_2, PH_3, H_2, Pump Fluid Vapors
Tungsten?Tungsten Silicide	SiH_4, WF_6. H_2	WF_6. WFx, SiH_4, SiHx, H_2, N_2, Pump Fluid Vapors

PROCESS EXHAUST GAS CONDITIONING

Controlled combustion is a method of reducing the toxic and flammable hazards of vacuum pump effluent.

Process exhaust gases enter the Controlled Combustion, Decomposition, Oxidation (CDO™) System (see Fig. 3) through the unit's flame check and under controlled conditions are mixed with an oxygen source in the oxygenator. The oxygen enriched gases then flow through a high temperature section where combustion takes place and exit the CDO™ System through a water mist cooling and scrubber section. Gases and pump oil vapors and combusted and oxidized.

In the CDO™ unit, the pump effluent is oxygen enriched under controlled conditions and exposed to a high temperature environment thereby increasing the liklihood of a complete chemical reaction.

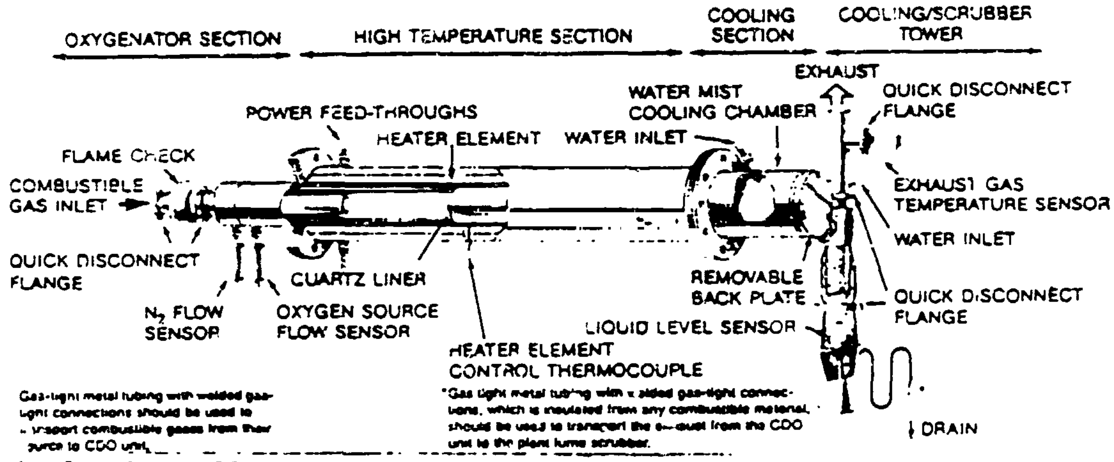

Fig 3. Controlled Combustion, Decomposition, and Oxidation System Cross Section

Control of time, temperature, turbulence, and oxygen is essential for complete reaction. Time is the period of residence of the waste gas(es) in the combustion chamber. Time is a function of combustion chamber length and diameter and gas volume.

Temperature is the temperature of the waste gas(es) in the combustion chamber. Turbulence is necessary to insure the proper mixing of the waste gas(es) and the oxygen source. Oxygen is required to support the complete reaction of the waste gas(es).

As reported by Arco Solar, Inc. in their January, 1937, "Evaluation of Hazards Associated With the Manufacture of Thin Film Solar Cells for Brookhaven National Laboratory": "The CDO approach has been shown to be highly effective in the controlled combustion of silane and diborane, the results suggesting performancy efficiency approaching 100% for silane. However, under the defined operating conditions, the system appears less efficient in the removal of phosphine." (11)

Since publication of the Arco report, Innovative Engineering Inc. has performed extensive testing with arsine, diborane, and phosphine.

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N91-15945

The Reactive Bed Plasma System for Contamination Control

by Joseph G. Birmingham, Robert R. Moore and Tony R. Perry

Introduction

In August 1987, NASA provided the Plasma Group at the Chemical Research, Development and Engineering Center (CRDEC) a list of chemicals including liquids, vapors, and particulates that are anticipated to cause contamination problems aboard the Space Station (1). CRDEC has selected several of these compounds to test an invention described as the Reactive Bed Plasma reactor. The objective of this paper is to summarize the contamination control capabilities of the Reactive Bed Plasma (RBP) system by delineating the results of toxic chemical decomposition studies, aerosol filtration work, and other testing.

Description of Reactive Bed Plasma

The Reactive Bed Plasma (RBP) was invented at the Chemical Research, Development and Engineering Center (CRDEC) to provide breathable air in chemical and biological warfare environments. The RBP is a synergistic combination of a plasma (or ionized gas) and catalytic technologies to produce an air purification system. The catalytic packing material's main function is to facilitate an increased amount of time in the active plasma region for contaminant molecules in a flowing air stream. The plasma generated high energy electrons and subsequently produced species decompose toxic materials. In addition, the RBP can perform as a highly efficient electrostatic precipitator to collect and eventually deactivate hazardous particulate material. Since, the RBP can handle toxic chemicals as well as hazardous aerosols, it can be described as an universal filter.

It is understood that trade-offs exist for any new technology. Some disadvantages of the RBP concept include the emission of electromagnetic noise (necessitating the shielding of the device), high voltage hazards and the treatment of reaction products. The advantages of the RBP include the potential for operating as an efficient, low temperature, long-lived, minimal energy-consumption, universal contamination control device.

Toxic Chemical Decomposition Studies

The list of chemicals provided by NASA included liquids and gases such as chlorinated compounds (such as hydrochloric acid, trichloroethane and chlorine), organics (such as benzene), and others. The RBP system has been tested against several compounds including cyanogen chloride (2), phosgene (3) and benzene (4). These test gases allow the contamination control capability of the RBP to be extrapolated to many chemical groups. Each gas's decomposition results reveals an important attribute of the RBP system. The efficient decomposition of cyanogen chloride demonstrated that the RBP did not exhibit the

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characteristic poisoning mechanisms of catalysts. Additionally, the phosgene results indicated that the RBP utilizes low temperatures (around 150 degrees C) and its performance does not degrade quickly. Also, any hydrochloric acid formed was converted to chlorine (as expected from a low temperature process). Finally, the benzene testing showed that the RBP can easily decompose organics flowing in ar air stream. The main reaction products from these decomposition studies include carbon dioxide and water, salts, and small amounts of acid gases (including halogens from the parent compounds and nitrogen dioxide from the air stream). The RBP has demonstrated the potential as a low temperature, efficient and universal decomposition system for hazardous compounds in a flowing air stream.

Aerogol Processing in RBP

Particulate materials on NASA's Contamination Control list include Polystryene Latex Spheres, microbes(which might include Bacillus Globigi spores and T-2 mycotoxin), and semiconductor processing aerosols. The Reactive Bed Plasma (RBP) reactor combines electrostatic precipitation with a packed bed to form a new aerosol filtration device. The testing of the RBP with Polystryene Latex spheres revealed that the RBP was a more efficient filter than for the empty plasma reactor (electrostatic precipitator) or a single packed bed (5). The biological aerosol challenges of the RBP including Bacillus Globigi spores (a heat resistant simulant for pathogenic species) and T-2 mycotoxin demonstrated efficient deactivation and decomposition, respectively (6). The RBP could become an ultrafiltration device with the incorporation of a ceramic High Efficiency Particulate Aerosol (HEPA) filter. Therefore, the RBP has the potential to become an aerosol filtration device for many applications.

Post-treatment of RBP Effluent

The requirement to neutralize any products found in the reactor effluent will be undertaken in the post-treatment section of the RBP system. Two approaches of removing the reaction products are packed beds and gas separation membranes. First, packed beds consisting of reactive material coated onto alumina support spheres has demonstrated the efficient removal of nitrogen dioxide and chlorine. This packed bed system will undergo additional testing. Next, some contamination control applications would allow a gas separation membrane to separate products to undergo further treatment in a scrubber solution. Since post-treatment burdens for contamination control are minimal, the solutions suggested may be adequate.

Contamination Control Approach Utilizing an RBP

The Reactive Bed Plasma (RBP) system has demonstrated the capability of efficiently processing many of the chemicals suggested by NASA. The ability to process liquids will require vaporization of the contaminate materials. This phase change may require the use of heat and air to introduce the hazardous

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material into the RBP. Alternately, waste gases can be processed directly. Additional work is required to meet the stringent size, weight and volume constraints of the Space Station. Nevertheless, it is believed that the Reactive Bed Plasma system can provide contamination control for many applications.

Summary

The Reactive Bed Plasma (RBP) system has demonstrated its unique capabilities to decompose toxic materials and process hazardous aerosols. The post-treatment requirements for the reaction products have possible solutions. Although additional work is required to meet NASA requirements, the RBP may be able to meet Contamination Control problems aboard the Space Station.

