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STUDY OF ALTERNATE METHODS OF DISPOSAL OF PROPELLANTS AND GASES AT KSC

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DESIGN ENGINEERING DIRECTORATE

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SECTION I
SUMMARY

Design Engineering, with the support of Launch Operations and Technical Support, has conducted a comprehensive study of potential propellant and gas release hazards at all the active KSC facilities under Design Engineering responsibility. The findings indicate that:

a. There are some relatively minor problems that can be readily corrected.

b. There are several GOX cloud problems requiring management decisions on the technical alternatives in relation to the degree of risks involved.

c. A few problems require further detailed study.

The requirement for dumping relatively large amounts of LOX at LC-39 is the most serious problem, with a choice between an effective but expensive catch tank method for controlled venting and something less elaborate depending upon acceptance of higher risk factors. Relatively large quantities of LH_2 or GH_2 are considered disposable by vaporizing and controlled burning, while smaller amounts of GH_2 vented to the atmosphere are seen as acceptable risks.

The study indicates that large quantities of LN_2 may be dumped in remote open areas, and that large quantities of GN_2 and moderate amounts of RP-1, GN_2, GOX, and GHe usually can be safely vented with suitable personnel controls plus provisions for dilution and monitoring to ensure that safe oxygen levels are maintained. Where there is a possibility of high concentrations of propellant vapors developing, it is recommended that electrical equipment be hazard proofed or turned off as verified by inspection tests.

Among the detailed studies currently being conducted are:

a. LV tests to determine whether or not tankers at LC-39 can be vented through the facility drain.

b. DE evaluation of methods for decomposition of hypergol vapors.

c. ULO comparisons of the alternatives for disposing of LOX and GOX at LC-17, and a study of possible extension of LC-36 vent lines.

SECTION II
INTRODUCTION

2.1 PURPOSE

This study was initiated by Design Engineering in cooperation with Launch Operations and Technical Support, at the request of the Apollo Program Manager, acting upon recommendations of the Board of Investigation for the Motor Vehicle Fire at LC-39, March 25, 1970. The primary purpose of the study was to identify problem areas and develop methods for the reduction or elimination of potential hazards to personnel or equipment exposed to persistent gas vapors generated by discharging large quantities of propellants, gases, or cryogenic liquids to the atmosphere.

It was also required that any of the alternative methods developed be based on retention of the existing basic system design and functional requirements.

2.2 SCOPE

All currently active KSC launch support facilities equipped with propellant or hazardous gas systems have been reviewed with respect to normal systems operation, maintenance, standby, and normal modes of failure such as leakage or an inadvertent operation that could normally be expected like activation of a safety relief valve. Abnormal or catastrophic failures have not been considered. The effect of environmental pollution as a result of propellant and gas discharges has not been considered except as specifically noted.

2.3 CRITERIA FOR EVALUATION OF ALTERNATIVES

Criteria selected for the evaluation of the alternative methods developed for reducing or eliminating the potential hazards described above include the following (in the order of relative importance):

a. System Operation: System design and functional requirements must be retained (back pressure, flow and temperature requirements).

b. Safety: Maximize safety, minimize probability of occurrence of hazardous conditions.

c. Cost: Alternative should be cost effective.

d. Schedule: Planning schedules should not be jeopardized.

e. Other KSC Resources: To include impact of implementation and operation, and maintenance.

2.4 STUDY PROCEDURE

For each area of concern the responsible design and operations and maintenance organization identified the quantities of materials vented or discharged in the system operational modes, and analyzed alternative methods in relation to the five criteria established above. The effectiveness of each alternative in satisfying these criteria was then summed to determine the overall ranking for each of the following operational modes:

a. System charging, i.e., filling storage vessels, etc.

b. System standby.

c. System operation, including functional tests, countdown demonstration test and launch operations.

d. Post-test operations, including returning system to normal standby mode.

From this data, recommendations were made as to the best alternatives, including supporting rationale as appropriate. Results are presented on an area-by-area outline in Section III.

SECTION III
SYSTEMS INVESTIGATION AND ANALYSIS

All active KSC launch support facilities under Design Engineering responsibility have been reviewed to determine the nature and extent of potential hazards from propellant and gas releases to the environment. The results of this review, alternative methods for reducing or eliminating the hazards, and recommendations pertaining to these alternatives are presented for the respective KSC areas: LC-39, Spacecraft and Industrial Area, and Unmanned Launch Operations.

