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MANNED SPACE PROGRAMS ACCIDENT/INCIDENT SUMMARIES (1963 - 1969)

General Electric Co.
Daytona Beach, Florida

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Project Management, Director, Manned Space Flight Safety, Washington, DC

16. Abstract

This summary is a compilation of 508 mishaps assembled from company and NASA records which cover several years of Manned Space Flight Activity. The purpose is to provide information to be applied towards accident prevention. The accident/incident summaries are categorized by the following ten systems: Cryogenic; Electrical; Facility/GSE; Fuel and Propellant; Life Support; Ordnance; Pressure; Propulsion; Structural; and Transport/Handling. Each Accident/Incident summary has been summarized by description, cause and recommended preventive action.

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PREFACE

The objectives of the NASA Aerospace Safety Research and Data Institute (ASRDI) are:

(a) To support NASA, its contractors and the aerospace industry with technical information and consulting on safety problems.

(b) To identify areas where safety problems and technology voids exist and to initiate research programs both in-house and on contract in these problem areas.

(c) To author and compile state-of-the-art and summary publications in our areas of concern.

(d) To establish and operate a Safety Data Bank.

In pursuing these objectives, ASRDI has assumed the responsibility for publishing two documents resulting from an effort initiated and supported by the NASA Headquarters Safety Office (DY).

The first of these documents is:

General Electric Co., Daytona Beach., Manned Space Programs Accidents/Incidents Summaries (1963-1969), March 1970, NASA, Director, Manned Space Flight Safety, NASW-410 (Safety Task), NASA-CR-120998.

This document is being reprinted to fill current needs.

The second of these documents is:

Cranston Research Inc., Manned Space Programs Accident/ Incident Summaries (1970-1971), April 1972, NASA Headquarters Safety Office, Charles W. Childs, Program Manager, NASW-2225, NASA-CR-120999.

This is the initial printing of this report.

Frank E. Belles
Director of Aerospace Safety
Research and Data Institute

FOREWORD

This summary lists some 500 errors and oversights that have caused loss of life, loss of funds and created expensive delays or embarrassment in space programs. Considering the magnitude of the program the number of "anomalies" were surprisingly few. Nevertheless, the purpose of this project is to help prevent repetition of these errors and oversights in future programs. An epigram ascribed to Emerson says, "Learn from the mistakes of others, you'll never live long enough to make them all yourself."

The compilation was made possible through the understanding and support provided by management and safety personnel of NASA Headquarters, NASA field centers, NASA contractors, associate contractors and subcontractors. The cooperation of the many companies who contributed to this document is greatly appreciated.

An accident or incident, in fact, any undesirable event, reflects on the efficiency of management and of participating personnel. Prof. Kenneth Andrews of the Harvard School of Business Administration noted that "every accident, no matter how minor, is a failure of organization." A repetition of the accident or incident is difficult to excuse if preventive information is available but unused.

The summaries are classified by ten systems. We would appreciate suggestions on improving the classification and especially your plans to encourage the use of this summary in accident prevention.

A well known ball player Tommy Henrich once said, "Catching a fly ball is a pleasure, but knowing what to do with it after you catch it is a business."

Jerry Lederer

Jerome Lederer, Director
Manned Space Flight Safety

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PART I, INTRODUCTION

A. Purpose and Objective

This compilation of accident/incident information relative to space programs has been prepared as part of the NASA Manned Space Flight Safety Program. The objective of the project was to contribute to safety by making available to government agencies and industrial concerns, the significant lessons learned from the accident/incident experience of Manned Space Flight Programs. No reference has been made in these summaries as to location, facilities, companies, organizations, products, programs, or individuals involved. The document has been prepared primarily for the use of management, supervisory, engineering, and safety personnel on space programs. For most effective use in future programs, the individual accidents/incidents recorded herein must be interpreted by program specialists for application to potential hazards of the particular program or systems involved. For the assistance of management in evaluating the potentially hazardous phases of a program, statistical summaries of cause factors and other significant information pertaining to accident prevention in future programs has been provided.

B. Information Sources

The summaries contained herein were compiled from existing documentation of accidents or incidents on Manned Space Flight Programs. In the compilation of this document approximately 10,000 case documents were reviewed from which a total of 508 summaries were selected. No attempt was made to record anomalies which occurred during manned space flight missions. Records reviewed included existing records of NASA Hdqs., NASA field centers concerned with space programs and 18 contractors, associate contractors and subcontractors on space programs. The majority of accidents/incidents selected, occurred during various phases of the Apollo Program with the remainder selected from other manned space programs.

C. Criteria Used

Each accident/incident summary contained in Part III has been summarized by description, cause and recommended/preventive action: The criteria used for each of these summary segments is defined below:

1. Descriptions

   Accidents/incidents were selected from records on the basis of the following criteria:

   a. An occurrence which reflected a significant lesson of importance to future programs.
   b. The occurrence involved space programs flight vehicle systems, hardware or ground support equipment and facilities providing direct support to space programs.
   c. The occurrence resulted in personnel fatality/injury, and/or caused damage to program systems, hardware, GSE and facilities or resulted in a potentially hazardous condition.

The description for each accident/incident relates what happened; how it happened; the phase of the program activity involved; hardware, equipment and/or and facilities damaged, personnel injuries and fatalities incurred or potential hazards created. The description of what happened has included the event that caused the accident/incident to occur. For example, "a gauge blew up and injured one person during development test of an engine, due to inadvertent cross connection of high and low pressure systems." Here, the first order cause factor was included as part of the description of what happened and permits concentration in the cause section on the second order of causes related to why it happened. This was done because it is believed that too often cause factors have not been identified in sufficient depth to provide guidelines for management or supervisory corrective programs.

2. Causes

The causes identified in these summaries reflect the causes shown in the accident/incident records. In many cases, the reports were supplemented by discussions with key people to more accurately identify cause factors. The second order cause factors considered were hardware or software deficiencies, as determined by the following criteria:

a. Hardware Deficiencies

- Material Failure - Material failure as used in cause determinations was defined as any failure of materials or components in development tests at less than design specification or failure under operational conditions.

- Design Deficiency - This cause factor was defined as any design specification inadequacy, resulting in deficient hardware which contributed to the occurrence of an accident/incident. Factors considered were omission of essential information, failure to specify safety devices or warnings, failure to determine stress/fatigue and other operational/interface factors, errors in material selection, or clerical errors in drawings and specifications.

- Materials Incompatibility - Materials incompatibility was defined as any cause in which incompatible materials were brought together through a design error, installation error, or procedural error.

- Malfunctions - Malfunctions were defined as any anomaly where a system, subsystem or component failed to function as intended, resulting in conditions which contributed to accidents/incidents.

b. Software Deficiencies

- Procedural - A procedural deficiency was defined as any case in which formal procedures contributed to accident/incident causes as a result of failure to prepare procedures, failure to follow procedures, deviations from procedures during a test, failure to coordinate concurrent tests, omissions of essential information in procedures, clerical errors in procedures, use of wrong procedures, or failure to update procedures.

- Planning - A planning deficiency was defined as any case where the cause of an accident/incident was due to failure to properly plan prior to an event. Included in these considerations were lack of or inadequate test planning, failure to perform pre-operations hazard analysis, deficiencies in planning for transportation, handling and storage, and failure to determine necessary equipment and personnel resources for an operation.

- Work Control - A work control deficiency was defined as any condition contributing to an accident/incident during installation, maintenance, storage, cleaning, repair, and fabrication of systems. Factors considered as work control deficiencies were inadequate records, inadequate area control, failure to exercise proper control over materials, failure to properly mark and identify equipment and failure to define work requirements.

- Management/Supervisory - This cause factor was defined to include errors in decisions, policies, or directives which contributed to the occurrence of accident/incidents. Included was failure to perform management or supervisory responsibilities for planning; training and certifying personnel; and failure to perform personnel surveillance of critical activities.

- Training - This category was defined as any deficiency in workmanship or duty performance in which lack of training, briefing, certification or specific work instructions contributed to an accident/incident.

- Inspection - An inspection deficiency was defined as any condition contributing to an occurrence in which inspection was involved through failure to verify, failure to maintain inspection records or errors in inspection records.

3. <u>Recommended Corrective/Preventive Action</u>

In this part, an effort was made to reflect all recommendations included in the reports reviewed. In many cases, recommended corrective/preventive actions were keyed solely to the one event and was not necessarily broadly applicable to other similar events. In those cases, the recommended corrective actions were extrapolated for application generally to like systems on future programs. Also, since cause factors were considered in terms of Hardware or Software deficiencies, the recommended corrective/preventive action was generally oriented by to these cause factors.

PART II, STATISTICAL SUMMARY

A. Distribution by System

The percentage distribution of accident/incidents by system categories are shown in Chart I. Of the ten (10) system categories used, the largest contributor to accident/incidents was Pressure Systems. The three systems having the highest percentage involvement were as follows:

1.	Pressure Systems	23%
2.	Facility/Ground Support Systems	19%
3.	Fuel and Propellant Systems	13%

Of significance, is the fact that ordnance systems were not a major source of accidents, constituting only 3% of the total and most of these occurred on programs other than the Apollo Program. Likewise, structural systems were not a major source of accident/incidents, comprising only 3% of the total.

B. Distribution by Causes

The distribution of accidents/incidents by cause factors is shown in Chart 2. Software deficiencies were a greater contributor to accident/incidents than Hardware deficiencies, and procedures, work control and inspection were the most significant Software cause factors.

1. Hardware Deficiencies

Hardware deficiencies were for the most part, related to design deficiencies. The number of cases in which design deficiencies contributed to or caused accident/incidents was significantly higher than those caused by material failures or malfunctions. In 37% of the cases, a design deficiency was identified, whereas, only 3% of the cases involved material failure as a cause and only 8% involved malfunctions. Cases involving malfunctions occurred mostly during operational tests and manufacturing checkout. Likewise, the number of cases where material incompatibility contributed to the cause of accidents/incidents was relatively small, only 4% of the cases, however, some very serious accidents occurred as a result of this factor.