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Reactive Bed Plasma System for Contamination Control

by Joseph G. Birmingham,
Robert R. Moore, and
Tony R. Perry

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(301) 671-2143

Reactive Bed Plasma Presentation

I. Introduction

II. Toxic Chemical Decomposition

III. Aerosol Filtration

IV. Post-Treatment of Reactor Effluent

V. Contamination Control Application

REACTIVE BED PLASMA DEFINITION AND OBJECTIVE

- REACTIVE BED PLASMA: The synergistic coupling of plasma (or ionized gas) and catalysis
- OBJECTIVE: To develop and demonstrate Reactive Bed Plasma technology to treat pollutants released into the environment
- GOAL: Technology Transfer to industry

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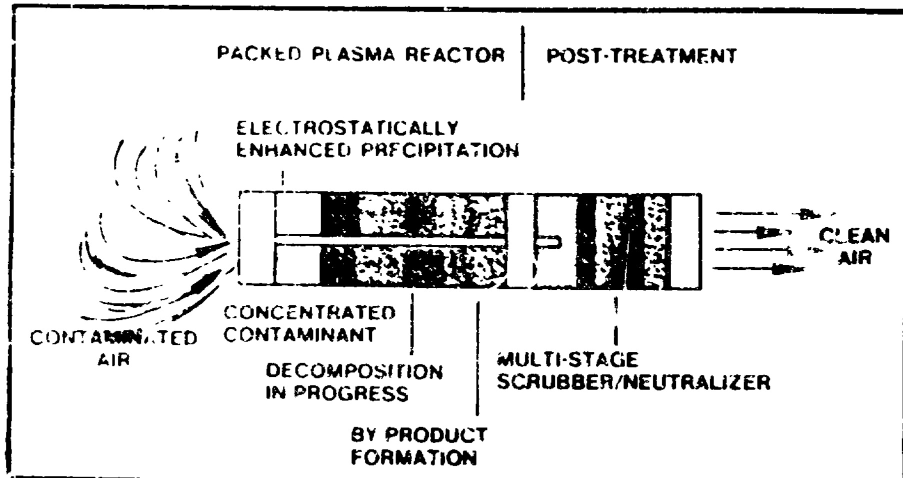
COLLECTIVE PROTECTION

REACTIVE BED PLASMA



- PLASMA IS AN ELECTRICALLY NEUTRAL, HIGHLY IONIZED GAS COMPOSED OF ELECTRONS AND IONS

STATUS

- LABORATORY INVESTIGATIONS ONGOING TO ESTABLISH TECH DATA BASE ON REACTION MECHANISMS AND POST-TREATMENT
- SCALE-UP

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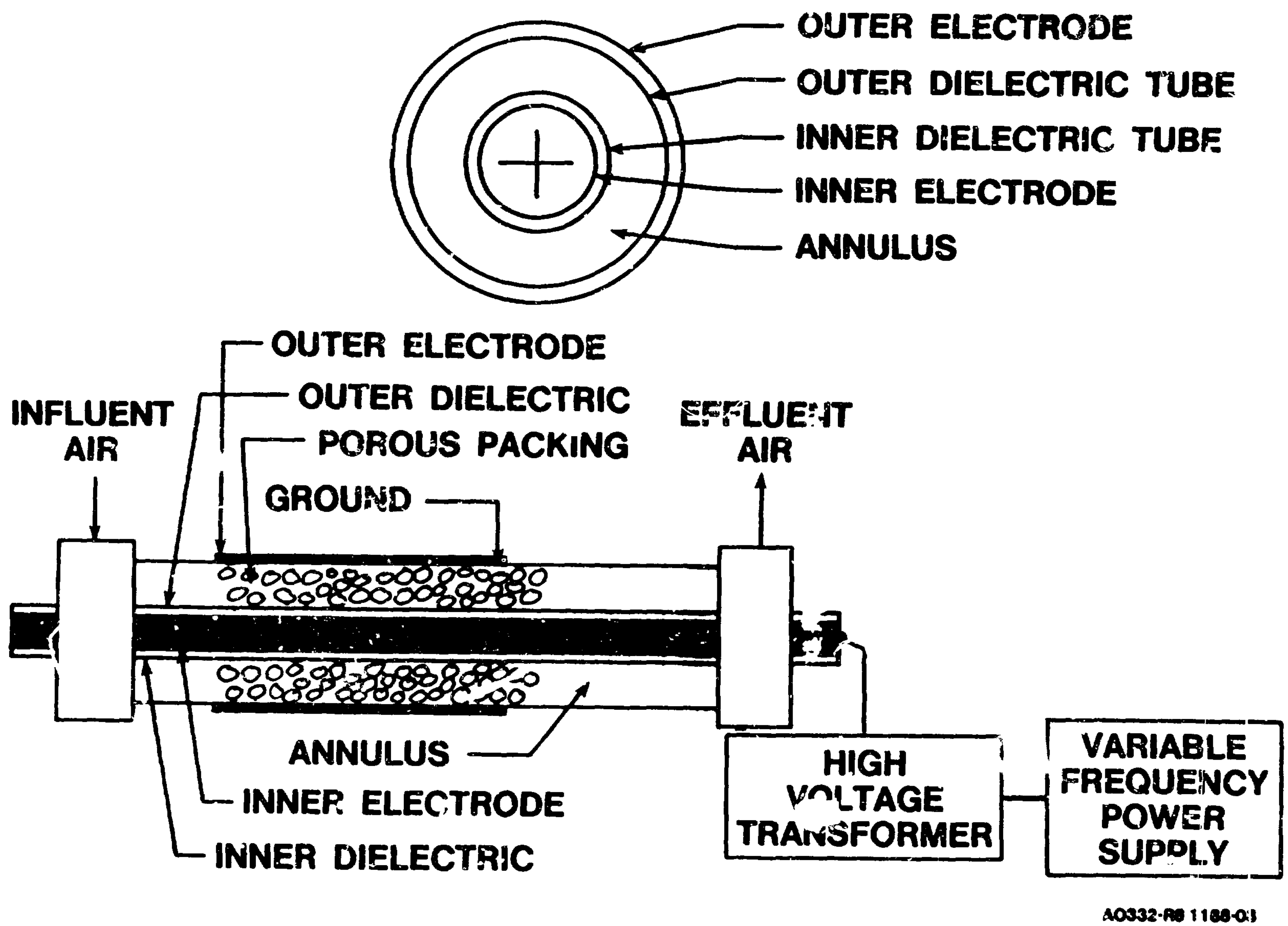
REACTIVE BED PLASMA



Reactive Bed Plasma Presentation

I. Introduction

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Contamination Materials

- Liquids including:
  - Acids (Acetic, Nitric, Hydrochloric, Perchloric, Hydrofluoric)
  - Organics (Benzene, Xylene, Toulene, Phenol, Trimethyl Benzene)
  - Hydrocarbons (Methanol, Trichloroethylene, Acetone, Dichloromethane, Trichloroethane)
  - Others

Contamination Materials

- Gases including:
  - * Air Components (Oxygen, Nitrogen, Argon, Helium, Hydrogen)
  - * Light Hydrocarbons (Methane)
  - * Carbon Monoxide / Carbon Dioxide
  - * Freons (Freon 22, Freon 113)
  - * Acid Gases (Chlorine, Fluorine)
  - * Others

RESULTS

CHEMICAL PROCESSING	% DECOMPOSITION
GD (Nerve Agent)	> 99.8 %
AC (Hydrogen Cyanide)	> 99.4 %
*CK (Cyanogen Chloride)	> 99.6 %
Cyanogen	> 99.8 %
Methyl Cyanide	98 %
*CG (Phosgene)	> 99.84 %
Carbon Monoxide -> Dioxide	84 %
Methane	> 97 %
**Benzene	97.85 %

* RBP

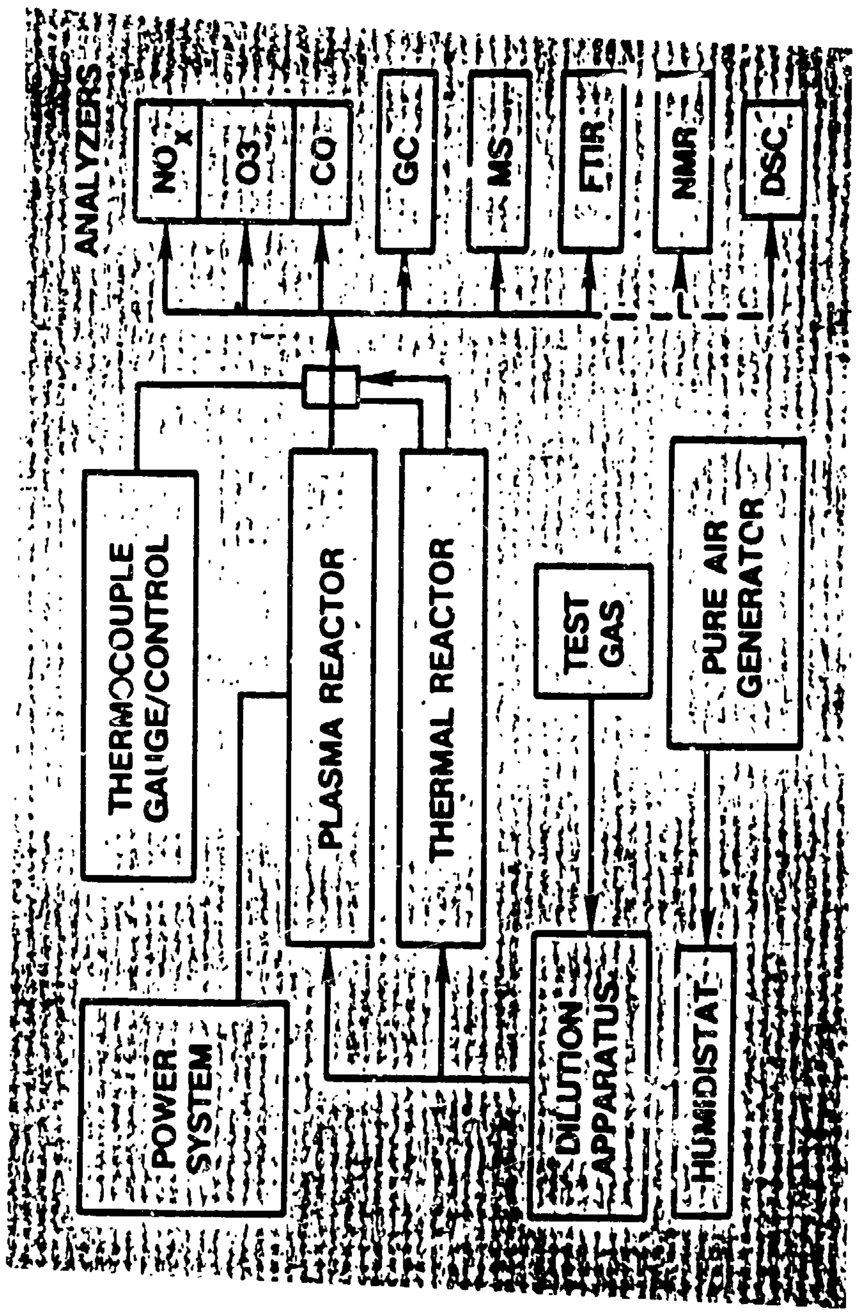
** Experimental RBP

">" LIMIT OF DETECTION

CHEMICAL PROCESSING RESULTS

MATERIAL				
DURATION	CONCENTRATION	FLOW RATE	RESIDENCE	EFFICIENCY
CK (Cyanogen Chloride)				
115 min	1576 ppm	2.6 cfm	0.44 sec	> 99.6 %
CG (Phosgene)				
78 min	200 ppm	5.5 cfm	0.31 sec	> 99.84 %
Benzene				
64 min	177 pp	2.0 cfm	0.92 sec	97.85 %