3.1 LAUNCH COMPLEX 39

3.1.1 PADS A AND B

3.1.1.1 LOX System

A. System Charging. During this mode of operation, the only hazard is the venting of GOX to the atmosphere at the tanker valve station, from 50 psi down to 5 psi, after the tankers have been off loaded to the storage tank. The alternative solutions to this problem, ranked in relation to the criteria, are as follows:

1. Vent tankers through facility drain system.
2. Provide separate venting system for tankers.
3. Continue present procedure (with modifications to reduce hazards).
4. Change venting procedure to vent one tanker at a time.
5. Partial vent at pad, complete venting at a remote location.

The first alternative method of reducing the hazard by venting tankers through the facility drain system is feasible; however, it uses a pump bypass line that may cause extended venting times, which would adversely affect the LOX System capability to meet the 23-hour turn-around requirement following a launch scrub after cryogenic loading. LV is presently scheduling tests to determine the venting rates for the tankers (Linde and Big Three) when venting through the bypass and facility vent line. If tests show that venting in this manner will not impact the 23-hour turn-around, this alternative would be preferred because of nominal cost, schedule, and other resources impact.

A separate venting system for the tankers is feasible. Such a system would have connections for removing vapors away from the loading area prior to venting them to the atmosphere. This system has an advantage over using the facility drain system in permitting disposal of vented gases even when tankers are being loaded from the storage tank. This system would be expensive because of new hardware, procedures, and substantial design work required for implementation. It would also increase system maintenance cost, but could probably be scheduled without impact on launch activities.

The third alternative method requires a procedural change to allow partial venting at the loading area. While this procedure would reduce the quantity of GOX released at the unloading area, it would require a new remote area for final venting that would have to be controlled. In addition, since the tankers would still be under some pressure, a new hazard would be created along the route between the unloading area and the remote area. Moving the trailers to the remote area would also have an adverse effect on turn-around times. This method of venting would allow sizable quantities of GOX to be vented in the venting area. It would not have a significant cost, schedule, or other resources impact.

The fourth alternative of venting one tanker at a time would reduce the GOX concentration in the storage area; however, experience indicates that under certain atmospheric conditions, a large GOX cloud can be produced by venting a single tanker. In addition, the tankers may be delayed while waiting to vent and this could keep the system from meeting the 23-hour turn-around. This method could also have a cost or schedule impact.

The last method of venting is undesirable because the present procedure has no specific precaution to control the GOX cloud. If this method is continued, some means for real time evaluation of the GOX cloud hazard should be developed, i.e., monitoring with oxygen detectors, controlling tanker venting as necessary. Although the procedure presently used could be modified as mentioned above, it would still be only marginally acceptable. This venting procedure would have little cost impact and no other resources or schedule impact.

RECOMMENDATION

If scheduled LV tanker venting tests indicate that the tankers can be satisfactorily vented through the facility drain system, it is recommended that the first alternative method be implemented. If the tests indicate that the system cannot be vented satisfactorily through use of the facility drain system, it is recommended that the second alternative be implemented. A separate venting system is more expensive from design and maintenance standpoints, but its implementation is not likely to impact launch activities, and this system has the added advantage of permitting venting during loading. Any design changes resulting from the scheduled tests will be initiated through the normal KSC change board process.

B. Standby. During standby periods, the LOX storage sphere is continually venting boiloff to the atmosphere.

RECOMMENDATION

Gas vented is relatively warm, its flow rate is low, and the point of discharge is elevated, thus minimizing associated hazards; therefore, this mode of operation is considered acceptable.

C. System Operation. There are three sub-modes of system operation that may produce clouds of GOX, and the alternative solutions will be discussed for the following sub-modes: Vent-Dump Basin, Leakage and Relief Valve Operation, and System Chilldown.

Vent-dump basin. Approximately 20,000 gallons of LOX are pumped into the LOX Dump Basin prior to S-II Fast Fill in order to purge the uninsulated 14-inch cross country line of "warm" LOX. This dump produces large clouds of GOX, which can travel considerable distances before dispersing. The alternative solutions to this problem are:

1. Provide a catch tank to contain dumped liquid and provide means to disperse vented gas.

2. Provide minor modifications for existing basin.

The first alternative is most satisfactory from a technical standpoint since the catch tank would permit separation, and the vented gas could be released at a controlled rate and sufficient elevation for adequate dilution of the GOX vapor. The tank could be of several different configurations including a pressure vessel with a capacity of up to 50,000 gallons (to allow for several main line dumps due to reverts or other reasons), and would have an elevated vent stack similar to that of the main LOX storage vessel. A detailed design and testing program would be required to determine the optimum configuration. This recommendation involves a very extensive hardware change, although tanks, piping, and other hardware which could probably be adapted to this service may be available in government surplus. Depending upon the degree of sophistication of the hardware required to reduce the GOX concentration to an acceptable level, the cost of designing, developing, and implementing this recommendation could exceed $100,000.