2. Software Deficiencies

The number of cases involving procedural deficiencies was significantly high and constituted the single largest contributor to accidents/incidents causes with 46% of the cases. Likewise, the number of related work control deficiencies was quite high. This area was a very significant factor in accident/incident causes and constituted the second largest contributor with 40% of the cases.

Management or supervisory deficiencies were involved in 4% of the cases. Seven per cent (7%) of the cases involved planning deficiencies and 11% of the accidents/incidents involved training deficiencies. In many cases, training deficiencies pertained to inadequate knowledge of the total operation. Individuals were not well enough informed of other work going on concurrently and/or what the previous shift had done as shown by the fact that 3% of the accidents/incidents involved failure to transfer essential information during shift changes. Although inspection deficiencies were not the primary cause of accidents/incidents, inspection was a major contributing factor since many accidents/incidents could have been prevented had there been sufficient and timely inspection and verification. For example, in 4% of the cases, there were cross connections of lines or cables which could have prevented by inspection. Twenty-six percent (26%) of the accidents/incidents involved inspection deficiencies.

C. Distribution by Program Activity

As records were reviewed, the accidents/incidents were identified to a program activity. The results of this compilation are shown in Chart 3. As shown in the chart, more accidents/incidents occurred during operational test and checkout than in any other program activity, accounting for 47% of the total. Manufacturing was also a signficant source of accidents/incidents with 30% of the cases occurring during this activity.

D. Distribution by Accident vs Incidents

An attempt was made to determine the number of accidents vs incidents, but problems of definitions made this very difficult. Under NASA Safety Manual NHB 1700.1 published in 1969, accidents and incidents are defined in terms of seriousness as related to monetary damage or personnel injury/fatality. Prior to the publication of this manual, there was inconsistency in the manner of defining accidents and incidents. However, those cases were identified where an investigating board was established and this was used as a basis for determining number of accidents. On this basis, accidents constituted approximately 17% and incidents 83% of the total summaries included.

E. Distribution by Work Shift

The statistical summary of accidents/incidents by work shift revealed a rather direct relationship to the level of activity or the number of people involved in each shift. With most of the work done on the day shift, as would be expected, the majority of cases occurred on the first shift. Although risks may have been higher, per level of activity, on second and third shifts, data was not available to make this correlation. Distribution of cases by shift was as follows:

First shift	-	65%
Second shift	-	26%
Third shift	-	9%

F. Distribution by Calendar Quarters

The seasonal distribution of accidents/incidents by calendar quarters was compiled as follows:

First Quarter (Jan., Feb., Mar.)	-	29%
Second Quarter (April, May, June)	-	24%
Third Quarter (July, Aug., Sept.)	-	27%
Fourth Quarter (Oct., Nov., Dec.)	-	20%

This compilation shows a shows a higher percentage occuring in the winter and summer which may be due partly to more severe weather conditions during these periods , or there may have been a higher level of activity during these periods. This distribution could not be correlated to any particular factor, and the variation in distribution was not enough to be significant.

G. Injuries/Fatalities/Damage

Records compiled on percentage of accident/incidents which involved injuries, fatalities, or damage showed the following:

	% of the total
Injuries	15%
Fatalities	1%
Damage (hardware, facilities, equipment)	68 %

In a number of the cases, personnel injury or fatality, as well as damage occurred. A number of incidents were included in the summaries where there were no injuries, fatalities, or damage, but the incident created a high hazard potential. For these reasons, the percentages shown do not cumulatively represent all the accidents/ incidents summarized.

H. Human Error

Separate emphasis was not given to human error in identifying cause factors because human error would be present to some degree in most unplanned events. Emphasis was placed, however, upon determining what caused or contributed to the human error and as the accident/incident records were reviewed, a notation was made as to whether or not human error was directly involved in the cause of the accident.

H. Human Error (Cont.)

Based upon a simple yes or no determination of direct human error involvement, 74% of the cases involved human error as a contributing factor to the cause of accidents/incidents. The number of cases where an individual act of carelessness or irresponsibility at the time of the occurrence was the only cause, was less than 1% of the total. Although human mistakes, poor workmanship, carelessness or irresponsible acts, were identified as directly or indirectly involved in 74% of the cases, the majority of these cases involved second order causes. Human error involvement could probably have been identified to the remainder of the cases had more detailed information been available. In practically all the cases there were indications that management and supervisory deficiencies were indirectly involved in accident/incident causes even though these deficiencies were not specifically identified in the reports.