">" LIMIT OF DETECTION



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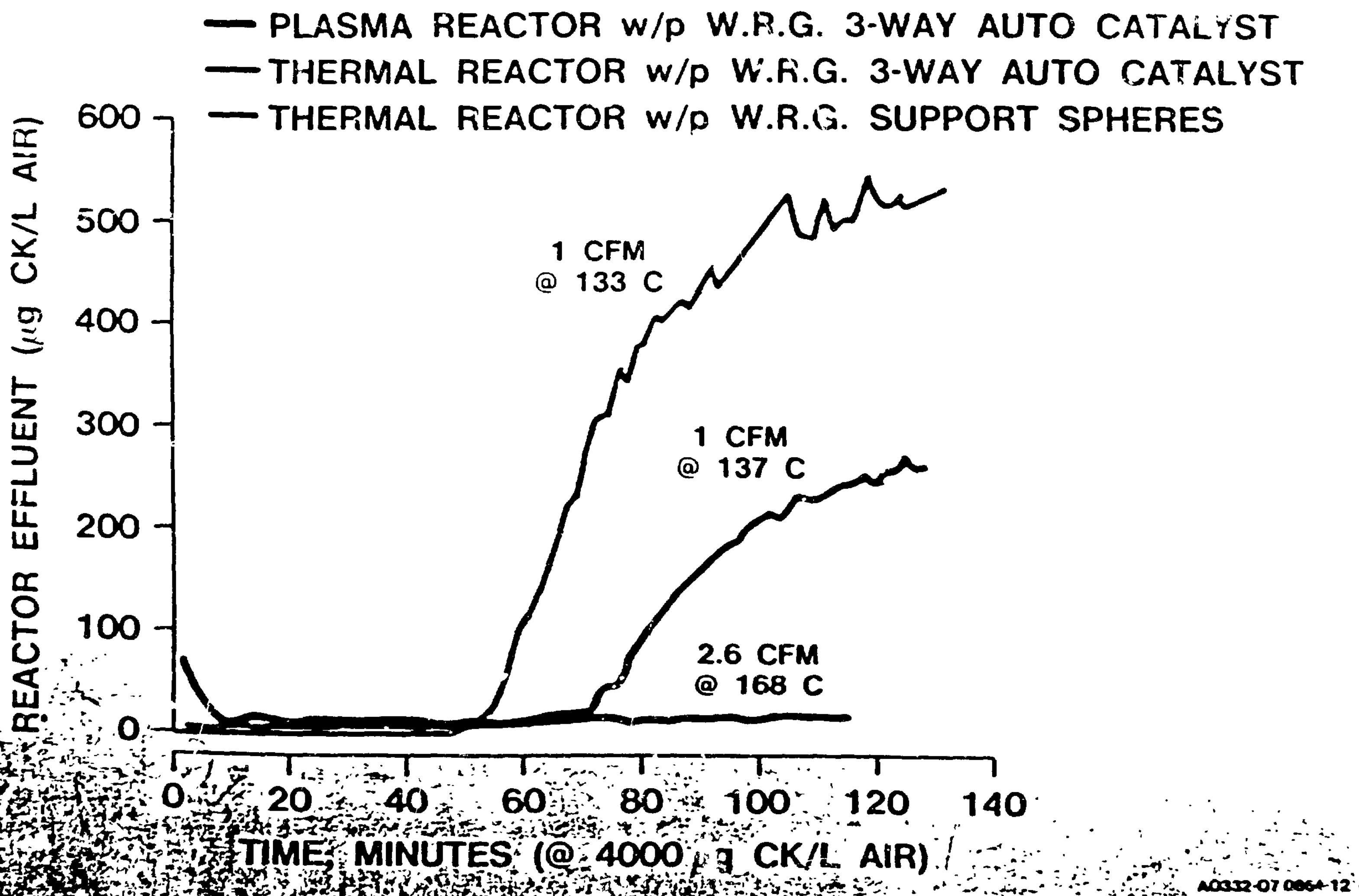
COMPARISON OF REACTIVE BED PLASMA AND THERMAL REACTORS



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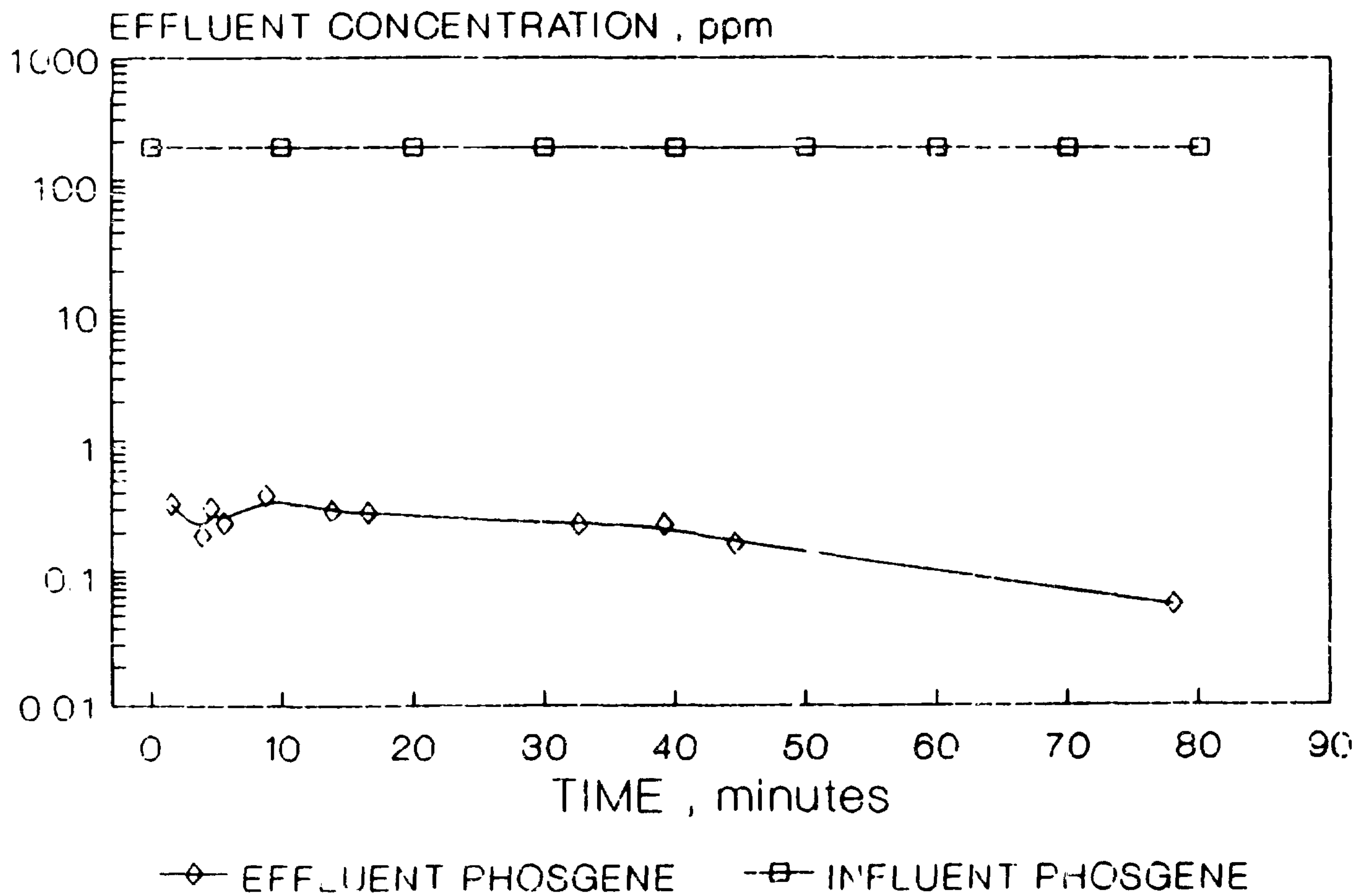
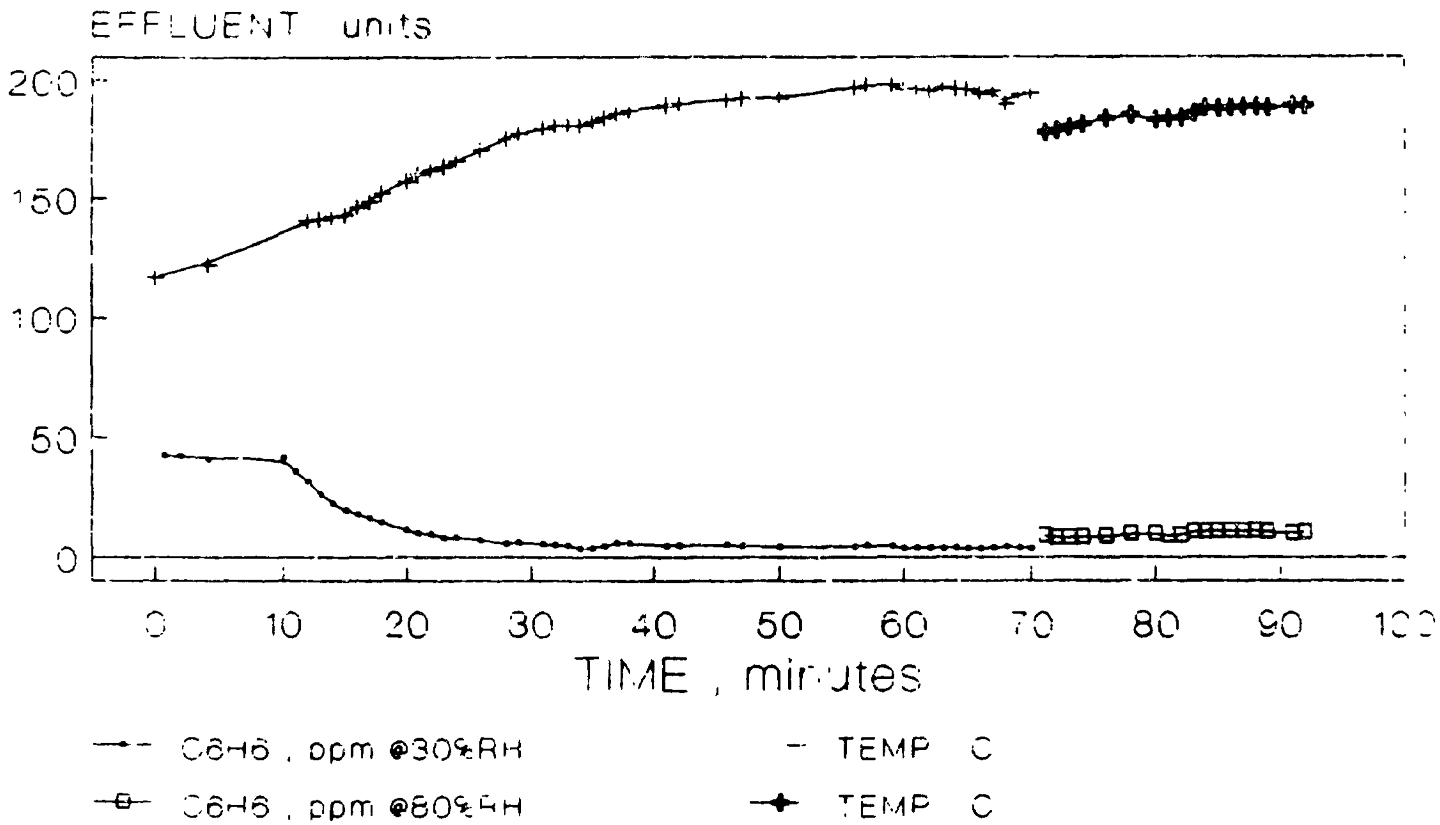
PHOSGENE DECOMPOSITION