The second alternative based on minimum change requires the acceptance of more risk and uncertainty with regard to the concentrations and locations of GOX clouds. This change involves increasing the area and height of the existing dump basin and providing an entry diffuser to prevent LOX from splashing out of the basin. This would effectively contain the LOX and would allow rapid vaporization but probably would not substantially reduce the size or concentration of the vapor cloud.

RECOMMENDATIONS

It is recommended that the second alternative be implemented and that the added risk be accepted.

Leakage and relief valve operation. During normal system operation, the potential exists for LOX/GOX to be discharged into the atmosphere. These discharge areas include relief valves, packing stem glands, valve bonnet gaskets, piping gaskets, and various system connections. The hazard appears to be relatively minor and no alternative approaches are suggested.

RECOMMENDATIONS

The risk arising from this sub-mode of operation appears acceptable because the quantities of LOX/GOX at the locations cited are small and results in a minimum hazard.

System chilldown. As a result of "preparations for vehicle loading" and "actual loading" operations varying quantities of LOX and GOX are dumped. Because of the differences in the pads, the relationships of existing drain lines from the storage areas to the ditches outside the perimeter fences require separate solutions of the problems for each pad; however, the alternatives are basically the same type, as follows:

1. Install catch tank with vent stack to dispose of vented LOX and GOX.

2. Perform site work (minor at Pad A) at existing installation.

3. Pad A: Extend facility drain lines. Pad B: Extend drain piping and perform site work.

4. Continue venting with existing installation.

The first alternative would provide a catch tank and vent stack at the end of facility drain lines, similar in design and function to the installation described for use at the LC-39 LOX dump basin. The tank could be located either at the end of the existing drain lines or at some more remote location. This modification would be most effective in dispersing the GOX cloud because it vents at an elevated location; however, it would be expensive because of considerable design, construction and testing requirements. It could, however, be accomplished without schedule impact and would not substantially impact other KSC resources.

The second alternative would entail minor site work at Pad A, including increasing the height of the existing revetment wall and possibly providing a large ditch leading out to the lagoon; at Pad B some of the existing ditches would have to be blocked off or rerouted and a new ditch provided between the dump area and the lagoon. In both cases action would be required to preclude personnel and equipment from entering areas with high GOX concentrations, and a study should be conducted at both Pads to determine alternate routes for the emergency vehicles parked at the slide wire bunker. Both Pad modifications would have small cost impact and no impact on schedules or other resources.

The third alternative of extending drain piping would decrease the GOX hazard by moving the dumping point further away from the facility. At Pad A this change would be more effective than the first alternative, but more expensive because of the additional hardware required. At Pad B, the general arrangement of drainage ditches and the close proximity of the lagoon would require site work in addition to extending the piping.

Leaving the installation unchanged is not recommended for Pad A because of the relatively small cost of the second alternative. To continue venting at Pad B with the existing installation is undesirable because the configuration of the drainage ditches promotes the flow of the GOX cloud toward the slide wire bunker and back toward the storage area. In both cases, continuation of present mode of operation would require action to preclude the entry of personnel and equipment into the area during dumping operations, and to develop alternate routes for the emergency vehicles parked at the rescue bunker. This solution would have little cost and no schedule or other resources impact.

RECOMMENDATION

Technically, the most effective method of reducing the hazardous condition at the facility drain area is the installation of a catch tank/vent stack at a remote area; however, this would involve considerable expense compared to the other alternatives. It is recommended that the second alternative be implemented in consideration of the adequate results for minimum cost. The last alternative would have the lowest cost, but acceptance of greater risk would be required.

D. Post Operations. After loading operations, the storage tank is depressurized. The tank is vented through the steady-state vent, which is at an elevated position near the tank equator. Alternative solutions to this problem, ranked in relation to the criteria, are as follows:

1. Leave the existing vent stack as it is.
2. Increase the height of the existing vent stack.
3. Move the tank vent to a remote location.
4. Install equipment to reclaim vented gases.

If the existing vent stack is not modified and the system operation continues unchanged, it would be advisable to implement strict controls to preclude the entry of personnel and equipment into the area during storage tank depressurization. This alternative would have a minimum cost, schedule, or other resources impact.