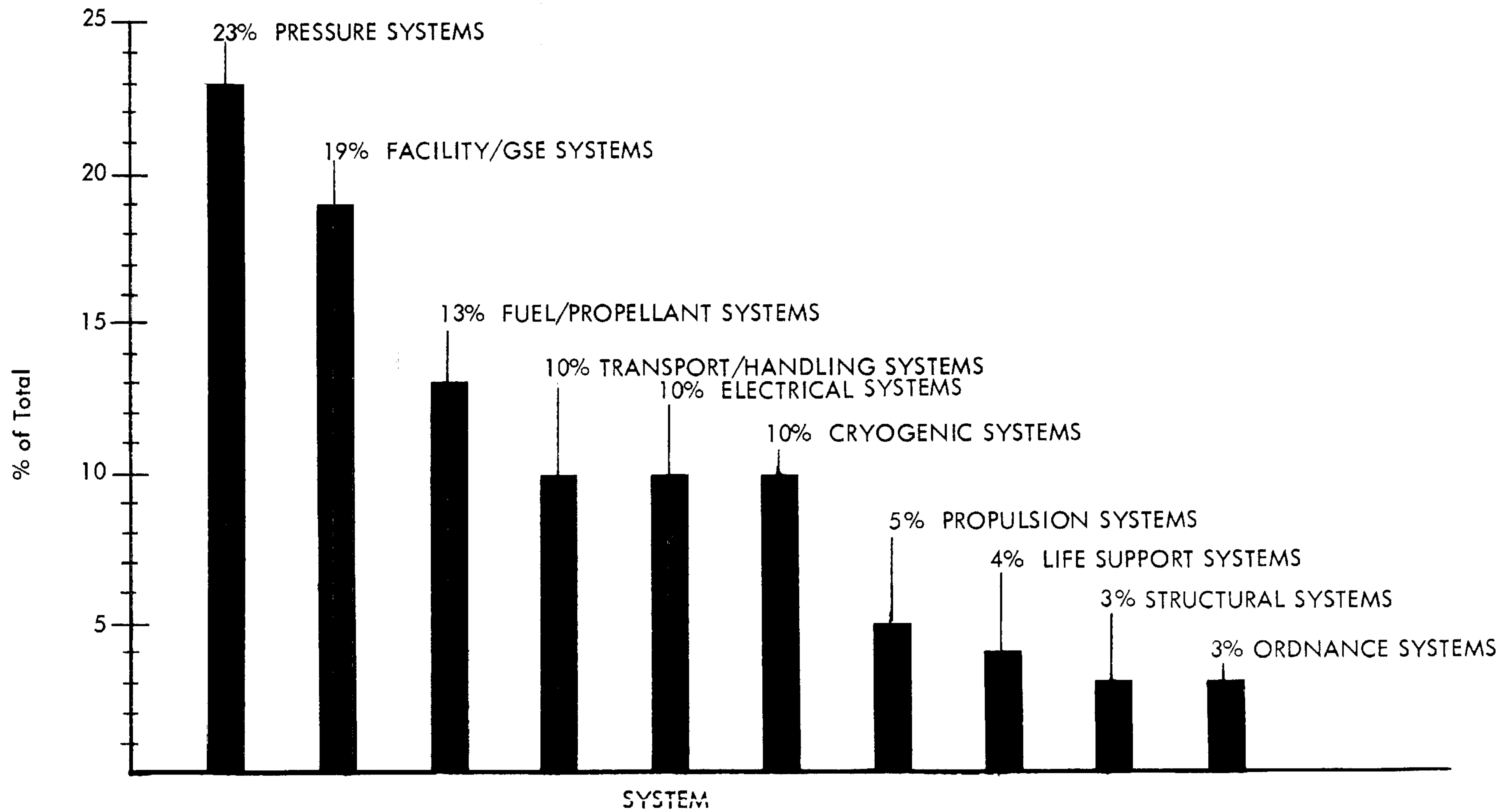


CHART 1 - DISTRIBUTION OF ACCIDENT/INCIDENTS BY SYSTEM

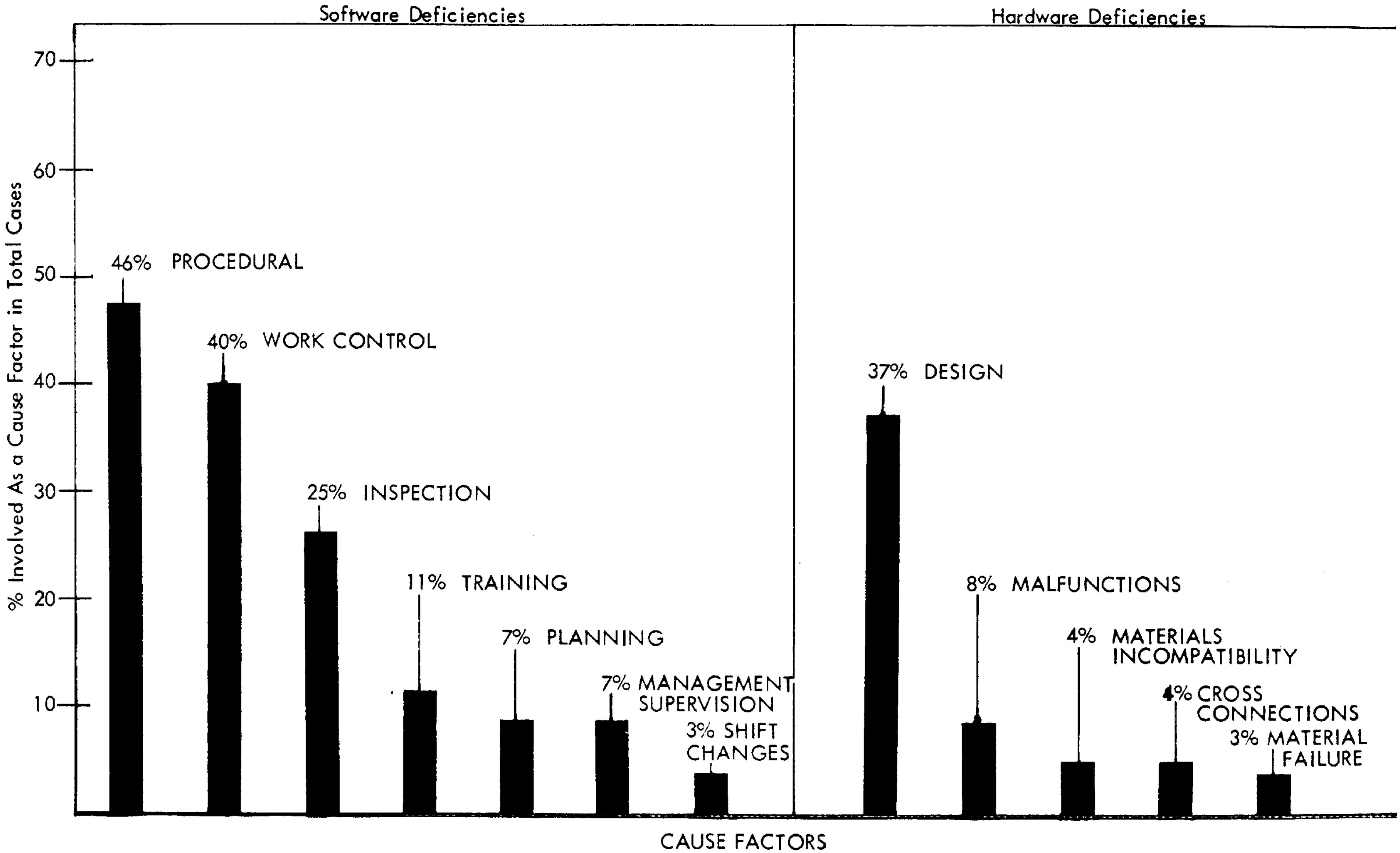
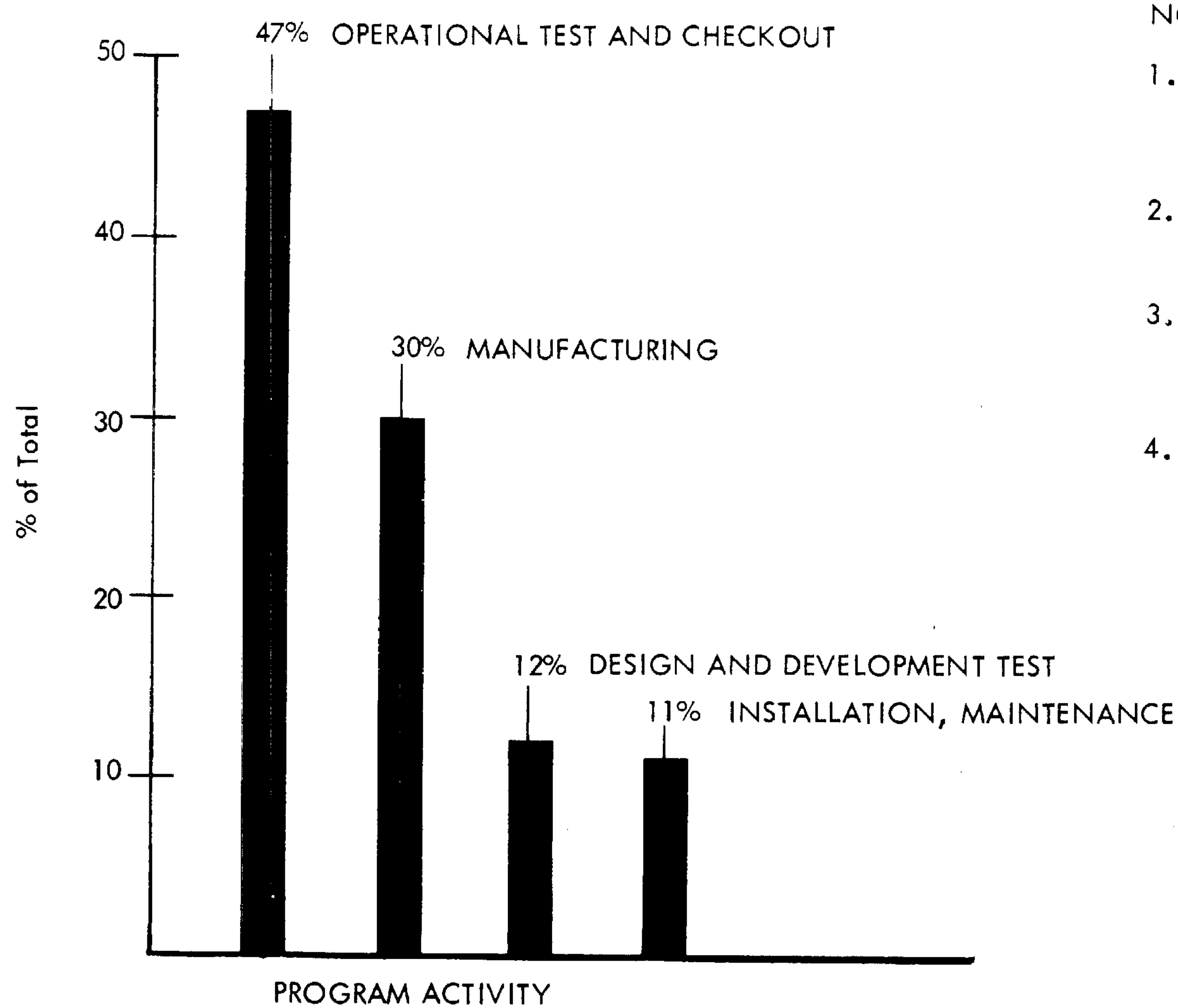


CHART 2 - DISTRIBUTION OF ACCIDENT/INCIDENTS BY CAUSES

Note: Several Cause Factors Could Be Involved in the Same Accident/Incident



NOTES:

1. Design and development tests are those cases in which an unplanned event occurred during Qualification or Development testing.
2. Manufacturing includes those cases involving functional checkout of systems, subsystems or components.
3. Installation and maintenance includes all cases occurring during installation and maintenance of facilities, systems, GSE or flight systems.
4. Operational test and checkout includes all tests of assembled vehicles and all testing at field sites, including integrated tests and pre-launch checkout.

CHART 3 - DISTRIBUTION OF ACCIDENT/INCIDENT BY PROGRAM ACTIVITY

SECTION I

CRYOGENIC SYSTEMS

Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
1. A fire occurred at a liquid oxygen pigtail vent valve when it was ignited by instrumentation wiring. Extensive damage to the system resulted.	A leaking LOX valve and inadequate installation of instrumentation circuits.	Ensure that electrical systems are routed so that they are not near or adjacent to LOX vents.
2. When the valve was opened, a liquid oxygen container exploded due to use of improper lubricant on the LOX fittings.	Inadequate procedures and training to prevent use of unauthorized lubricants on LOX fittings.	Ensure that procedures are established to require use of only non-petroleum based lubricants on LOX fittings. Special fluorolubes or perfluorolubes should be specified.
3. A major explosion and fire occurred at a test facility during qualification testing of a booster engine fuel injector system. Major damage to the test set up and the facility resulted.	Material failure in that the LOX splitter plate failed from fatigue, allowing LOX to be dumped into the test area. Contributing cause to the damage was inadequate cleanliness and housekeeping in the test area.	Perform periodic inspections of the splitter plate area on fuel injection systems. Ensure that all test areas are periodically inspected for cleanliness and housekeeping.
4. During qualification test of a LOX turbo pump for a booster engine, the pump exploded on the 33rd start.	A design deficiency in that there was inadequate clearances between the LOX seal and the slinger and between the impeller and the backplate.	Insure that adequate clearance is provided in LOX pumps for pump cavitation conditions. Provide for positive flow of LOX to seal area at all times.

SECTION I

CRYOGENIC SYSTEMS (CONT.)

Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
5. During stage LOX manual loading test, the line ruptured upstream of the main source valve immediately after the valve was opened to start loading. 800,000 gallons of LOX was spilled and the tank was partially collapsed from vacuum.	A design deficiency in the main source valve which permitted trapped air in the line and automatic closing of the valve when the liquid hit the valve with a "hammer effect" following the trapped air.	Ensure that cryogenic storage tanks main source valves are designed with a vent line to permit trapped gases to be vented to the tank through the tank fill line and thus provide liquid to the valve at all times.
6. During initial activation test of an Altitude Simulation Facility, a LOX fire occurred when LOX was turned on after normal purge operation and resulted in damage to a facility pump and piping.	Ignition apparently occurred as a result of contamination in the line and LOX impact. Installation and maintenance procedures were not adequate to prevent contamination. Also purge and inspection procedures were not adequate.	Ensure that contamination control procedures are established for installation and maintenance of LOX systems. Require three purges of systems prior to initial activation tests. Require Q.C. verification of all critical line connections or component installations in LOX systems.
7. During Altitude Simulation test of a booster stage, a piece of Buna rubber broke off the LOX feed valve and caused impact ignition when it struck the pump impeller, destroying the pump.	A design deficiency in using non-compatible materials (Buna Rubber) in a LOX system. Contributing cause was failure to transmit information from a previous incident, for a similar incident occurred 6 days earlier when a piece of Buna rubber was found in a LOX discharge screen.	Establish procedures for reporting all anomalies and incidents from previous tests to other facilities and departments concerned. Establish LOX compatible materials list for all LOX components. Require Quality Control to verify compatibility of materials prior to installation in LOX systems.

Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
8. During preparation for transfer of LH2 from a test pad, a workman was removing a steel dust plug from the LH2 line when the plug blew out and struck him. The plug blew out because of pressure between the plug and the main manifold cutoff valve.	Lack of vent and drain provisions in the isolated section of the line between the main valve and the plug. Contributing cause was apparently a leaking helium purge line which allowed pressure build-up in the line.	Ensure that vent and drain valves are provided between all isolated sections of propellant systems. Identify all propellant transfer operations as Safety Critical and perform a pre-operation hazard analysis.
9. During transfer of LOX from tanker to tanker, the main valve malfunctioned resulting in dumping of 3200 gallons of LOX on the ramp.	Liquid control valve for the pressure build-up coil was jammed by a piece of aluminum which apparently came from one of the baffles in the tank.	Inspect all tanker baffle plates for material failure at all overhaul or major inspection periods.
10. During an LH2 transfer from a tanker, the burst disc ruptured at 50 psi. Pressure limit for the operation was 30 psi.	The operator turned on the pressure valve and left it unattended, permitting pressure buildup past the allowed 30 psi.	Require the use of checklists and formal written procedures for all fuel transfer operations. Install visual and audio warning devices for all critical pressure levels.
11. During a welding operation on the LH2 fill line it was discovered that LH2 was still in the tanks although it was supposedly drained. Vacuum purge was not effective and a potential for a major explosion existed.	A deviation from procedures when the purge was continued without 400 cycle power to the tank sensing probes in the LH_2 tank. When GN_2 purge was introduced, it liquified and blocked the system since it boils at -320° F whereas LH_2 boils at -423° F.	Require strict adherence to procedures during LH2 tanking or detanking. Do not permit operations to continue when instrumentation is not operable. Require the use of LH2 sniffers through the purge ports, after detanking and purging.

SECTION I

CRYOGENIC SYSTEMS (CONT.)

Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
12. During unloading of LOX from rail car to sphere, a LOX spill occurred when fill hose was disconnected. Two men were exposed to LOX.	Failure to allow sufficient boil off time prior to disconnecting fill line. Contributing cause was lack of specific instructions for boil off times of different types of cars.	Require procedures for transfer of LOX to storage areas to include specific boil off times for different types of cars. Require that all transfer personnel be briefed on boil off times.
13. During countdown for static firing, a leak occurred at 12th level in the LOX fill and drain lines. The topping operation was discontinued for assessment but a dangerous condition resulted when an excessive number of people were allowed in the area during this emergency.	Material failure of the LOX hoses, causing cracks. Contributing to the potentially hazardous condition was inadequate control over entry of personnel to the area during an emergency and lack of clearly defined authority of stand talkers and test stand engineers.	Ensure that test procedures require test conductor authority for entry of personnel to a test area under emergency conditions. Require all emergencies to be reported by the test conductor over the oral warning system.
14. During a routine post cryogenic proof inspection of a stage LH_2 tank, pieces of teflon gasket from a flapper valve installed in the LH_2 facility transfer system were discovered. No injury to personnel.	A design deficiency in that the teflon gasket did not have a metal retainer but was merely bonded in place. Contributing cause was that the check valve was installed downstream of a filter.	Provide a metal retainer for holding seals in place instead of bonding to prevent contamination entering cryogenic tanks. Install a filter at stage/GSE interfaces to provide redundancy if failures should recur.
15. During post static countdown securing operations, the LH_2 barge was being disconnected from the dock when a flash occurred in the vent stack. No damage occurred, but the potential existed for major damage.	A series of pin holes in the LH2 burst disc which permitted GH_2 to enter the land vent line after samples were taken. Explosive mixture occurred when air entered the disconnected line.	Perform a thorough hazard analysis of all LH_2 systems to ensure that cutoff valves and vents are positioned in such a manner as to preclude inadvertent build up of GH_2 in disconnect lines.

SECTION I

CRYOGENIC SYSTEMS (CONT.)

Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
16. Flashback explosion occurred in a barge LH_2 vent stack during transfer of propellant to storage. Explosion occurred when LH_2 line was disconnected without GH_2 purge and without closing of the line valve.	The test procedure was not complete. Valves were not identified as to function, there was no QC monitoring and tasks were being performed without central TC direction. Communications were poor and technician failed to close vent valve and test conductor failed to purge system prior to disconnection of lines.	During fuel and propellant transfer operations, all valves should be identified as to function on the valve and in the test procedure. All tasks performed during transfer should be only as directed by the test conductor. No lines should be disconnected during fuel transfer until verified by QC and directed by the test conductor.
17. During hook-up of a freon filter to a tanker to obtain a liquid freon sample for test purposes, trapped freon blew off in face of operator.	Bleed down of the line was not accomplished. Trapped freon in the line had expanded due to ambient temperature and pressure had build up. No pressure relief device was provided in the line.	Require bleed off of all isolated sections of pressure lines prior to disconnecting. Require relief devices to be installed in isolated pressure lines.
18. During a demonstration test involving nine pressure and temperature countdowns to demonstrate certain capabilities of foam insulation, a LOX tank dome ruptured and scattered throughout the test area. Occurred on seventh countdown when pressure reached 77 psig in a scheduled 79 psig test. No personnel were injured.	Failure to proof test the tank after rework. Contributing causes were poor workmanship in the welding and inadequate inspection of welds.	Require proof testing of all pressure vessels or systems after any rework or modification. Require verification and qualification tests of all welding methods and inspection techniques prior to use in flight systems.
19. While preparing for vacation period, workmen failed to shut down test stand LN_2 standby purge panels, resulting in premature depletion of the LN_2 tank.	Failure to follow check lists and failure of Q.C. to verify closing of critical pressure valves. Lack of warning devices for pressure drops contributed to this incident.	Require use of check lists for shutdown of test stands. Require Q.C. verification of all critical valves following all tests or shutdown of stand. Provide audible and visual devices to warn of pressure drops.

SECTION I

CRYOGENICS SYSTEMS (CONT.)

	Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
20.	Low stress/high frequency vibration during LOX fill operation of a stage, resulted in leakage of the GSE fill ducts and shutdown of the operation.	Material failure induced by low stress/high frequency vibrations caused by excessive fill rates. Engineering had not performed a fatigue analysis to determine an optimum fill rate.	Perform pre-operational studies on fatigue limitations of cryogenic fill lines and establish fill flow rates commensurate with the fatigue limitations.
21.	After transfer of LN_2 from a mobile tanker to a lunar laboratory tank farm, a spill of 3000 gal. of LN_2 occurred when the manual fill valve failed. Personnel had to climb wall to escape LN_2 vapor.	Material failure of the fill valve. The welded portion of the stem housing failed allowing it to be forced away from the valve seat by the tank pressure (37 lbs.). Contributing to potential hazards was lack of adequate emergency exits from the area.	Require critical welds in cryogenic systems to be verified by X-ray inspection prior to installation. Ensure that cryogenic fill valves are periodically checked for structural failure. When possible, bolt the stem housing flange and the valve body flange of the fill valve together to prevent separation. Provide redundant shutoff capabilities for LN_2 fill and drain lines. Ensure that all tank farm areas have adequate emergency exit provisions.
22.	During manufacturing installation an accumulator water boiler in a flight vehicle, using LN_2 to isolate open lines, the LN_2 thawed causing a water/glycol spill. Equipment was contaminated and one person injured by contact with extreme low temperature liquid.	The procedure did not specify monitoring of the temperature of lines during the operation. Contributing cause was failure to prepare backout or emergency plans in event of malfunction and failure to require proper protective clothing for personnel.	Require that hazard analysis be performed prior to conduct of operations involving cryogenic freeze techniques. Require all personnel to be briefed on hazards of the operation and require emergency or backout procedures to be included in the written procedure. When using freeze technique for plugging lines, require positive monitoring of line temperatures at all times.

SECTION I

CRYOGENIC SYSTEMS (CONT.)

Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
23. Main stage exploded during final countdown phase of static firing, destroying the stage and causing major damage to the facility.	Failure of the LOX vent valve to function due to solid LOX particles. Contributing causes were failure to follow approved procedures and an unsatisfactory Helium shut off valve during cold conditions. Test preparation was inadequate as evidenced by 9 valves being overlooked during pre-test checks and not in the proper position.	Ensure that all valves and components have been pre-qualified for cryo operations prior to tests. Prohibit deviations from test procedures without prior approval. Ensure that all critical steps in the procedure such as switches, valves and control movements are verified by QC.
24. During a simulated altitude test, a facility solenoid valve controlling helium flow failed, permitting 200 gallons of monopropellant fuel to leak to the cell floor.	Inadequate maintenance since the valve stem had been bent and had not been replaced. Contributing cause was lack of inspection procedures which would have detected the faulty actuator and valve stem.	Extreme care must be exercised in the design and maintenance of equipment for handling cryogenic materials, particularly monopropellants. Designers should consider the reduction in material fatigue life at low temperature. Inspection procedure should require certification of cryogenic equipment at frequent intervals.
25. During pneumatic control subsystem checkout, a LOX chilldown pump housing was inadvertently overpressurized and had to be replaced when two adjacent lines were cross-connected.	Installation error caused by identical pipes and joints located together in a manner that permitted cross connection. The purge line to the chilldown pump was connected to the shutoff valve piping. A contributing cause to the accident was a design deficiency in not locating pipes so they could not be cross-connected or sizing or keying to prevent cross-connection.	Require all pipes or connections subject to cross connection to be located such that cross connection is impossible. If lines are located in a manner subject to cross connection, size or key joint to make cross connection impossible.

SECTION I

CRYOGENICS SYSTEMS (CONT.)

Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
26. An LH_2 tank exploded resulting in fatal injuries and major damage when hot wire sensors were used in the tank after purging.	The crew had been instructed to remove the cover without positive sampling to ensure a non-explosive atmosphere. The hot wire sensors provided an ignition source for residual hydrogen vapors in the tank.	Require that positive sampling of all propellant tanks is carried out prior to removal of tank covers. Sampling should assure that hydrogen residue (vapor) does not exceed 5%. Prohibit the use of hot wire sensors in propellant tanks unless specifically authorized by Engineering.
27. A LOX system exploded during a static firing due to cleaning fluid corrosion in the system.	Non-compatible cleaning fluids were used and periodic inspection for corrosion was not accomplished.	Ensure that cleaning procedures are adequate to prevent residual cleaning fluid in propellant systems. Require frequent inspection of LOX systems for corrosion.
28. Major damage to a test facility occurred when a LH_2 Dewar exploded during conduct of laboratory tensile tests of metals at cryogenic temperature. Two explosions occurred, the initial one equivalent to 1/4 pound of TNT and a secondary explosion, from mixing of released vapors, of a much high order.	A design deficiency in the test installations. Two electric heaters being used to accellerate boil off provided the ignition source when the surface temperature was allowed to rise too high. Air had entered the dewar through the dewar vent and air probably leaked into the system through cryogenic pumping of air through the porous foam insulation in the top of the dewar.	Surface temperature of heaters used with LH_2 should be controlled to prevent surface temperature in excess of $400^{\circ}F$ ambient air. Polyurethane foam insulation should not be used for walls of LH_2 containers.

SECTION I

CRYOGENIC SYSTEMS (CONT.)

Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
29. A LOX system caught fire and exploded due to the use of hydro-carbon lubricants on connections.	Failure to specify compatible lubricants for use on oxygen systems.	Require a list of compatible materials to be prepared prior to installation and use of oxygen systems. Require Q.C. verification of all lubricants used.
30. A titanium sphere used in a LOX system exploded and burned causing serious system damage.	Design deficiency in using a titanium sphere in a LOX system. Titanium is not compatible with LOX.	Do not permit use of titanium in LOX systems. Require the use of stainless steel or aluminum or copper alloys.
31. A LOX system was contaminated by use of incompatible ink used for internal stamping during manufacture of components, causing complete analysis of system and cleaning of components to be performed.	A procedural deficiency in manufacturing. Action had not been taken to determine compatibility of the ink with LOX prior to specifying its use.	Require LOX compatibility analysis to be performed on any materials used for stamping or identifying LOX components during manufacturing.
32. Electrical wiring and plumbing were damaged in a test set up when electrical wiring near an oxygen pig tail vent shorted and ignited the oxygen.	A design deficiency in the test installation. The pigtail vent was located in such a manner that it vented directly to adjacent wire bundles. Contributing was a procedural error in continuing the test with a leaking LOX valve which resulted in the venting and the fire.	Ensure that propellant vents are installed/located in such a manner that venting will not be performed near or on electric wiring or other ignition sources.

SECTION I

CRYOGENICS SYSTEMS (CONT.)

Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
33. An explosion of a LOX container occurred when the valve was turned on due to use of improper lubricants on threaded fittings.	Inadequate work control procedures and failure to perform inspection of LOX installations, which permitted incompatible lubricants to be used and to be undetected.	Require preparation of and strict adherance to a materials compatibility list for LOX systems. Require Q.C. to verify LOX installations prior to use. Do not permit the use of petroleum-base lubricants on LOX systems. Specify use of fluorolubes or perfluorolubes.
34. An explosion occurred in a LOX system when it was inadvertantly overpressurized due to installation of improper bleed plugs in a pressure regulator.	Deficiency in work control procedures and inadequate identification of bleed plugs. Contributing was inadequate inspection of test installation.	Require positive marking and identification of LOX system components which are interchangeable. Require Q.C. verification of system installations before and after work is performed.
35. A liquid hydrogen system exploded and burned during fill operations due to inadequate purging after the previous operation.	Purging had been accomplished with gaseous nitrogen but had not been repeated with gaseous helium or hydrogen and air was still in the system.	LH_2 systems should be purged with gaseous helium or hydrogen prior to admitting LH_2 to the system. Require a positive pressure to be maintained on the system to prevent air from entering.
36. During de-fueling operations after a test, a fire occurred at the vent when LOX was ignited by an electrical short during venting.	A design deficiency in the test installation in that the LOX vent was located in a manner in which vapors were emitted in the area of electrical wiring.	Insure that all propellant vents are located so that vapor will not be emitted near electrical components or other ignition sources. Require a hazard analysis to be performed of all vent installations.

Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
37. A 63,000 gal. LOX spill occurred at a test stand when the LOX transfer valve was inadvertantly left open after transfer operations were completed.	The transfer procedure was signed off as "valve closed" but it actually was open. The bleed valve was open, as it should be, to allow bleed off of residual and caused the tank to drain through the transfer valve.	Require inspection verification of valve positions before and after LOX transfer. Ensure that transfer valves are located where they can be readily seen and operated. Install automatic provisions to ensure transfer valve is closed five minutes after opened if bleed valve is not closed.
38. An LH_2 prevalve was destroyed and 3 men were injured when it was over-pressurized during an insulation resistance test.	Failure to install a relief valve prior to the test and improper operation of the dome regulator. The inlet supply shutoff valve was not closed when the remote valve was energized. Inadequate training of personnel, and lack of adequate schematics of the system. Also the test procedure did not have a test set up verification step.	Ensure that all personnel operating cryogenic systems are periodically retrained. Ensure that drawings and schematics of the facility system are available to operating personnel and kept up to date. Require all test procedures to include a test set up verification step. Require all pressure test setupsto be protected by pressure relief devices.
39. During pre-launch checkout, inadvertant LH_2 venting occurred when a check valve failed in the "open" position, causing an unscheduled checkout and replacement of components.	An error in an installation drawing occurred in which a wrong part number was called out resulting in system contamination and valve failure.	Require engineering verification of all installation specifications prior to release for manufacturing purposes.

SECTION I

CRYOGENICS SYSTEMS (CONT.)

Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
40. During pre-firing checkout, the LOX flowmeter was inadvertently spun when the prevalves and chilldown shutoff valves were left open. No damage occurred but a potential existed.	Before the test, it was discovered that certain steps had been left out of the procedure and the test was carried out with verbal instructions only, resulting in the wrong sequencing of the valves.	Require verification prior to each test, that the test procedure is the latest revision and complete. Prohibit conduct of tests without completely documented and approved test procedures.
41. When the start button was initiated on a vaporizer conversion unit (LH_2 to GH_2) a hydrogen explosion occurred, as a result of a pin hole leak in a stainless steel heating coil in a GN_2 purge cabinet. Minor damage occurred but no injuries were sustained.	Arcing from thermocouple wires touching the heating coil resulting in the pin hole leak and accumulation of an explosive mixture in the purge cabinet. The severity of the explosion was minimized by the GN_2 purge. When power was applied to the vaporizer, arcing ignited the gaseous mixture in the GN_2 confined purge space of the coil housing.	Ensure that heating coils in vaporizer units are wired in such a manner that electrical circuitry cannot come in contact with the coils. Ensure that heater coils are blanketed with an inert atmosphere.
42. During operational testing of a stage, the gas generator LOX injector purge flex line was cross connected with the thrust chamber injector purge flex line on an engine. This resulted in contamination of the flex lines and the LOX dome. No injury to personnel.	A design deficiency in that adjacent flex lines were not properly coded and were of similar size and design. This contributed to the error on the part of the maintenance personnel who cross connected the flex lines. Contributing causes were workman was in an uncomfortable posture when connecting the lines, with lighting that is not optimum, and cramped for space to use tools.	Ensure that all adjacent flex lines are properly coded, marked, or sized to preclude inadvertent cross connections. Test procedures should require Quality Control verification of critical flex line connections. A positive corrective and preventative alignment tool should be provided to preclude inadvertant cross connecting of lines.

SECTION I

CRYOGENICS SYSTEMS (CONT.)

Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
43. During a test of an 8' scale tank loaded with 7500 gallons of LH_2, the tank burst at 77 psi destroying the test installation. No fire or explosion occurred and area control was successfully recovered within 24 hours.	A material failure in the tank. The test was programmed for 79 psi maximum and the tank burst at 77 psi. Contributing to potential hazards was the lack of an emergency recovery plan for such an emergency.	Require that all pressure and fuel/propellant tests be designated as safety critical, and require that emergency recovery planning include provisions for contingencies applicable to hardware failure.
44. During an engine sequence to check start tank, a LOX flowmeter spin occurred when the engine valves were opened. Spin lasted for 106 seconds at 700 RPM. The fuel flowmeter did not spin. No damage.	A pressure differential caused by pressure build up in the LOX system while tank vents had been closed for 110 minutes. Pressure buildup did not occur in fuel flowmeter because it was an insulated tank.	Always cycle vents open for a period of time prior to running an engine sequence.
45. Following loading of propellant run tanks in preparation for a firing of a vehicle stage, the insulation jacket (filled with Perlite) on the common vent and pressurization line for the test stand LH_2 storage tank burst, due to expanding cryogenic liquid and generation and storage of liquid air. The burst disc on the jacket failed to relieve the overpressurized condition.	Failure of the burst disc to relieve the overpressurized condition due to ice formation. Design should have taken in to consideration the possibility of the insulation leaking "in" moist air and the formation of ice on the disc. Also, periodic inspection of insulation was not being performed.	Ensure that frequent inspections are required of cryogenic systems insulation to identify hazardous conditions created by the buildup of moisture.

SECTION I

CRYOGENICS SYSTEMS (CONT.)

Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
46. During changeout of a stage LOX fill and drain valve, the valve assembly separated from the umbilical line with sufficient force when the mechanical seal was physically broken, to overcome the grasp of the technician and it fell to the 4th deck of the test stand striking two personnel. No stage damage, however the valve was damaged beyond repair.	Failure to exercise sufficient precautions in removing the valve which was extremely unbalanced with respect to the throat body vs. the actuator mechanism.	Repair/maintenance procedures should include precautionary instructions pursuant to removal of unwieldy valves and hardware where unusual unbalance conditions exist.
47. During temperature shock tests of a booster LH_2 check valve, using an electric heater blanket as a heat source and a 1500 gal. LH_2 Dewar, flashback from the vent stack fire occurred causing an explosion and fire which injured 3 persons and caused damage to equipment.	Inadequate instrumentation of the heater blanket to detect hot spots and leaking packing on the LH_2 test valve stem. Heating of the valve caused excessive reliefing of GH_2 and flash back. Contributing was lack of a pre-operations hazard analysis and safety approval.	Require all heating elements with LH_2 systems to be provided with adequate temperature readouts to prevent hot spots. Require all LH_2 tests to be designated as safety critical and require a pre-operations hazard analysis and safety sign off.
48. During preparation of a spacecraft LH_2 tank in an environmental test chamber, an LH_2 fire occurred in the chamber while the tank was being "topped off" causing damage to the facility and test system.	Procedural. Ignition occurred as a result of bare wires in the heater access hole and a protective insulation grommet had inadvertantly been omitted. The discrepancy had not been identified by inspection. Explosive gas occurred as a result of removal and change of fill and vent line quick disconnects.	Require frequent inspection of all wiring in LH_2 test chambers and require inspection verification of each installation. Require analysis of flow rates of inert gas in the chamber to assure adequate inerting and provide adequate heat exchange equipment to control gas temperatures.

SECTION I

CRYOGENICS SYSTEMS (CONT.)

Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
49. A major LOX spill (26,000 gal.) occurred at a test stand during securing operations following a test. The tank valve was left open during a lunch period after the piping system drain was opened.	System was kept wet after the test due to planned test of the turbo pumps. Subsequently, a decision was made to secure. The technician went through normal draining operations that would be done with the tank valve closed and did not close the tank valve. There was no verification procedure in effect for valves.	Require all propellant valves to be verified in the procedure after all securing operations. Use a double check prior to draining ducts. Require use of checklist in securing LOX system. Install a temperature measurement instrument in LOX dump lines.

SECTION II
ELECTRICAL SYSTEMS

Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
1. During a scheduled 75 sec. acceptance test of a booster engine heat exchanger, the test was terminated due to separation of the hot gas exhaust system and a gas generator explosion which resulted in flame and smoke damage to the test stand and structural damage to the hot gas exhaust system. A squib wire common to both gas generator igniters failed (broke), resulting in unignited propellants reaching the hot gas after-burner flame and causing subsequent explosions in the exhaust stack and gas generator.	A design deficiency in the gas generator igniter electrical harness which incorporated a single squib wire common to both igniters. The link interlock to prevent continuing the start sequence was by-passed because the broken wire contacted other exposed wires in the same electrical harness.	Require incorporation of separate electrical harnesses for each ignition system in propulsion test set-ups. Provide time delay circuits to insure ignition burning before propellant valves are opened.
2. During explosion proof testing of spacecraft cabin components, an explosion occurred in the test chamber due to breakdown of insulation in the chamber heater coil. Components were exposed to an explosive mixture of 100/130 aviation fuel at an air/fuel ratio of 13:1, ambient temp. of 71°C and 20,000 feet. Insignificant damage to test specimens. No personnel injuries.	Apparent lack of preventive maintenance on the heater coils due to extended or frequent use of the test chamber and inadequate inspection of chamber systems prior to each run.	Establish formalized maintenance and calibration/inspection schedules for explosion chambers to preclude damage to test specimens from faulty wiring and deteriorated chamber apparatus.
3. During countdown for static firing of booster, primary battery failed, causing a fire which destroyed the battery and damaged the booster electrical harness and skirt.	Failure of the battery heater circuits in the cell terminals due to a design deficiency in the transistor heat sink installation which was inadequate for dissipation of heat from the transistor junctions. Contributing causes were an inspection defiiciency, since one transistor was not properly seated and poor workmanship in the manufacturing process.	Require qualification testing of all batteries and components at full operational loads and conditions prior to installation on a stage. Ensure that test procedures require inspection verification of all transistor seatings prior to each test.

SECTION II

ELECTRICAL SYSTEMS (CONT.)

Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
4. Environmental Control System was destroyed during test in altitude chamber when commercial grade strip heater failed and ignited flammable material. Chamber environment was enriched oxygen at 5 psi.	There was no approved materials list for tests in oxygen enriched environments, no written test procedure, and no safety plan. Contributing causes were inadequate engineering design of test set-up, inadequate inspection and unsatisfactory installation of equipment.	All materials, equipment and components used in chamber tests under oxygen enriched environments should be specifically approved and certified for such use prior to tests. All chamber tests under oxygen enriched environments should be designated as Safety Critical and tests should not be permitted without a pre-operational Safety Hazard Analysis. No tests should be permitted to be conducted in oxygen enriched environments without approved, detailed test procedures.
5. During a 6 1/2 hour simulated trans-lunar test in a chamber, stage batteries, being used for the first time, overheated, caught on fire and were destroyed.	The cell vent valves were improperly operated resulting in overpressurization of the cells. Contributing cause was hardening of the rubber bands on the battery vent valves due to age, causing vent relief pressures in excess of battery structural design limits.	Establish positive controls to ensure that age life requirements for critical materials are complied with. Require pre-test inspection of battery vent relief valves for proper functioning. Ensure that sequential position of critical valves and controls are specified in the test procedure and verified by inspection. Require all electrical components used in chamber tests to be specifically qualified prior to operational tests.

SECTION II

ELECTRICAL SYSTEMS (CONT.)

Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
6. During prelaunch checkout of a space vehicle, three crew members were fatally injured and the spacecraft destroyed when a cabin fire resulted from an electrical arc in the 100% oxygen environment of the spacecraft.	A design deficiency in the materials and electrical components used in the spacecraft. Contributing cause was failure of design, test, quality control and operations personnel to properly consider the safety hazard created by an oxygen environment, lack of a fire extinguishing system, no emergency egress provisions, no contingency precautions and poor workmanship and inspection practices.	Designate all manned tests under oxygen enriched environments as safety critical and require a formal pre-operational Hazard Analysis. Provide emergency egress capabilities of crew members within a maximum of 20 seconds in all oxygen enriched chamber tests. Require all materials and electrical components to be prequalified under oxygen enriched environments prior to manned tests. Prepare a formal list of materials for use in oxygen enriched environments.
7. Fire destroyed an unattended computer trailer used for engineering control system analysis. A power supply was left on to keep the computer warm over a weekend. Source of the fire was unknown.	Failure to prepare and adhere to operating instructions for the trailer. Contributing causes were inadequate inspection and maintenance procedures which resulted in failure of CO_2 system due to low battery power and a design deficiency in that a backup power source was not provided for battery powered fire extinguishing system.	Provide backup power for all battery powered systems on unattended Facilities/GSE. Ensure that detailed maintenance and inspection procedures are followed for all unattended Facilities/GSE equipment.

SECTION II

ELECTRICAL SYSTEMS (CONT.)

Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
8. During calibration of electronic components in a GN2 low pressure facility system, power was inadvertently applied to vaporizer heaters. Resultant fire extensively damaged heater elements requiring replacement. Power was applied due to a malfunctioning circuit breaker and on-off lights, which had not been repaired and were not tagged as being non-operational.	Faulty equipment was not "red tagged", and documented when found inoperative at an earlier date by maintenance personnel. Contributing to this accident was lack of caution and warning instructions in an interim test procedure for hazardous electrical equipment.	Ensure that repair/maintenance procedures require positive identification of faulty equipment by tagging. Require that inspection verify all maintenance records prior to safety critical tests. Require all interim test procedures to be approved by safety for adequate warning and cautions.
9. During a nickel battery charging operation on stage test stand a battery vent cap was removed per procedure and pressure caused spray to burn the face, hands and arms on one person.	Failure to provide a vent relief to prevent pressure build-up during charging and lack of any protective devices over batteries. Contributing causes were face shield did not offer sufficient protection and lack of protective clothing for hands and arms.	Provide a relief valve for batteries during charging to provide venting and avoid internal pressure buildup. A face shield should be provided that will afford more protection and protective clothing should be worn for hands and arms. Batteries on charge should be covered with plastic covering at all times.
10. Twenty-eight volt DC batteries were damaged when they were inadvertently overcharged due to being placed on "full charge" rather than "trickle charge" after a power outage.	Adequate instructions had not been posted on the batteries and charger on how to reset when power outage occurs. Contributing cause was a shift change and failure of personnel to take action when "full charge" warning light was noted.	Require all battery charging units and batteries to have posted emergency instructions for resetting chargers after power outage and normal instructions for normal setup for charging. Require Quality Control seal of reset button on battery chargers to prevent inadvertent setting.

SECTION II

ELECTRICAL SYSTEMS (CONT.)

Accident/Incident Description	Cause	Recommended Preventive/Corrective Action
11. During trouble shooting of a stage electrical problem, the ground lead of an oscilloscope was inadvertently inserted in the wrong pin of a breakout box, causing damage to several circuits.	Unsatisfactory environmental conditions of poor lighting and high noise level. Inadequate lighting had been previously reported. Contributing cause was employee's carelessness and failure to provide temporary lighting.	Perform an inspection of environmental conditions prior to work on flight hardware to determine adequacy of lighting and equipment required to perform job safely.
12. During LOX tank repair, an electric heater blanket was installed on the LOX filter unit to provide heat inside the tank. The blanket overheated and the stage LOX tank caught fire, causing extensive damage.	A modification had been made to install the heater blanket without a formal engineering work order, without a hazard analysis and without safety approval. The "Kluge" installation connected the 220V AC blanket to a 440V AC line (reduced to 240V AC) and no temperature control devices were provided on the blanket.	Require formal engineering work authorization for all test/maintenance installations. Require safety approval of any modifications to electrical or fuel and propellant systems. Prohibit use of electric blanket heaters with flight hardware unless a temperature control capability exists.
13. Battery was overcharged in the test control center causing overheating and damage to battery.	Technician failed to plug in automatic temperature/overcharge cutoff circuit. Contributing cause was failure to pass information at shift change and poor coordination between contractors.	Require use of checklist in battery charging operation. Establish positive procedures for transfer of information at shift changes.