Challenge: 200 ppm $COCl_2$ in Air

BENZENE DECOMPOSITION IN A REACTIVE BED PLASMA



Challenge: 177 ppm Benzene @ 2.0 CFM Air
Applied Power: 1000 watts

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ADVANTAGES OF RBP TECHNOLOGY

- Low Temperature Process for minimal power consumption
- Highly Efficient Decomposition of most groups of toxic chemicals
- RBP does not exhibit characteristic catalyst poisoning mechanisms

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DISADVANTAGES OF RBP TECHNOLOGY

- Scale-up of technology from 10 CFM to 100 CFM
- Requires post-treatment for reaction products in some applications

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Reactive Bed Plasma Presentation

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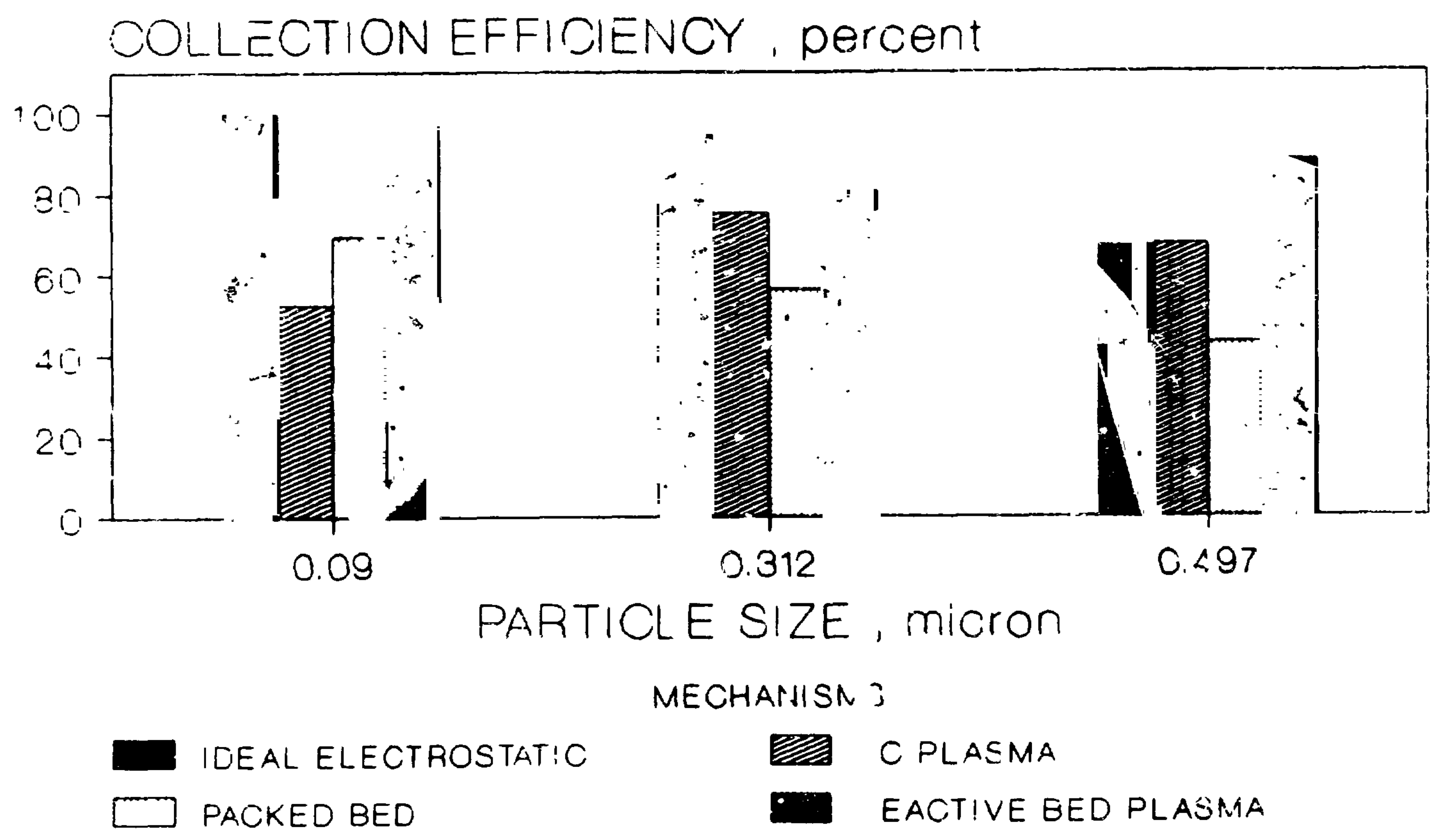
Contamination Materials

- Particulates including:
  * Semiconductor Processing (Germanium, Silicon, Gallium Arsenide)
  * Latex Spheres
  * Microbes
  * Others

AEROSOL REMOVAL MECHANISMS OF POLYSTYRENE LATEX SPHERES



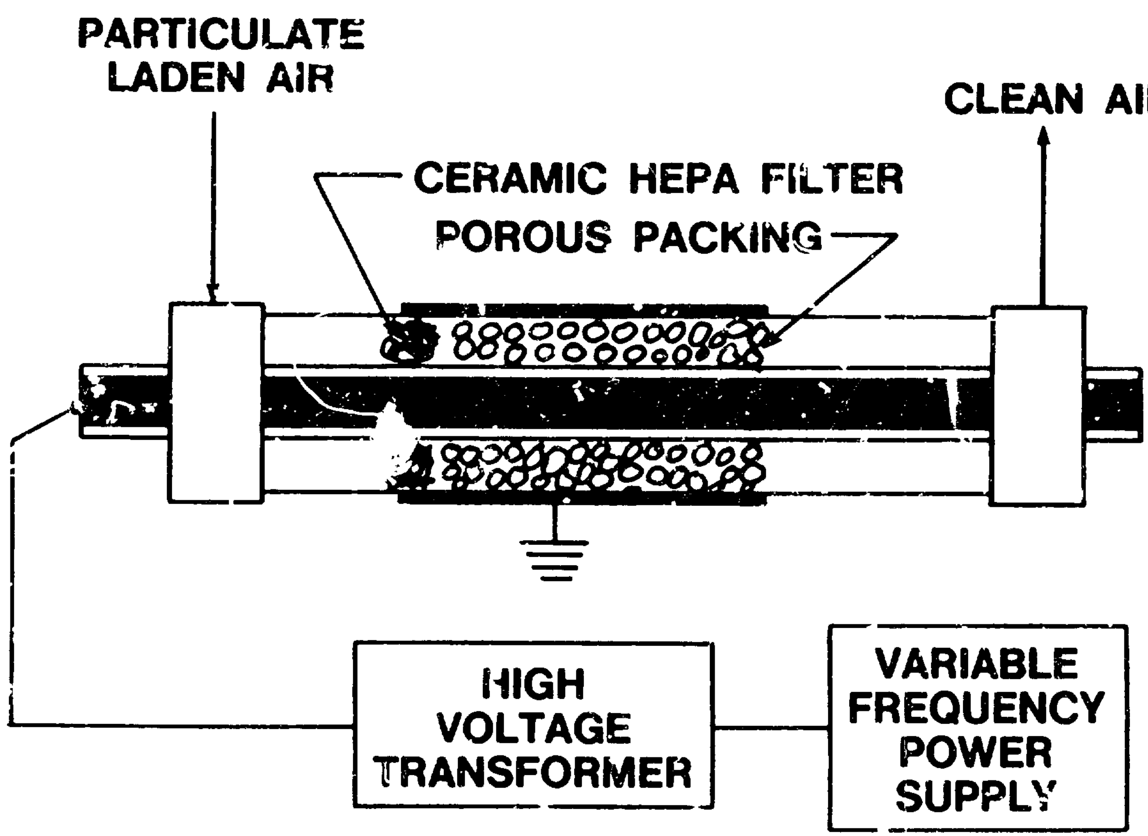
RESULTS

BIOLOGICAL PROCESSING	% DEACTIVATION
*BG SPORES	> 99.9999 %

BIOCHEMICAL PROCESSING	% DECOMPOSITION
*T-2 MYCOTOXIN	>99.72 %

*> LIMIT OF DETECTION

CONFIGURATION OF ULTRA HIGH EFFICIENCY RBP AEROSOL COLLECTION SYSTEM



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Reactive Bed Plasma Presentation