The second alternative would allow more complete mixing of the cold, heavy GOX vapors as they fall toward the ground from the higher stack level; however, the hardware modifications would be relatively expensive. They could be accomplished without schedule impact and would have little other resources impact. Moving the tank vent to a more remote location as suggested by the third alternative would reduce the hazard in the storage area; however, this would involve an extensive hardware change and would be expensive. In addition, the increased length of pipe would be very costly. Also, the increased length of pipe would cause an increase in line pressure drop which could adversely affect the tank blowdown rates and ullage space in the storage tank. This modification could be accomplished without schedule impact and would have little other resources impact.

Installing equipment to reclaim the vented gases would require substantial design and testing effort. Because this modification would be very expensive and could affect the system operation, it is not recommended. It could, however, be accomplished without schedule impact. It would also create additional system maintenance.

RECOMMENDATION

It is recommended that the tank vent stack be left as is. The existing stack has been used successfully in the present mode of operation and, with strict control of personnel and vehicles, it should provide safe operation with no cost impact.

3.1.1.2 LH2 System

A. System Charging. There are three sub-modes of system charging which release gaseous hydrogen to the atmosphere, and the alternative solutions will be discussed in the following order: Venting at Top of Storage Tank, Purging of Gases after Loading, and Venting Tankers after Loading into and out of the storage tank.

Venting at Top of Storage Tank: During storage tank loading, gaseous hydrogen is vented to the atmosphere at a height of 85 feet at a rate of approximately 240 scfm (0.024 lb/sec). The alternative solutions to this problem are ranked as follows:

1. Route gas to burn pond and burn.
2. Continue to vent gas to atmosphere at top of storage tank.
3. Route gas to burn pond and vent to atmosphere.

Routing the gas to the burn pond is undesirable because it increases the hazard area and the area which must be controlled (approximately 700 feet to burn pond). In the past this has proven difficult. (It has been reported personnel have climbed over the fence surrounding the pond during an operation.) Confining the gas in a pipe makes it easier to detonate, but unconfined hydrogen requires a powerful ignition source (such as a blasting cap) to detonate. The first and third alternatives are therefore not recommended.

The second alternative is preferred because it limits the hazard area and therefore the control area. Detonation would be extremely unlikely to occur. At Lewis Research Center the allowable vent rate (in a congested area) is 0.25 lb/sec. At Plum Brook Station (an uncrowded area) the allowable vent rate is 0.5 lb/sec.* The vent rate during storage tank loading is 0.024 lb/sec., 10 percent of that at Lewis.

RECOMMENDATION

As the existing hydrogen gas discharge rates meet the requirements of NASA TMX-52454, with which KSC concurs, it is recommended that venting in the present manner be continued, and engineering for a suitable static discharger be initiated (LC-34 and LC-37 have workable designs).

*Lewis Research Center Liquid Hydrogen Safety Manual, NASA TMX-52454, governs venting of hydrogen at Lewis and Plumb Brook installations.

Purging of Gases After Loading: After tankers have off loaded liquid hydrogen, the hose between the tanker and the fill manifold is purged of hydrogen with gaseous helium. This action causes venting of gaseous hydrogen from the tanker bleed valve at the personnel level. The alternative solutions suggested for this problem are ranked as follows:

1. Connect a flex hose from the bleed valve to the vent system on the fill manifold.

2. Connect bleed valve to vent above the personnel level.

3. Continue purging flex hose to the atmosphere.

The first alternative would require a modification to allow venting through the fill manifold vent system. It would also require a procedure change to purge the line before connecting, and to provide sampling instructions. This operation is complicated and risky because there is a possibility of air getting into the system. The second solution would require a system modification including vent piping, purge system, sampling and pipe supports. Gaseous hydrogen would still be vented to the atmosphere so that a sample may be taken, but not as much hydrogen would be released.

The third solution is preferred because inerting the hose takes little time and personnel can be kept clear of the venting area.

RECOMMENDATION

As the existing method takes but little time and discharge rates meet requirements of NASA TMX-52454, it is recommended that this method be continued and strict safety procedures be used to clear personnel from the venting area.

Venting Tankers After Loading: After the tankers have off loaded liquid hydrogen they are presently vented to the onsite atmosphere to maintain tankers at standby pressure. Each tanker vents at a rate of approximately 0.45 lb/sec at a level 10 feet above ground. Two to three tankers are normally vented at the same time, so that the total flow rate could be 1.35 lb/sec. The alternative solutions to the problem are ranked as follows:

1. Vent tankers through fill manifold vent system to burn pond.
2. Vent tankers through storage tank vent.
3. Continue to vent tankers to the atmosphere.
4. Provide a separate vent system for tankers.