SECTION II

ELECTRICAL SYSTEMS (CONT.)

Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
14. During test checkout, a printed circuit board for support equipment at a launch pad caught on fire when three resistors on a power isolation board were overloaded. Board was badly burned.	Procedural deficiency in overloading of the resistors. Contributing cause was a design deficiency of the electrical wiring insulation (glass-epoxy) which sustains combustion.	Require a thorough analy sis of electrical wiring insulation to preclude use of materials which sustain combustion. Ensure that a preoperational hazard analysis is performed to identify potential electric over-load conditions.
15. An internal short of a battery cell caused overheating and decomposition of battery electrolyte, leakage, and eventual generation of potassium hydroxide vapors, creating a hazardous condition to personnel in the area. No injury to personnel.	Malfunction of battery cell and failure to provide adequate venting of battery areas and failure to provide warning and detection devices in battery areas where toxic vapors can be encountered. Contributing to these hazards were lack of respirators, goggles, protective clothing and other safety equipment in the area.	Designate battery storage areas as hazardous. Require venting in all battery areas capable of dispensing potential toxic vapors. Provide personnel protective equipment and toxic vapor warning and detection devices in all battery areas.
16. During manufacturing functional checkout, electrical equipment on a stage was damaged when an arc occurred during switchover to auxiliary batteries.	The auxiliary battery power had been erroneously hooked up causing reversal of polarity. Contributing were design deficiencies in that the test set up permitted cross connection of electrical lugs. Cable leads were not color coded or adequately identified.	Design electrical mating connections so that inadvertent cross connection of lugs are impossible. Use cable lengths that preclude cross connection. Color code and identify both sides of all electrical connections.

SECTION II
ELECTRICAL SYSTEMS (CONT.)

Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
17. During thermochemical test area operations, the area control light warning system malfunctioned by giving erroneous colored light conditions in the guard monitoring station. Because of this condition, personnel not acquainted with the operation could have entered facilities which were engaged in possibly hazardous test operations.	The original design called for shielded cable to be installed. The installed cable was found to be unshielded and subsequently shorted out from water that had accumulated in the cable trenches.	Facility activation group inspection should verify that all designated materials are installed per design requirements and signed off per procedure. Require use of independent circuits for warning devices and perform functional check of warning devices and circuits prior to each test.
18. During testing of a routine sample under static conditions in an ignition test chamber, the electrical harness ignited and caused smoke and soot damage. Parts of the burning sample fell on the electrical harness and ignited adhesive backed fiberglass tape which in turn ignited insulation on the harness wire. Considerable chamber cleanup, hardware retest, recalibration, etc., resulted.	A design deficiency in the test setup, which allowed highly combustible insulations to be used in conjunction with flammable materials under tests. Contributing was the apparent lack of a hazards analysis of test set-ups and operations.	All electrical wiring used in material ignition chambers should be placed inside metal conduits insofar as practical and highly combustible insulations should not be used in fabrication of electrical harnesses, used in proximity to ignition tests.
19. During conduct of a functional test of a power pack, the power pack was damaged when the test operator inadvertently reversed polarity by reversal of positive and negative connections of test leads to battery terminals.	The primary cause of the accident was a design deficiency in that the test leads had not been sized or keyed to prevent inadvertent reversal of terminal connections. Contributing causes were inexperience of the test operator and erroneous marking of the test leads.	Size and key all test leads to batteries such that reversal of connections to battery terminals is not possible. Ensure that all test leads to batteries are color coded and marked as positive/negative. Require Q.C. verification of test lead connections to batteries, prior to power on.

SECTION II

ELECTRICAL SYSTEMS (CONT.)

Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
20. During initial power application to an electron beam welder, an explosion occurred in the battery enclosure. Six volt lead-acid batteries were being used.	Lack of adequate ventilation in the heavy plexiglass battery enclosure which permitted the accumulation of hydrogen gas during the 16 hr. charge period for the batteries. When the voltage potential approached 20,000 volts, an arc occurred, and ignited the hydrogen gas.	Ensure that all lead-acid battery enclosures are adequately ventilated to prevent build up of hydrogen gas. Use transformer rectifier type power in confined spaces in lieu of batteries whenever possible.
21. During a manned crew training test in a vacuum chamber, electrical arcing of an interior light and fixture occurred at a chamber pressure equivalent to 200,000' altitude. No personnel injury or hardware damage; however, a potentially hazardous fire situation existed.	Chamber design deficiency in specifying fluorescent lights when failure of fluorescent lights in any environment is not unique over extended periods of time. Contributing was an apparent inadequacy in maintenance practices in that fluorescent lights were not being replaced annually.	Facility maintenance practices should ensure that fluorescent lights are replaced on an annual basis.
22. During test of a flight vehicle in an environmental chamber, a stimuli generator hose failed due to being installed too close to a high intensity chamber light causing re-run of the test and minor schedule delay.	The hose was installed too close to the light and a hole was burned in it. Contributing was lack of adequate inspection after installation of the test set up.	Require pre-operational inspection of all test installation in chambers to verify that equipment is not installed too close to ignition or heat sources. Prohibit the use of high intensity lights in chambers except where absolutely required for test objectives.

SECTION II

ELECTRICAL SYSTEMS (CONT.)

Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
23. During the installation of a lead "H" positive to a battery, the technician inadvertently placed a small tool between the battery terminal and the case of the battery causing a short, subsequent arcing, and destruction of the battery. Had this occurred in other than ambient conditions, a potential fire hazard would have existed.	Failure to require insulation of tools used around electrical systems and failure to follow good maintenance procedures when working on electrical equipment.	Require all tools used with electrical systems in flight vehicles to be nonconductive or insulated. Require tools to be restrained to prevent inadvertent misplacement and establish procedures requiring all tools to be checked in and out when working on flight vehicles.
24. During removal operations of a battery used in the pyrotechnics firing circuits of the vehicle, it was discovered that battery acid had escaped from the cell and had contaminated the battery bracket, and the thermal wrapping the battery was encased in. Subsequent investigation revealed that replacement of the battery, battery bracket, and thermal wrappings were required.	The sequence of installation in a confined area was such that it was conducive to a minor acid spill. The spill was not detected at the time and inspection of the installation was not made nor were daily inspections made thereafter.	Require post installation inspection and buy-off of all battery installations installed in flight systems and require daily inspection of all batteries.
25. Shortly before completing the hook-up of electrical power to a flight critical equipment, the supervisor requested and received verification that electrical power to the cable was "off". On attempting to mate the cable, power arc-over occurred causing destruction of 3 pins to the connector. Equipment was out of service until the pins, plug, and assembly were repaired.	Supervisory error in that the technician received verification from supervisors that power was "off" when actually it was "on".	During any operation where power is being introduced to a newly completed system, procedures should direct that Q.C. inspection is mandatory before mating to ensure that power is not "on". Require verification of power sources with a voltmeter prior to mating power on any new installation.

SECTION II

ELECTRICAL SYSTEMS (CONT.)

Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
26. During mating operations of a vehicle in manufacturing, the indicator lens of the electronic control assembly was inadvertently broken and was not reported. Due to its isolated location, it required disassembly and subsequent re-run of the test.	Work control procedures permitted unnecessary people in the area during a critical work phase and personnel were not adequately briefed on the need for reporting any damage or discrepancy during mating. Inspection verification was not being required at critical sequences.	Require designation of mating/de-mating operations as safety critical and restrict personnel to those absolutely essential. Require briefing of all personnel prior to any operations where critical components are isolated to ensure that any discrepancies will be reported. Require Q.C. sign off at critical sequential steps during mating/de-mating.
27. During checkout, 440V AC facility power was applied to a 208V AC circuit in the forward umbilical service unit, damaging the controller units.	Improper identification of facility power outlets, resulting in plugging into the wrong facility power outlet.	Require inspection verification of proper identification of power outlets in test facilities prior to operations.
28. During removal of epon epoxy residual from a control panel in a spacecraft, a burnishing tool contacted communication equipment switch tips containing promethium 147, a radio active material used for illumination. The cabin area, personnel working in the area, clothing, and tools were contaminated above safe levels.	Lack of procedural precautionary instructions to perform potentially hazardous repair operations, worker carelessness, and lack of supervision.	Require that all hardware having radioactive elements be specifically identified and Safety standards be prepared for the installation and maintenance of such elements. Ensure that all radioactive elements are properly color coded and are marked as hazardous. Ensure that test procedures include caution and warnings for radioactive materials.

SECTION II

ELECTRICAL SYSTEMS (CONT.)

Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
29. During a propellant loading countdown, the spark igniters were left on for 8 minutes 53 seconds (max. allowable, 5 seconds) causing test stoppage and replacement of igniters.	A procedural error in that a problem was encountered and out of sequence testing was initiated without adequate back-up procedures. When back-up was initiated the wrong procedure was used and the igniters were not turned off.	Require all back-up procedures to include turn-off of igniters as first step. Prohibit out of sequence testing without formal engineering approval and written backup procedures.
30. During pre-launch installation of batteries in a stage, the position of the batteries was inadvertently reversed during transfer from the dolly and a misinstallation was averted only because the connecting harness would not fit.	Inexperienced technicians were assigned to transfer batteries from the dolly and were not properly briefed. The technician and inspector did not verify the order in which batteries were being transferred. Also, the installation procedure did not provide detailed steps to ensure proper installation.	Require procedures for battery installation to include detailed steps of installation. Require QC verification and sign-off for each battery installation. Ensure that personnel are properly briefed on installation procedures.
31. During conduct of a chilldown test, the LH2 Chilldown Pump was inadvertently operated dry for 3 minutes when the safety can was opened and safety plug was left installed.	The Safety Can was opened and safety plug installed in violation of procedures and was actually not needed. The installation was made incorrectly and the incorrect wire connected. When the test was resumed, the plug was not removed. Contributing was an inexperienced stand engineer and poor communication discipline. Technicians failed to get instructions because their headsets were off.	Require positive control of chilldown pump safety can by test conductor. Require QC verification of each step involving chilldown pump electrical connection and safety plug installation.