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Air By-Product Formation in RBP

Air By-Product	Concentration (ppm)
Nitrogenous Oxides (NOx)	60
Ozone (O3)	< .01
Carbon Monoxide (CO)	< 1

REACTION PRODUCTS
CLASSES AND REMOVAL TECHNIQUES

$ClCN + 2H_2O \rightarrow NH_4Cl + CO_2$	LIQUID SCRUBBER, PACKED BED, OR PARTICULATE FILTER
$COCl_2 + O^* \longrightarrow Cl_2 + CO_2$	LIQUID SCRUBBER OR PACKED BED
$C_6H_6 + 15(O^*) \longrightarrow 6CO_2 + 3H_2O$	NONE
$N_2 + 2O_2 \longrightarrow 2NO_2$	LIQUID SCRUBBER OR PACKED BED

INORGANIC SALT : NH_4Cl

INORGANIC ACID GAS : Cl_2 & NO_2

POST-TREATMENT

PACKED BED ALUMINA) (10 cm bed depth @ 88 °C)

MATERIAL				
DURATION	CONCENTRATION	FLOW	RESIDENCE	REMOVAL
CHLORINE (Cl_2)				
40 min	140 ppm	28.3 lpm	0.15 sec	96%
NITROGEN DIOXIDE (NO_2)				
35 min	100 ppm	10.1 lpm	0.42 sec	95%

GAS SEPARATION MEMBRANE (N_2/O_2 SEPARATION)

NITROGEN OXIDES (NO_2/NO)			O_2 ENRICHMENT (5 lpm)
60 min	250/56 ppm	45/5 lpm	+8% NO_2, +60% NO

Reactive Bed Plasma Presentation

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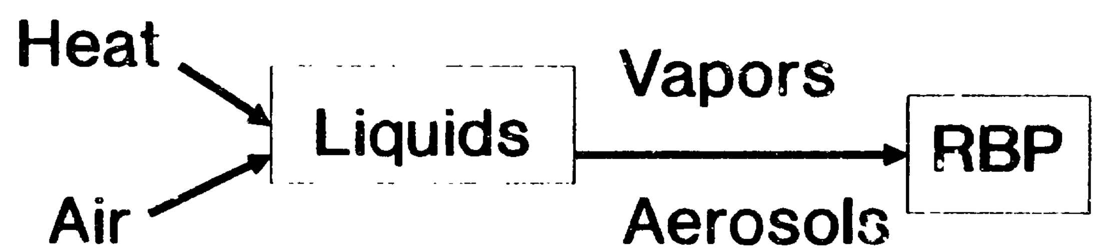
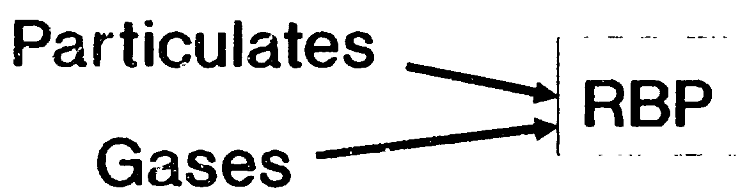
RBP Contamination Control

Liquid Processing:



Gas Vapor and Particulate Handling:



APPENDIX A. WORKSHOP ATTENDEE'S ISSUES/CONCERNS

This appendix lists issues, concerns, and recommendations noted by workshop attendees. They are as follows:

Ken Lienemann — Teledyne Brown Engineering

1. There is a strong conflict between the payload desire to vent waste and the restrictions on external contamination. All sides appear to be unaware of the rational on the part of others, and little information is being exchanges. This issue calls for coordination by Level II since it involves many Code areas and Work packages. Just because final data is not available yet is no reason for preliminary information not to be disseminated

2. Another area which should receive direction from Level II is the shared atmosphere between modules and the contamination there-of. This is a key element in safety, and is relevant to ECLSS design, contamination control, toxic materials handling, and open cabin spills.

3. Protective clothing and equipment should be a part of safe processing. Inputs are required from many sources (work packages, systems designers, facility designers, etc.). These should be coordinated at level higher than individual NASA centers, to find an approach that is acceptable, technically feasible, and provides adequate levels of safety. Duplication of effort should be avoided.

4. Everyone needs to operate with the same definition of safety terms; a similar attitude towards safety; a common interpretation of safety requirements; and a timely judgement of whether or not they have been met. We often write down a set of rules and procedures and feel as if we have legislated safety but this is not true. Situations are amorphous, multi-dimensional, modified by exceptions, and continuously variable. A centralized authority should be established to field safety questions, provided immediate judgements, direct the questioner towards appropriate documentation, or defer the question to resource panels at the Work Package level. This should not become another required "hoop" or a full bown analytical group, but act as a "help line" to give quick answers or referrals, and a focal point to establish a common safety mind-set.

5. An area related the previous item which requires special attention is establishing the process by which toxic/hazardous materials safety will be ensures on Space Station Freedom. It is obvious from the discussion that occurred at the conference, that many options exist on what will be allowed and what will make it safe. User facilities want no material restrictions, but are working in an information vacuum. Rules, limitations, and safety procedures must be defined before designs mature to prevent costly redesign and reduce residual risks (a safety fix is seldom as safe as good initial design).

   In addition to the facilities many systems are involved: PMMS, Manned systems, ECLSS, etc. The current approach seems to be to let each entity work independantly and wait until later to see if the pieces fit together. WP01 should establish the framework now for approval of facility design, materials handling, materials approval, containment, and other safety related issues. Even if the process were not implemented yet, the outline would serve as a design guideline, and ensure that everyone was headed in the same direction.

6. Common interfaces, both physically and functionally, between the various Space Station Modules are critical to the payload community. Someone at Level II or higher needs to take an action to ensure that this becomes a reality. Putting everything in a common 74-inch rack is irrelevant if FMMS equivalent interfaces are not available in the ESA and JEM modules.

7. Direct communication between Facility designers and Work Package 01 systems designers is a top priority. The current structure for data acquisition and exchange is based upon a premise of linear, sequential, development where one task leads to the next. In this scenario, a centralized information source under configuration control ensures that everyone is working swith the same requirements. However, such a system has the disadvantage of being cumbersome and slow to respond.

   A more significant problem, however, is that the Space Station Phase C-D is on a risky "fast track' with Payloads and Lab Accommodation developing in parallel (rather than one proceeding the other) Communication therefore needs to occur directly and continuously at a lower level. Level II needs to act as an "off-line" listener, recording data that is fed up, but not forcing all information exchange to funnel up through it. Otherwise designers on both sides will be stymied by the system; each will make his own assumptions, interpretations, and derive his own requirements; and the disaster we were trying to avert will have been fueled. We may build a car with square wheels in 7 different sizes.

8. A key issue highlighted by the conference was the relationship between waste generated internally and external contamination. Venting of experiment waste is a strong desire of the payload community which is severely restricted by the limitations in JSC-30426. Unfortunately, many of the parties with an interest in the external contamination were not present to participate in the discussion. Resolution of this issue is key to the design of paylaods and US Lab systems.

   A follow-up workshop on external contamination would greatly enhance exchange of information and concerns from all interested parties. A number of tests and studies are ongoing on this topic, and interim results could be presented. Partcipating groups could include:

   Level II
   Representatives of the NASA Codes
   Work package representatives
   Vacuum vent
   The Payload community (materials, Life sciences, and external)
   Shuttle & astronaut offices
   Plasma working group
   Neutral working group
   Nick Johnson (on the Russian Space Station)
   Groups experienced in low density physics and modeling.

Charles A. Horton E.I Dupont DeNemours & Co.

1. Utilizing Existing US Industry Laboratory Expertise

NASA has proven expertise in the design, fabrication, training, procedures, use, and maintenance of the Space Station and also in the integration of systems that are needed to put people and payloads into space. This expertise was developed over many years with thousands of people contributing.

Now NASA is designing the Space Station to be a national laboratory. We in the chemical industry, and at Du Pont in particular, have developed laboratory expertise the same way NASA has developed the space expertise

Why not utilize this expert knowledge in the Space Station design, fabrication, training, procedures, use, and maintenance?

2. Establishing a defined safety management system

Leadership, responsibility, communication, and a systems approach understood by all and involving all are basic requirements for successful safety performance.

Safety is like any other manageable activity. Goals must be established with check points all the way to determine if the goals are going to be met. Early warning indicators of safety problems must also be studied.

Many people do not believe safety can be managed like other activities such as quality. Du Pont believes it can be done.

Du Pont has 26 separate laboratories employing 9,779 people. Our safety management system has provided guidance to the labs so that we achieved an OHSA recordable rate of 0.953 which occurred during 1987. This safety performance measurement means that an OHSA recordable is the minimum safety recording event required by U.S. law. This translates to the fact that one individual working in a Du Pont laboratory can expect to work 10.3 years between recordable injuries. Our laboratory safety performance in 1988 has improved over 1987 to 15 years between recordable injuries.

If you need more information on successful safety management systems, please let me know.

3. Creating a continuing hazard management system

The lessons Du Pont has learned in operating dangerous processes and equipment over the past 186 years are responsible for the development of our Process Safety Management System. In every serious incident we have studied, two things have occurred--the management system has broken down and/or the process and equipment have changed.

We have developed a workable Process Safety Management system to manage these two areas and if you are interested in more information, please let me know.

4. Studying spills, containment, and clean-up

The transport, loading and unloading, and storage during the experiments need to be studied and protective designs and workable procedures need to be addressed.

5. Communicating standards, rules, and procedures

Communicating between the engineers and scientists at all levels of NASA need special attention.

Robert N. Hager, Jr., Ph.D.

Engineering Consultant
756 Woodridge Road
Franktown, CO 80116

I suggest a Mission Specialist Astronaut be assigned the primary responsibility for determining the safe operation of all experiments and systems planned to be a part of Space Station Freedom. This person would sustain contact with all contractors and agencies associated with hardware on Freedom during each phase of design and fabrication, looking objectively from experience in safe and effective laboratory operations.