In the first alternative, the high vent rates and the height-above-ground factor indicate that it would be preferable to vent through the fill manifold system, but the problem of personnel control in the larger hazardous area and the one-minute vent time reduce the advantage. Also, all tankers would have to be empty before venting and relief pressure may be exceeded during the waiting period, causing tanks to vent to the atmosphere.

Using alternative two appears desirable because GH_2 vented through the storage tank vent would be at a safe elevation for adequate dispersion. The tankers would be vented down to a pressure of 10 psig. Venting could be accomplished through liquid in the tank; or, with a pneumatics change to enable local control of valve A3304, the tankers could be vented through the ullage space in the tank. Venting through the ullage space would be preferable to prevent upsetting thermal balance in the tank.

In the third alternative it is difficult to determine the hazard level of venting tankers to the atmosphere because the vent rate is larger than at Lewis or Plum Brook, but the duration is shorter. Also, the tankers will build up pressure during warmup and may activate a relief valve. Venting of the tankers to the atmosphere has been the standard mode of operation at Pads 34, 37, and 39, and by ensuring adequate grounding and lightning protection, has resulted in no incidents.

The last alternative would require an extensive modification for adding the separate tanker vent system including overhead vent lines, purge and sampling systems, plus additional setup and maintenance time.

RECOMMENDATION

It is recommended that tankers be vented through the storage tank vent.

B. Standby. During normal standby conditions the storage tank vents GH_2 gas to the atmosphere at a rate of approximately 0.00136 lb/sec at an elevation of 85 feet. The stack on top of the tank occasionally ignites because the existing design is inadequate. This fire is easily extinguished by increasing the purge rate and closing the storage tank vent valve to allow the vent stack to cool below the hydrogen ignition temperature. The suggested alternatives to this problem are ranked as follows:

1. Continue the operation in the same manner.
2. Pipe gas to the burn pond and burn.
3. Increase the GN_2 purge rate.

Continuing the operation at a vent rate which is far less than that used at Lewis Research Center or the Plum Brook Station is not considered hazardous. Occasional fires which may occur in this operation could be prevented by an adequate static discharger design. The second alternative solution would extend the hazard area and personnel control area, and the burn pond would have to operate continuously; therefore, it is not considered a practical method. The third suggested solution would prevent fires by diluting the hydrogen with GN_2, but the cost would be prohibitive.

RECOMMENDATION

> As vent rates are within the requirements of TMX-52454, it is recommended that the storage tank venting to the atmosphere be continued.

C. System Operation. During S-II/S-IVB vehicle loading, a large quantity of GH_2 is burned in the burn pond located midway between the pad and the LH_2 facility. No alternative solutions or design changes are suggested because the method of disposing of large quantities of gas with low back-pressure is considered acceptable.

3.1.1.3 Hypergols System

A. Modes. All hypergol system modes of operation appear to have adequate flush and drain capabilities, but the existing vapor venting capabilities are worthy of consideration. The alternative solutions for this problem may be ranked for all operational modes as follows:

1. Continue venting to the atmosphere.
2. Install dilution system (air or water).
3. Install decomposition system.

A separate, detailed study of the hypergol vapor decomposition methods used by industry is being conducted by DD-MDD-41 to determine if any would be feasible for use at KSC. Several methods of decomposing hypergol vapor into harmless gas have been developed by industry, but all are based on steady flow and continuous operation; therefore, these methods are not directly applicable for the variable flow and intermittent operation at KSC. The Design Engineering study to determine the optimum method for converting LC-39 hypergol vapor to harmless gases is being conducted as follows:

1. Data on present industrial methods are being gathered.

2. Industrial methods are being analyzed for adaptability to variable flow and discontinuous operations.

3. Industrial methods will be rated according to adaptability to KSC conditions.

4. Cost/time impacts for each method will be developed.

5. Optimum method will be defined by analysis of data developed in steps 3 and 4.

RECOMMENDATION

Although the present methods of venting are considered acceptable, it is recommended that the detailed design study now being conducted be completed to determine the optimum method of hypergol decomposition and the resulting findings and recommendations communicated through normal KSC channels, i.e., reports, change board process, etc.

B. Hypergol Training Facility. Hypergol vapor clouds produced for training firemen, rescue specialists and technicians are currently included in a separate DE detailed assessment of pollution at KSC and corrective measures for compliance with Presidential Order 11507 (Reduction of Pollution).

The Hypergol Training Facility appears to have adequate flush and drain, and vapor venting capabilities, but all system functional designs are considered to be suitable for investigation. Alternative solutions would be considered appropriate only after a detailed design analysis.