This safety specialist would work with a Space station Safety Committee to develop safety standards and requirements similar to those now existing for Shuttle flights. In addition, he or she would serve as an overall facility observer, viewing the interaction of the three laboratories as well as the facility control systems for integrated safety and crew workability.

This individual would be experienced in laboratory equipment operations, laboratory management, hazardous materials handling, toxicology, ventilation engineering, trace contaminant monitoring methods and standard safety practices in a laboratory work environment.

I request to be this individual.

Wallace W. Youngblood

Wyle Laboratories

Combustion Facility Waste Disposal:

The Combustion Facility proposed by NASA/Lewis is anticipated to generate gaseous, liquid and solid waste materials as a result of various combustion experiments. A methodology must be developed to collect and store these waste materials, some of which are likely to be toxic and/or reactive. Also, a methodology is required for preparing the stored waste materials for delivery to the Space Station PMMS.

Atmosphere Monitoring for Incipient Fire Detection:

Monitoring of the cabin and avionics air has been discussed and rapid, real-time monitoring is desirable. It is recommended that such monitoring be extended, ultimately, to include detection of incipient fire conditions as an additional level of fire detection. Micro-encapsulated trace gases could be incorporated on component/cabinet surfaces for release and detection at temperatures well below material ignition.

George L. Curran — The Bionetics Corporation

1. Designs of any materials handling hardware and operations should be reviewed by sources outside of NASA. These should include atleast a safety officer from a chemical production company and people involved in the cleanup of hazardous materials spills, i.e. the Environmental Protection Agency.

2. Many materials handling operations could benefit from automation to avoid "human error" potential.

3. Space Station operations planning should not be viewed as an extended spacelab flight! The resources available on freedom will be <u>very</u> different from Spacelab.

Dr. M. Vedha-Nayagam — Wyle Laboratories

Microgravity Fluid Dynamics for Waste Material Transport:

All the major hardware systems proposed for the Space Station produce processed material in the form of liquids, solids, and gases inside their working volume. Ultimately they are removed and recycled or stored either by the PMMS or by the ECLSS. However, the mechanisms through which the transfer of these materials are effected was not discussed in detail technical and basic scientific issues associated with separation of solids/liquids/gases, vacuum filling and venting, and multi-phase flow dynamics deserve more attention.

Roger Chassay — NASA/MSFC/JA52

1. Absence of plans/requirements for use of robotics in handling hazardous conditions (e.g. overpressure safing, cleanup or spills, safing of ruptured toxic experiment samples)

2. Apparent absence of materials science inputs in establishing the venting constraints of JSC 30426, i.e., it appears that the observing science people haven't tried to achieve mutually satisfactory constraints with the materials science people.

3. Limitations on simultaneous use of PMMS by multiple users.

W. Bouchelle Hamilton Standard

Factors of safety and back-up analysis requirements seem to vary from center to center. Is there a way this could be made uniform to enhance the possibility for commonality of hardware items?

Ross Cushman Hamilton Standard - Space and Sea Systems

Before we spend millions on systems to avoid or timeline venting, someone must evaluate the impact of unavoidable Space Station cabin leakage on the local environment (2000 lbm/yr). This contamination may render venting avoidance useless.

F. L. Worley Jr. University of Houston

Concern: The design of the lab (USL) is probably trying for too much as a first stage. Why not set the goal for our "wish list", but have a more modest first level objective which does not involve solution of these very difficult problems and retard the progress of the over-all project.

Don Stafford Compliance Consulting Services

1. As an "outsider" to the Space Industry, I felt a general absence of unity in a very large effort.

2. The workshop covered a subject of hazardous materials that much research has been done in other industries and I have concerns that this information is not being used.

3. How is large quantities of waste returned to earth to be handled?

P. K. Seshan JPL

The workshop was very valuable for the magnitude of new information gained. On the contrary, it became glaringly clear that system concepts development (though recognizing the value of input from guidance to subsystem developers) continues to proceed without the participation of subsystem developers and end users. Do we have to wait for these infrequent workshops and be surprised or even shocked into knowing what we should have been aware of before the workshop? Because of this, (perhaps deliberate) lack of information exchange, the workshop lacks depth (i.e., nuts and bolts discussion).

Catherine C. Johnson — NASA/Ames (415) 694-5768

1. O_2 and CO_2 provided by PMMS. Cylinders provided to the user need to be compatible with our system or else have the capability for recharging user provided cylinders.

2. Materials of construction for distribution of electronic grade water was not sufficiently addressed in the workshop. Plants are very sensitive to heavy metals, i.e. p of Ni in toxic.

3. Are contaminants from the International partners being factored in?

Dinah B. Higgins — NASA/MSFC

The workshop was well organized and desperately needed. My primary concern is the safety of the PMMS as presently designed. I have not seen any evidence that would indicate that Boeing or TBE have even considered alternate approaches to the current concept. It would probably be cost effective in the long term for them to do so now. Judging from at least two of the presentations at the workshop, I am not the only person with this opinion.

The payload community needs to have a facility where the experiments can be interfaced with the PMMS and other systems, and experiments conducted, and wastes disposed of. Usefulness of simulations only go so far.

I think that future workshops are required, with more time alloted to discussion amongst the participants. The issues and concerns brought up need to be addressed (and actions taken) by NASA, Boeing, and TBE.

Bill Hanks — Teledyne Brown Engineering

An area of great concern to me in the design of the Space Station Process Fluids distribution/storage system is to define the Process Fluids Requirements of the laboratory facilities, both user experiments and lab support. Four questions I would like to pose to every user of Process Fluids are:

1. What fluids are needed? (Ar, N_2, O_2, He, CO_2, H_2)

2. How much of each are needed per use? (kg, l)

3. What pressure and temperature should they be at?

4. At what flowrate are they delivered? (kg/s)

John R. Little Jr. — Boeing Co./Space Station Mission Operations
J. A. McClendon — TBE SS Mission Operations

Concern: Commonality needed for standardized operations -

It appears that similar payload operations if conducted in the U.S. Lab, ESA, and JEM Modules will have to be done differently due to design differences in the modules. If this is so, it is a real concern for long-term operations. It affects the development and maintenance of crew procedures and crew training, as well as the planning and scheduling of orbital operations. Further, the need for commonality in supply of subsystem resources to racks within each module; USL, TEM and ESA is essential to enhance standardized development of these crew procedures and training.

Concern: Safety Office Involvement -

During several sessions, it became apparent that visibility of safety requirements for the program and level of authority for implementing them is not clear, particularly in the area of this workshop, USL contamination. This group would enjoy seeing clear pictures of the safety office span of influence for the SS program from Level III up through Level I. As an example, it is thought the activities of the WP-01 (Boeing) safety activities have contributed to SS developing requirements but apparently, this is not visible to the various working groups. It is suspected the same situation may exist for the other work packages. Visibility throughout the program of these activities is needed by all.

The user handoook development mentioned by MSFC safety should most certainly include the involvement of both the WP01 (Boeing) safety office and mission operations contingent. As an initial thought, separate sections for the USL, ESA, and JEM should be considered.

Dr. H. J. T. Powell — User Integ. MDAC-SSD-KSC

Radiological aspects with respect to experiments have hardly been touched in this workshop. Make known any existing "rules/regs" regarding this area or have a proposed position presented at the next workshop. This should cover both ionizing and non-ionizing areas A speaker on radiological experiments would be good if you could find one. The Cape has processed spacecrafts that have used RTGs and RHUs.

Report

on

Space Station Freedom

Toxic and Reactive Materials Handling Workshop

by

Patrick G. Barber

Professor and Director of Chemistry

Longwood College, Farmville, Virginia 23901

3 December 1988

There are many tasks that must be completed and coordinated before a variety of toxic and reactive materials can be handled safely on the Space Station over extended periods. This and similar workshops are very necessary. The mutual recognition of still existent problems, the effective utilization of past experiences, and the increased communication and coordination that result from such meetings are all important.

Because chemicals may eventually be moved from one space station module to another, coordination among the three agencies involved is essential. Labeling and storage procedures must be coordinated. Spill response procedures and emergency equipment must also be coordinated. Further, it would be beneficial if the procedures to be used in all three experimentation modules were at least well understood by all. Franco Ongaro reported that ESA may be considering a rule that all experimenters must handle all chemicals and wastes within their experiments and not rely on a common collection and handling system. This seems to be different from the philosophy adopted for the U.S. and Japanese modules. Can both procedures be used simultaneously on the Station? Is one philosophy better than the other? To a chemist the common collection of toxic and hazardous wastes is a difficult and dangerous undertaking that has not even been effectively accomplished on earth. The potential for catastrophe may be increased when the variety of collected chemicals is increased. Countering this observation is the fact that hazards also increase when a large variety of researchers each handles their own wastes and stores them in proximity to other wastes.

Recommendations:

- **Continue to have such meetings and to shorten lines of communication.**
- **Involve to a greater extent those responsible for similar tasks in Japan and ESA.**
- **Evaluate whether the general collection and treatment of wastes is safer than requiring each experimenter to treat and contain their own wastes.**

The presentations indicated that the best available data, procedures, and equipment were being evaluated to solve the problems of handling toxic and hazardous materials and wastes on the Space Station. The Space Station will operate in a very fragile environment, i.e., one without the numerous and extensive buffering systems that exist on earth to mitigate and to dissipate hazards and wastes. The level of care and preparation needed for the safe handling of such materials on the Space Station is accordingly greater than required on earth. The question of whether or not to vent into the ecospace about the Station is one that must be carefully weighed. This is especially true in light of the experiences of the Soviet MIR Station described by Mr. Nick Johnson.

Recommendation:

- **Continue to adapt the best data bases, procedures, and equipment for use on the Space Station. Where suitable ones do not exist, develop the needed technology. This applies to the safe storage of reagents, dispensing procedures appropriate for microgravity, collection procedures, detoxification procedures, and long and short-term storage of spent reagents.**

Because the environment in which the reagents are going to be used is different from that found on earth, it may be necessary to break away from the traditional methods of handling chemicals. For example, on earth the traditional method of moving chemical and biological wastes is to do so with copious amounts of water. To plan to continue to do this on the Space Station may needlessly involve processing ever increasing volumes of wastes. It may be beneficial to consider if it would be better to move, reprocess, and store smaller but more concentrated wastes. It must first be ascertained that this may be done safely. It will mean that any leak or spill will be more hazardous than if it were diluted, but it will also mean that there will be far less of it to be handled and accounted for.

An example of earth-based technology that could be considered for moving chemicals and wastes without large volumes of water is the manner that is used to move natural gases from Texas and Louisiana to the mid-west and east. Different gases are moved along the same pipeline by inserting moveable plugs between samples. On the Space Station such lines and containers should be transparent so that astronauts can visually observe what is actually in the lines and tanks.

In microgravity it may be beneficial to consider designing air flows to give directionality to the movement of fluids in the cabins of the Space Station. On earth gravity is relied to pull hazardous and toxic chemicals down away from the faces of experimenters. On the Space Station a creative solution may have to be found to do the same job, for the greatest personnel hazards are from eye contact, inhalation, and ingestion.

The fact that the quality of air in the mid-deck region of the Space Shuttle is an order of magnitude worse than that in the actual laboratory, e.g., 34000 vs. 3000 m^{-3}, and the fact that animal feces moved from the laboratory to the command center are disturbing to a chemist. On earth the experimentation spaces should be at negative pressure compared to office spaces. Why should air-flow management be different in microgravity? If the toxins move throughout the Shuttle, where is the safe haven? Because ingestion is a major mode of entry for toxins, food is never consumed in a laboratory on earth. In the Space Station where may food safely be consumed? The old rhyme takes on new meaning in microgravity:

"Alas, poor Jack is no more
What he thought was H_2O was H_2SO_4."

Is the Space Station being designed with the same air-flow patterns as used on the Shuttle?

Procedures developed for the Space Station have direct and immediate applications on earth. Procedures that effectively handle wastes in the physical chemically closed system found on the Space Station can be adapted for use on earth to improve the more open industrial processes and to reduce the costs associated with preserving the environment. Further, during the thirty year use of the Space Station, water may well become the resource in short supply on earth. It has already become a significant factor in industrial and military decisions in the Western U.S. Space Station technology may well become necessary on earth in the next century.

Recommendations:

- **Explore alternative procedures for moving and reprocessing wastes that do not involve the use of large volumes of water.**
- **Explore alternative procedures for controlling the movement of fluids inside the cabin. Consider moving them away from the astronauts' faces.**
- **Review the air-flow patterns.**
- **Expand the effort to adopt technology developed for the Space Station to industrial and environmental problems on earth.**

From the report given by Bonnie Dunbar, the potentially hazardous and toxic accidents that occurred on the D-1 mission were due to unknowns. The rod that broke may not have been the one anticipated. The ability of silicon fluid to creep into otherwise inaccessible spaces and coat equipment was not anticipated. The leaked electrophoretic buffer solution may have been changed just before flight. In working with chemicals no matter how careful the preparation, there is always to possibility for the unexpected. Procedures and preparations must be developed to handle the unexpected.

In laboratories on earth, chemists rely upon their senses and past experiences to alert them to the unexpected. If the color or odor of a substance is not as expected, the chemist will not proceed without first checking. Because of the variety of experiments to be run on the Space Station, it is not possible or desirable to use only scientists experienced in handling chemicals. This puts an increased burden on adequate preparations and design.

Recommendations:

- **Design and prepare for handling the unexpected. Have spill clean-up equipment and procedures.**
- **Broaden the training of astronauts to include recognition of potential chemical hazards by giving them experience in recognizing colors, textures, and odors of substances to be used in space laboratories.**

APPENDIX B. WORKSHOP SUMMARY PRESENTATION TO SPACE STATION ENVIRONMENTAL STEERING GROUP

TOPIC: SUMMARY OF THE SPACE STATION FREEDOM TOXIC AND REACTIVE MATERIALS HANDLING WORKSHOP

PRESENTED TO: SPACE STATION ENVIRONMENTAL STEERING GROUP

PRESENTED BY: PAUL GALLOWAY
WORKSHOP COORDINATOR

TELEDYNE BROWN ENGINEERING

DECEMBER 20, 1988

SS FREEDOM TOXIC AND REACTIVE MATERIALS HANDLING WORKSHOP

WORKSHOP BACKGROUND AND ATTENDANCE

- WORKSHOP SPONSORED AND SUPPORTED BY CODES E, R, AND S

- WORKSHOP CONSISTED OF THREE ONE-DAY SESSIONS WITH 40 SPEAKERS
  1) PAST, PRESENT, AND FUTURE SPACE HAZARDOUS MATERIALS HANDLING REQUIREMENTS
  2) SPACE STATION SYSTEMS
  3) ADVANCED TECHNOLOGIES FOR CONTAMINATION DETECTION AND CONTAMINATION CONTROL

- OVER 150 INVITATIONS MAILED TO POTENTIAL WORKSHOP ATTENDEES

- RECIEVED 220 WORKSHOP PRE-REGISTRATIONS

- A SUCCESSFUL WORKSHOP WAS HELD ON NOV. 29 - DEC. 1 IN HUNTSVILLE, AL

- AVERAGE DAILY WORKSHOP ATTENDANCE OF 175

- SPEAKERS AND ATTENDEES REPRESENTED GOVERNMENT, INDUSTRY, UNIVERSITIES, AND INTERNATIONALS (1 FROM ESA, 2 FROM NASDA)

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BROWN ENGINEERING

PAUL GALLOWAY
DECEMBER 20, 1988

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ACKNOWLEDGEMENTS

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KENNETH L. MITCHELL, NASA/MSFC

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TERESA STROTHERS
WHEELER VANN

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WORKSHOP RESULTS SUMMARY

- INCIDENTAL WORKSHOP RESULTS
  - INCREASED SAFETY AWARENESS FOR SPACE STATION PROGRAM PARTICIPANTS
  - CLARIFICATION OF SOME KEY SAFETY REQUIREMENTS
  - INITIATED DIALOGUE AND COMMUNICATION BETWEEN VARIOUS PROGRAM PARTICIPANTS
  - PROVIDED AN OVERALL EDUCATION AND BETTER UNDERSTANDING OF THE INTERNAL CONTAMINATION ISSUE FOR WORKSHOP PARTICIPANTS

- WORKSHOP RESULTS AND RECOMMENDATIONS
  - PANEL RECOMMENDATIONS
  - ADDITIONAL RECOMMENDATIONS

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PANEL RECOMMENDATIONS: POLICY AND ORGANIZATION

1. *ESTABLISH CLEAR AND UNIFORM SAFETY POLICIES FOR ALL MODULES: JEM, COLUMBUS, AND USL. APPROACHES TO SAFETY POLICY IMPLEMENTATION SHOULD BE SIMILAR TO THOSE USED FOR GROUND BASED NATIONAL LABORATORIES (CONSULT NRC GUIDELINES)*

– TWO RECENT AND APPLICABLE NATIONAL RESEARCH COUNCIL (NRC) PUBLICATIONS

"PRUDENT PRACTICES FOR HANDLING HAZARDOUS CHEMICALS IN LABORATORIES"
"PRUDENT PRACTICES FOR DISPOSAL OF CHEMICALS FROM LABORATORIES"

2. *EXPEDITE DEVELOPMENT OF THE SPACE STATION SAFETY ORGANIZATION AND UTILIZE EXISTING NASA SAFETY ORGANIZATIONS AS REQUIRED. (FLOW CHART THE DIFFERENT CENTER RESPONSIBILITIES)*

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PANEL RECOMMENDATIONS: POLICY AND ORGANIZATION (CONTINUED)

3. ***DEVELOP ACCIDENT SCENARIOS, SUCH AS FOR "IN-CABIN SPILLS", AND ASSIGN RESPONSIBILITY FOR DETECTION AND REMOVAL (BOTH HARDWARE AND PROCEDURES DEVELOPMENT) TO APPROPRIATE ORGANIZATIONS.***

- ECLSS RESPONSIBILITY
  REMOVAL OF RELEASED AEROSOLS AND OTHER TRACE CONTAMINANTS
- PMMS RESPONSIBILITY
  USL PAYLOAD AND SUBSYSTEM LEAK DETECTION
  HARDWARE AND CREW DECONTAMINATION
  NO SPECIFIC HARDWARE OR PROCEDURES HAVE BEEN IDENTIFIED
- ONLY ONE DOCUMENTED STUDY TO DATE: MDAC-HUNTSVILLE SS PHASE B REPORT
  "SS USL CONTINGENCY SPILL RECOVERY STUDY"

4. ***REQUIRE ALL MODULES TO DEVELOP COMMON APPROACHES TO THE DISTRIBUTION, HANDLING, CONTAINMENT, AND USE OF TOXIC AND REACTIVE MATERIALS. SAFETY DICTATED DESIGNS SHOULD IMMEDIATELY BE TRANSMITTED TO JEM AND COLUMBUS DEVELOPERS.***

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PANEL RECOMMENDATIONS: POLICY AND ORGANIZATION (CONTINUED)

5. *IMPROVE COMMUNICATIONS ACROSS THE BOARD: NASA CENTERS, INTERNATIONAL PARTNERS, CONTRACTORS, USERS, INDUSTRY, FLIGHT OPERATIONS, SAFETY ORGANIZATIONS, ETC.*

6. *SCHEDULE MORE USER/DESIGNER/OPERATOR MEETINGS TO COMMUNICATE SAFETY RELATED DESIGN REQUIREMENTS*

   - SEVERAL ATTENDEES NOTED THAT THESE TYPES OF MEETINGS ARE AN EFFECTIVE METHOD OF COMMUNICATION AT THIS STAGE OF THE DESIGN

SS FREEDOM TOXIC AND REACTIVE MATERIALS HANDLING WORKSHOP

PANEL RECOMMENDATIONS: STATION SUBSYSTEM DESIGN

7. UTILIZE MORE GROUND BASED LABORATORY SAFETY FEATURES.

- MINIMIZE AIR FLOW BETWEEN MODULES
- CONSIDER CREW PROTECTIVE GEAR REQUIREMENTS SUCH AS EYE PROTECTION AND FULL BODY CLOTHING

8. REEVALUATE THE TOTAL NUMBER OF ECLSS STATIONS FOR TRACE GAS MONITORING.

- SEVEN ECLSS MONITORING LOCATIONS CURRENTLY BASELINED FOR THE ENTIRE SPACE STATION FREEDOM CONFIGURATION

9. CONDUCT A SEPARATE REVIEW OF THE PMMS IN THE FOLLOWING AREAS: WASTE STORAGE SYSTEMS, COMMONALITY WITH JEM AND COLUMBUS, 30 YEAR FLEXIBILITY, WASTE LIMITATIONS AS THEY RELATE TO USER REQUIREMENTS, INTRODUCTION OF WASTES TO THE SYSTEM, AND QUANTITY OF WATER REQUIRED FOR OPERATIONS.