A separate, detailed design analysis of the facility is now being conducted by DD-MDD-41 to correct operating anomalies. Considerable improvement in operation and some improvement in safety is expected to result, but this will not reduce (nor increase) production of vapor clouds, which is a required operational capability controlled by IS-PEM operating procedures.

RECOMMENDATION

It is recommended that the detailed design analysis now being conducted be carried to completion and optimizing recommendations implemented through the normal KSC change board process.

3.1.1.4 RP-1 System. No RP-1 liquid or vapor hazards were identified for normal system operations, and no design changes are recommended.

3.1.1.5 GN_2 System. During normal operations the high pressure GN_2 system vents GN_2 by the operation of relief valves, vents, etc. As all the vents are piped to discharge in a manner which presents no hazard to personnel or equipment; therefore no design changes are recommended.

3.1.1.6 ECS Operations. Hazardous ECS operations start when purge GN_2 shutoff valves and manual inlet valves are opened to configure GN_2 standby. This occurs prior to air-to-GN_2 changeover, which is initiated 80 to 30 minutes before cryogenic loading preparations and during the T-9 hold. This hazardous operation continues until liftoff and is terminated by closing the purge GN_2 hand valves when pad access is obtained. For CDDT, hazardous ECS operation is terminated by GN_2 to air changeover 30 minutes after cryogenic drain by closing the purge GN_2 handvalves.

The existing procedures and safety equipment are considered adequate to prevent hazards to personnel from a GN_2 rich atmosphere. These safeguards include oxygen monitoring, safety clearance, provision of Scott air packs, and venting relief valves to areas outside of the ECS room.

RECOMMENDATION

No changes are recommended. The safety oxygen monitoring procedural requirements for pad rooms adjacent to the ECS room are adequate for periods following hazardous ECS operations.

3.1.1.7 GH_2 System. For all normal operations or emergencies, GH_2 is vented to the atmosphere. The system is designed so that all vent valves and relief valves vent to a 40-foot high flare stack which burns the GH_2 safely. As this is not considered a problem area, no design changes are recommended.

3.1.1.8 Helium System. All normal operations of the helium system vent gaseous helium to the atmosphere, but this is not considered a problem because vent and relief valves are all piped to vent in a manner which presents no hazard to personnel or equipment. No design changes are recommended.

3.1.2 CONVERTER COMPRESSOR FACILITY

3.1.2.1 LN_2 System

A. System Charging. During filling of the storage tank LN_2 boiloff of GN_2 is vented from the tank, and after unloading, LN_2 tankers are vented to the atmosphere. Venting from the storage tank is approximately 30 feet above the ground level and considered adequate to prevent displacement of oxygen at the personnel level. Venting from the tankers can be limited procedurally if necessary.

RECOMMENDATION

No design changes are recommended, however, measurements should be taken during a worst-case typical LN_2 tanker vent operation to verify that there is no significant reduction in the oxygen content of the air.

B. Standby. During standby periods LN_2 storage tank boiloff vents GN_2 to the atmosphere 30 feet above ground at a rate of about 65 scfm. Venting at this level is considered adequate to prevent displacement of oxygen at the personnel level.

RECOMMENDATION

No design changes are recommended.

C. System Operation. During normal operations there are three sub-modes of operation which release GN_2 to the atmosphere. The low pressure N_2 vaporizer automatically vents outside the building about 10 feet above ground during the standby mode (backup for Big Three) to prevent excess pressure buildup; system relief valves and/or vent/drain valves may vent as part of normal system operation; and Big Three relief valves and/or vent valves may vent during normal operation. None of these operational sub-modes is considered a problem, but some measurements should be taken below the L.P. vaporizer vent to verify that the oxygen content of the air is adequate.

RECOMMENDATION

No design changes are recommended; however, the air below the L.P. vaporizer should be checked during venting to determine if there is any significant reduction in oxygen content. Tests should be conducted during the worst period of ambient contamination.

3.1.3 VEHICLE ASSEMBLY BUILDING

3.1.3.1 Pneumatics System. All operational modes of the pneumatics system vent GN_2 and GHe in confined areas. Failure of several vent or relief valves would result in large quantities of these gases being released into nonventilated areas and consequently lower the oxygen content of the air below allowable minimums (see "VAB Gas Venting Hazard Survey," Bendix Launch Support Division, July 1967). The alternative solutions to this problem are ranked as follows:

1. Route all vents to the outside of the building.

2. Route vents to bay areas in VAB where dilution would prevent oxygen concentration from becoming too low.

3. Continue operation in the present manner.

RECOMMENDATION

Further investigation of the above alternatives is required in order to determine a proper course of action. Design Engineering and the Safety Office will look into this problem further and any design changes resulting from subsequent recommendations will be processed through normal KSC channels.

3.1.4 PROPELLANT SYSTEMS CLEANING LABORATORY. This facility is used for cleaning, checkout, calibration, and testing of various components. No problems have been identified with any of the systems involved.

3.2 SPACECRAFT AND INDUSTRIAL AREA

3.2.1 OPERATIONS AND CHECKOUT BUILDING. Gases vented by all operating modes of all gas systems are piped outside the Operations and Checkout Building and no problems have been identified.

3.2.2 ENVIRONMENTAL SYSTEMS TEST FACILITY. The 10,000 psi GO_2 System is the only source of any appreciable gas release at this facility. High pressure GO_2 is vented from relief valves and vent valves, but no problems were identified in any mode of operation.

3.3 UNMANNED LAUNCH OPERATIONS

3.3.1 COMPLEX 17

3.3.1.1 Liquid Oxygen System. The problem areas identified at LC-17 were in two sub-modes of system operation: Detanking (Dumping, Venting) and Vehicle Venting. No problems were apparent in the charging, standby, or post operational modes.

A. Detanking (Dumping, Venting). The dump line is located at the east edge of the launch deck, dumping into the flume. If an emergency dump is necessary, it is possible that the rooms underneath the launch deck will be filled with GOX. The electrical equipment in the room is not hazard proof. The emergency dump probability is estimated at 5 percent per detanking attempt. The alternative solutions for this contingency are ranked as follows:

1. Relocate and extend the dump line.
2. Seal and pressurize the rooms under the launch deck.
3. Hazard proof all electrical equipment.

RECOMMENDATION

A detailed study of the first and second alternative solutions is now being conducted and should be completed in about 30 days. Hazard proofing the electrical equipment may require replacing the equipment and would be expensive. Upon completion of the detailed study, any recommended hardware or procedural changes will be processed through the normal KSC change board process.

B. Vehicle Venting. The LO_2 cold flow is performed with the service structure around the vehicle. The venting of the vehicle LO_2 tank during this operation could fill some of the service structure rooms with GOX. The alternative solutions to this problem are ranked as follows:

1. Inspect the rooms to ensure that any electrical equipment that is not hazard proof is turned off. Inspect all rooms after the operation to ensure that the atmosphere is not oxygen-rich before returning to normal operations.

2. Remove the service structure during this test.

3. Seal and pressurize the rooms.

RECOMMENDATION

The first solution is recommended because the rooms could easily be inspected with electrical power off, and they could be ventilated to reduce oxygen concentrations if necessary. Pressurizing the rooms is not considered economically feasible, and removing the service structure is a lengthy, hazardous task that would require additional support expense.

3.3.2 COMPLEX 36

3.3.2.1 Liquid Oxygen System

A. System Charging and Operating. During the venting sub-modes of these operations, LOX storage tanks are vented through a vent at the tanks, creating a GOX cloud in the storage tank area (in a controlled condition during this period). The alternative solutions for this problem are ranked as follows:

1. Continue present method of venting.
2. Extend vent lines out of the storage area.

NOTE

There are no standby or post operations problems at Complexes 36A and 36B.

RECOMMENDATION

A detailed study of the second alternative solution is now being conducted and should be completed in about 30 days. If a change is recommended, it will be initiated through the normal KSC channels.

B. System Operation. During the liquid oxygen cold flow test, performed with the service structure in place, venting from the top of the umbilical tower could fill some of the service structure rooms with GOX. The alternative solutions to this problem are ranked as follows:

1. Turn off service structure power after test and inspect rooms before opening the structure for normal work.

2. Remove the service structure during this test.

RECOMMENDATION

Because removal of the service structure is a lengthy task requiring added support expense, the first alternative is recommended. Service structure power can be secured without affecting the test, the rooms can be inspected for oxygen enrichment of the atmosphere, and ventilation can be readily performed if required.

3.3.2.2 LH_2 System. The only problem identified in this system is venting of LH_2 during storage tank filling and vehicle tanking.

RECOMMENDATION

It is recommended that the present venting procedure be continued because storage tank hydrogen is vented to a burn stack located 50 feet above the umbilical mast. During tank filling, the tankers are separately vented to a line 100 feet from the storage tank.