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DECEMBER 20, 198[illegible]

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PANEL RECOMMENDATIONS: STATION SUBSYSTEM DESIGN (CONTINUED)

10. EVALUATE POTENTIAL LOCATIONS AND DESIGN REQUIREMENTS FOR A DECONTAMINATION CENTER IN LEIU OF AN "EMERGENCY SHOWER".

- LARGE VOLUME OF WATER REQUIRED FOR EFFECTIVE DECONTAMINATION
- CONSIDER LOCATING EMERGENCY SHOWER IN NODE TO FACILITATE:
  1) CONVENIENT ACCESS FROM ALL MODULES
  2) IMMEDIATE ISOLATION OF A CONTAMINATED MODULE

11. REEVALUATE ISOLATION OF ECLSS AVIONICS AIR LOOP FROM EXPERIMENTS.

12. REVIEW ECLSS, FMS, AND PMMS DESIGNS WITH RESPECT TO HUMAN FACTORS: MAINTENANCE AND REPAIR, CAUTION AND WARNING, AND EMERGENCY PROCEDURES.

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PANEL RECOMMENDATIONS: STATION SUBSYSTEM DESIGN (CONTINUED)

13. EXPEDITE THE DEFINITION OF SPACE STATION SMAC LEVELS

- REQUIRED FOR THE DETAIL DESIGN OF ECLSS TRACE CONTAMINANT REMOVAL SYSTEMS
- CURRENTLY BEING DEFINED BY THE NATIONAL RESEARCH COUNCIL FOR 90 DAY MISSIONS

14. EXAMINE THE BENEFITS AND LIMITATIONS FOR DECENTRALIZATION OF HAZARDOUS MATERIALS HANDLING.

- CURRENT PMMS DESIGN CONCEPT IS PRIMARILY CENTRALIZED
- DECENTRALIZATION IMPLIES MORE USER RESPONSIBILITY OR PMMS EQUIPMENT LOCATED IN THE USER'S RACK
- RACK LEVEL CHEMICAL REMOVAL TECHNIQUES COULD INCLUDE SUCH ACTIVITIES AS PARTICULATE FILTRATION, MOLECULAR SIEVES, COLD TRAPS, AND CATALYTIC OXIDATION

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PANEL RECOMMENDATIONS: STATION SUBSYSTEM DESIGN (CONTINUED)

15. ***DETERMINE IF DESIGN VERIFICATION FOR CERTAIN FLUID HANDLING SYSTEMS IS REQUIRED ABOARD SPACE SHUTTLE FLIGHTS PRIOR TO SPACE STATION IMPLEMENTATION.***

16. ***OPTIMIZE AIR FLOW WITHIN THE MODULES AND THE GLOVEBOXES FOR SAFER OPERATIONS.***

    - TOP-TO-BOTTOM MODULE AIR FLOW WOULD MINIMIZE (OR PREVENT) THE INGESTION OR INHALATION OF AN AIRBORNE TOXIC CONTAMINANT

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PANEL RECOMMENDATIONS: EXPERIMENT DESIGN

17. ***DETERMINE THE STATUS OF POTENTIAL CONTAMINATION DUE TO EXTERNAL VENTING OF EXPERIMENT WASTE GASES BY ALL MODULE ELEMENTS. THIS INFORMATION MUST BE ACQUIRED IMMEDIATELY SO THAT DESIGN PROCESSES FOR THE FMS AND EXPERIMENTS CAN CONTINUE. (THE EXTERNAL ENVIRONMENTS WORKING GROUP MAY BE PERFORMING THIS ASSESSMENT)***

- TWO REQUIREMENTS FOR VACUUM IN USL
  1) HIGH QUALITY VACUUM FOR THERMAL VACUUM JACKETING
  2) BULK WASTE GAS REMOVAL (E.G., EXPERIMENT PURGE)
- CURRENT PLANS FOR VENTING
  A) USL

     DIRECT OVERBOARD VENT OF HIGH QUALITY VACUUM LINE (APPROX. 0.25 TORR TO 10-3 TORR)

     SEGREGATE, RECOMPRESS, AND STORE BULK WASTE GASES FOR PERIODIC VENT THROUGH RESISTOJET

  B) ESA MODULE —— TBD VENTING REQUIREMENTS

  C) JEM MODULE —— TBD VENTING REQUIREMENTS

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PANEL RECOMMENDATIONS: EXPERIMENT DESIGN (CONTINUED)

18. *GENERATE A SPACE STATION USER'S MANUAL AND EXPERIMENT DESIGN DATA BASE WHICH DISCUSSES DESIGN REQUIREMENTS AS THEY RELATE TO SAFETY*

   - INCLUDE THE FOLLOWING INFORMATION AS A MINIMUM:

     A) S.S. AND USL SUBSYSTEM DEFINITIONS AND CAPABILITIES

     B) CHAPTER ON SAFETY WHICH INCLUDES SAFETY REQUIREMENTS AND GUIDELINES AND INTERPRETATIONS OF THESE REQUIREMENTS (E.G., "TWO-FAILURE TOLERANT DESIGN", "CREDIBLE FAILURE", ETC.)

19. *RE-EXAMINE CREW OPERATIONS OF EXPERIMENTS BOTH FROM A SAFETY POINT OF VIEW AND FOR OPTIMIZING SCIENTIFIC RETURN. OPTIMIZE THE AUTOMATION/CREW OPERATION MIX.*

20. *REEVALUATE THE GLOVEBOX DESIGN AND USER REQUIREMENTS (UTILIZE PREVIOUS FLIGHT EXPERIENCE WITH THE ESA GLOVEBOX FLOWN ON STS-61A)*

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PANEL RECOMMENDATIONS: INTERNAL CONTAMINATION DETECTION AND CONTROL (CONTINUED)

21. IMPROVE COMMUNICATIONS WITH BOTH INDUSTRY AND THE MILITARY FOR DETECTION, REMOVAL, AND CONTROL OF TOXIC AND REACTIVE MATERIALS.

- CURRENT CONTAMINATION DETECTION REQUIREMENTS:
  - A) ECLSS RESPONSIBILITY
    DETECTION OF METABOLIC CONTAMINANTS AND EQUIPMENT OUTGASSING
  - B) PMMS RESPONSIBILITY
    DETECTION OF PAYLOAD CONTAMINANTS
    LEAK DETECTION OF STANDARD GASES, GLOVEBOXES, AND THE CHEMICAL STORAGE LOCKER
- THE U.S. MILITARY HAVE DEVELOPED ADVANCED TECHNOLOGY CHEMICAL AND BIOLOGICAL DETECTION AND CONTROL EQUIPMENT FOR FIELD APPLICATIONS

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ADDITIONAL RECOMMENDATIONS

- ROUTINE CLEANING/DECONTAMINATION OF PRESSURIZED MODULE INTERNAL SURFACES HAS NOT BEEN ADDRESSED
  - ASSIGN PROCEDURES DEVELOPMENT AND HARDWARE/MATERIALS DEFINITION TO ECLSS OR PMMS
- DEVELOP A SPACE STATION DIRECTORY
  - SHOW WORK BREAKDOWN STRUCTURE AND PERSONS RESPONSIBLE
  - INCLUDE NASA AND CONTRACTOR PHONE NUMBERS
  - IDENTIFY USER CONTACTS
- CONSIDER A WORKSHOP ON EXTERNAL CONTAMINATION
- PERFORM A STUDY ON GROUND PROCESSING OF WASTES
- FORM A PANEL TO ADDRESS WORKSHOP ATTENDEE'S WRITTEN CONCERNS

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SS FREEDOM TOXIC AND REACTIVE MATERIALS HANDLING WORKSHOP

FINAL REMARKS

- PANEL RECOMMENDATIONS WILL BE INCLUDED IN THE WORKSHOP PROCEEDINGS DOCUMENT
- WORKSHOP PROCEEDINGS DOCUMENT WILL BE COMPLETED AND MAILED OUT NEAR THE END OF THE YEAR
- AUDIO TAPES OF THE WORKSHOP ARE AVAILABLE
- FUTURE WORKSHOP RECOMMENDATIONS
  - ALLOW MORE TIME FOR OPEN DISCUSSION AND SPLINTER GROUPS

TELEDYNE BROWN ENGINEERING

PAUL GALLOWAY
DECEMBER 20, 1988

APPENDIX C. ATTENDEES LIST

A

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16. Abstract

Viable research in materials processing in space requires the utilization of a wide variety of chemicals and materials, many of which are considered toxic and/or highly reactive with other substances. As a result, an imprecise perception has evolved that many of the experiments necessary to successful research on the Space Station are dangerous and will require substantial operational restrictions, if they are to be allowed at all in a manned space environment. This workshop concentrates on a realistic view of the experiments which are most likely to be accomplished in the early Space Station phases and addresses design issues related to their safe implementation. Included in the papers are discussions of materials research on Skylab, Spacelab, and the Shuttle mid-deck; overviews of early concepts for specialized Space Station systems designed to help contain potential problems; descriptions of industrial experience with ground-based research; and an overview of the state-of-the-art in contamination detection systems.

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