3.3.3 WESTERN TEST RANGE

3.3.3.1 Liquid Oxygen System. The only problem identified at the Western Test Range occurs during the normal LOX tanking and leak check operation, which is performed with the service structure in place. Vented GOX could fill some of the service structure rooms during this operation. The alternative solutions to this problem are as follows:

1. Turn off service structure power and inspect area after test and before opening the structure for normal work.

2. Hazard proof the service structure rooms either by positive purges, ventilation, de-energizing unused circuits and/or hazard proofing electrical equipment.

RECOMMENDATION

The complex will undergo major modifications after the next launch, and it is recommended that the second alternative be implemented then.

SECTION IV
CONCLUSIONS AND RECOMMENDATIONS

4.1 SYSTEMS SUMMARY

The results of this study are summarized below by area and system. Conclusions and recommendations are presented on a system by system basis with a distinction between recommendations concerning existing facilities and alternatives which should be considered for new facilities.

4.1.1 LOX. The best technical solution to dumping relatively large amounts of LOX is to discharge the LOX into a pressure vessel which would separate liquid and gas and vent the gas at a sufficiently high elevation to provide adequate dilution under all atmospheric conditions.

An alternate method involving the acceptance of greater risk with respect to the size and location of vapor clouds is to discharge the LOX into an open top tank, basin, ditch, or directly onto the ground. The degree of risk varies with how remote the location of the discharge is with respect to personnel and equipment, and the probability that the vapor cloud will be moved to a more hazardous location by wind, normal dispersion, or the geometry of the containment area. This risk can be minimized by consideration of these factors.

4.1.2 LH_2. The best solution for disposing of large quantities of hydrogen is to vaporize the liquid and burn the resulting gas. In cases such as steady state venting of the LH_2 storage vessel or other small flow rates of hydrogen gas, the risk of venting raw hydrogen is acceptable (TMX-52454).

4.1.3 RP-1. There appear to be no problems associated with handling and disposing of RP-1, provided that proper safety procedures are utilized. Environmental pollution should be considered however, in disposing of RP-1.

4.1.4 LN_2. It is felt that LN_2 may be safely dumped in remote open areas where there is little chance of depleting oxygen content. In all cases however, safety procedures should be followed to monitor oxygen content and to prevent personnel from inadvertently entering the discharge area. Thermal environmental pollution should be considered, however.

If small quantities of LN_2 are discharged into inhabited areas such as at the LN_2 tank fill manifold during storage tank filling, safety procedures to include oxygen content monitoring should be enforced.

4.1.5 HYPERGOLS. Present methods of venting hypergols to the atmosphere at KSC are considered an acceptable risk due to rigid safety procedures. A better alternative, however, would be dilution of the hypergols to a nonhazardous level with air, H_2O, or by some other method. This, however, again adds to environmental pollution.

Methods of disposing of all vented quantities of hypergols to include vapor decomposition are being further studied in detail. The results of this study will be communicated through normal KSC channels.

4.1.6 GOX. GOX should be vented at relatively high locations with respect to personnel and equipment. If there is a reasonable possibility of the occurrence of high concentrations of GOX in closed areas containing electrical equipment, hazard proof equipment should be used or power turned off at such times.

4.1.7 GH_2. Relatively large quantities of GH_2 should be vented into a flare stack and burned. Small quantities may be vented through high vent stacks without burning.

4.1.8 GN_2. Large quantities of GN_2 should be vented at high elevations to allow for adequate dispersion. Closed areas in which there is a risk of GN_2 should have an oxygen monitoring system which will warn personnel entering of low oxygen content.

4.1.9 GHe. Large quantities of GHe should be vented at high elevations to allow for adequate dispersion. Closed areas in which there is a risk of GHe should have oxygen monitoring system which will warn personnel entering of low oxygen content.

4.1.10 ECS. The operating mode of the ECS system is the only hazardous condition in this system. Since GN_2 is used in this mode, the recommendations are the same as for venting of large quantities of GN_2.

4.2 OTHER RECOMMENDATIONS

4.2.1 LOX STUDIES, LC-17 AND LC-36. Unmanned Launch Operations is presently making a detailed study of LOX systems in LC-17 and LC-36 areas. The results of these studies will be communicated through normal KSC channels.

4.2.2 OTHER POTENTIAL HAZARDS. It is recommended that the Safety Office look into the following areas which were not included in the scope of this study:

a. Hazards created by volatile fluids used in such locations as cleaning facilities or photo labs.

b. Hazards created by venting of space vehicle tanks during checkout in the VAB.

It is also recommended that Installation Support review potential radiation hazards which also were not covered by this study.