SECTION II

ELECTRICAL SYSTEMS (CONT.)

Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
32. During checkout of a stage, the engine solenoids were inadvertently left on for 133 minutes resulting in destruction of the solenoids.	Concurrent running of two test procedures and failure to reolace the solenoids with simulators as required. Contributing was inadequate power switching arrangements and lack of an "engine on" warning lamp.	Do not run concurrent tests except when absolutely necessary. When concurrent tests are run, require QC verification of required equipment change in the test procedure. Provide power switching capability to the test conductor and "engine on" warning lamps.
33. During voltage checks of a space vehicle, fuses and connector pins were damaged when a technician inadvertently touched a structural member with the meter end of the probe and grounded out a 400 HZ power supply. Ninety minutes schedule time lost.	Operator error and carelessness in handling the volt meter. Operator was not adequately trained and certified for the job.	Ensure that all personnel working on end item hardware are adequately trained and given periodic retraining on hazards to program hardware.
34. During checkout of a spacecraft, a test conductor inadvertently struck an ACE console circuit breaker with his foot. Although the circuit breaker was not actuated, it was moved and could have been tripped.	A Design deficiency in not providing protective covers over electrical circuit breakers.	Require all circuit breakers in areas adjacent to operating personnel to have protective covers installed to prevent inadvertent activation.
35. Power was inadvertently cut-off from the vacuum tooling chuck inside a booster tank, causing the vacuum to be lost and the chuck to fall off. No damage incurred but potential for damage was considerable.	Inadequate control procedure for the electric power panel. The panel was locked but 22 keys had been issued and an unknown person had unlocked the panel and turned the power off. A similar incident had occurred earlier.	Require placarding of electrical power panels when critical operations are in process which depend on power. Limit access key to panel locks to an absolute minimum of people.

SECTION II

ELECTRICAL SYSTEMS (CONT.)

Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
36. During assembly of spacecraft, a nut was dropped inside requiring removal of floor panels. During reinstallation, electric wire bundles were pinched causing subsequent arcing and damage to wire harness and insulators.	A design deficiency in that the cover panels had sharp edges and the wire bundles had not been properly bundled and were not covered with Teflon-wrapping. Contributing was poor workmanship and inadequate inspection verification of work performance.	Require all electric wire panel covers to be inspected for sharp edges prior to installation. Require all wire bundles to be tightly tied and covered with Teflon wrapping. Require QC inspection of wire bundles prior to installation of panels.
37. During a manufacturing test, a 28.5 VDC power supply unit was inadvertently set for 34.5 volts. No damage was done since error was noted and corrected prior to power on, but could have resulted in significant damage.	A power unit had been substituted for the regular unit and the OCP and hookup instructions had not been changed. Contributing causes were failure to require hookup verification and performing hook-up on verbal instructions only. The crew inadvertently set the wrong power unit to 34.5 volts.	Require all power supply units to be clearly labelled as to function. Require hook-up, power-up and power-down steps to be included in test procedures for all power supply units. Require verification steps for power hook-ups and application sequences.
38. During dusting and cleaning of a stage, an extension cord grounded against the weld drip pan and burned the number six cylinder.	The extension cord being used was a domestic type rather than a commercial heavy-duty type. Connections had not been taped and were not twist-lock type fittings.	Require inspection of all extension cords used around flight vehicles prior to each operation. Require use of only heavy duty commercial type extension cords with twist-lock fittings. Require all connections to be taped.

SECTION II

ELECTRICAL SYSTEMS (CONT.)

Accident/Incident Description	Cause	Recommended Preventive/Corrective Action
39. During activation of a spacecraft pyro battery with activating agent (KOH) at a launch operations laboratory, one of the cells started to boil and fume. Walls, table top and lockers were sprayed with the chemical agent. No personnel injuries, however the battery was destroyed.	The activation procedure did not require a verification of the battery insulation qualities prior to activation. The failed cell was found to have internally shorted leads.	Require all chemical batteries to be electrically tested (megger checked), prior to activation, to preclude destruction.
40. Electric sparks (static discharge) were observed while crewmen were handling O_2 conditioning cannisters in a vehicle at normal air atmosphere. Static electricity was not bled off causing electrical discharge - which could be a source of ignition in a 100% O_2 atmosphere. No personnel injuries.	A design deficiency in selection of insulating material in the storage boxes for the cannisters. The material generated a static charge when the stainless steel cannisters were removed, due to inadequate grounding of storage boxes.	Ensure that a hazards analysis and study fully covers all aspects of static generating sources for manned testing in 100% O_2 atmospheres. Crewmen, storage boxes, cannisters and couches should be grounded.
41. During calibration of a power supply in a response conditioner located in an operational test area, excess loading and damage was sustained by test area electrical system due to improper wiring hookup of the power supply unit.	Lack of detailed calibration procedures resulting in improper wiring of the power supply during calibration and lack of verification of the hookup to the test area system.	Require that calibration procedures specify detailed sequential steps and verification of calibration test equipment attachments and hookups to prevent damage to other interfacing systems.

SECTION II

ELECTRICAL SYSTEMS (CONT.)

Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
42. During cryogenic loading tests on a 3' dome test specimen, malfunctions of the pressure transducers and a heat lamp rheostat caused a test abort. Subsequent troubleshooting of the heat lamp resulted in temperature overstress and damage of test specimen beyond economical repair.	An incorrect troubleshooting technique and inadequate training of personnel. The checkout engineer noted overtemping but did not report it to the test conductor. Contributing was inadequate instrumentation and inadequate rheostat control. No written troubleshooting procedure was available.	Require use of formal troubleshooting procedures on high voltage equipment. Ensure that equipment voltage control and instrumentation is adequate to prevent overstress or operation beyond design limits, and require that temperature limit controls are installed on high intensity heat source systems. Electrical technicians performing troubleshooting should be formally trained and certified.
43. Five external batteries being used as an external power source for checkout of a spacecraft were hooked up with reverse polarity and when turned on caused a fire and extensive damage to the spacecraft and 13 days schedule delay.	A specific hookup procedure was not used and the terminals were not color coded or sized to prevent cross connecting. The positive terminal was painted black leading the technician to assume it was a negative terminal. Contributing was the lack of QC verification and supervision during installation.	Color code or size and key battery terminals to prevent cross connections. Require written verification of battery hook-ups prior to use and require preparation of specific procedures for battery installations.
44. During manufacturing checkout and modification of a ground test vehicle, a wiring harness assembly was damaged scorched and burned, by a heat gun overheating. A heat gun was used to heat shrink sleeving over harness splices. Harness damage necessitated considerable repair/replacement and delay in checkout operations.	Inadequate control and monitoring of various modification and repair activities which were being performed simultaneously. Contribu- was the apparent lack of personnel training and instruction in the use of heat guns in cramped quarters on end-item hardware.	Require detailed documentation and control of repair work on end-item hardware. QC acceptance/verification of work performed should be required for each repair or rework procedure.

SECTION II

ELECTRICAL SYSTEMS (CONT.)

Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
45. An explosion and fire occurred on a test stand, causing major damage and personnel injury, when an electrical control circuit for the oxidizer system was inadvertantly cross connected to the fuel control system.	Deficiencies in the performance of maintenance and installation. The connections were identical and were not keyed or color coded to prevent cross connection. Continuity checks were not run after the installation and inspection had not verified the installation.	Require keying or coding of all electrical connectors for propellant control circuits. Require continuity checks to be performed after any installation of propellant control circuits. Require Q.C. verification of all electrical control connections.
46. A major explosion occurred on a test stand when an electrical connection was de-mated with power "on", causing arcing and ignition of propellant from an adjacent transfer valve.	The de-mating was made with power on. Also, propellant loading was being performed simultaneously with maintenance on the electrical system and operations were not properly coordinated.	Avoid concurrent maintenance of electrical systems during propellant loading. Require that all concurrent operations be covered in pre-operations briefings. Prohibit disconnection of electrical circuits with power "on".
47. A technician was seriously injured during maintenance of an electrical circuit after a test shutdown, when residual voltage in a capacitor was not completely bled off prior to work.	Formal work procedures were not being followed and supervisory action was not taken to ensure bleed off voltage in the capacitor prior to work.	Require use of checklists for maintenance work on electronic/electrical systems to ensure that residual voltage is bled off.
48. An explosion occurred on a test stand due to corrosion of propellant and electrical lines from a leaking battery above the lines.	Inadequate inspection of batteries prior to tests and design deficiencies in not providing protective devices for lines located beneath batteries.	Require a pre-operational check of all batteries prior to each operation. Ensure that batteries are not installed above critical electrical or propellant lines. Require a hazard analysis to be performed on battery installations to ensure lines subject to battery leakage are provided with protective devices.

SECTION II

ELECTRICAL SYSTEMS (CONT.)

Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
49. One person was fatally burned and one seriously injured in a space chamber under 100% oxygen when a flash fire occurred during routine maintenance from an electrical spark. The chamber was destroyed.	Inadequate maintenance procedures for 100% oxygen environments. Contributing was failure to ensure that non-flammable materials were used and failure to specifically rate equipment for use in oxygen environment.	Require all equipment used in oxygen enriched environment to be specifically tested for flammability and ignition potential prior to approval for use in manned tests in oxygen enriched environments. Require emergency plans which would ensure rescue of crewmembers within 20 seconds.
50. During an unmanned 500 hour life cycle test of a space vehicle in a chamber with 100% oxygen, a fire broke out at 480 hours from a spark from an electrical tape. Severe damage to the chamber and vehicle resulted.	A design deficiency in the test installation. The heat tape had been installed as part of the test setup and had not been specifically rated for a 100% oxygen environment.	Require all electrical equipment to be specifically rated for use under 100% oxygen environment. Require frequent inspection of electrical circuits for potential shorts.
51. Two flight crew members were seriously injured in a space chamber under 100% oxygen when an electrical spark caused a fire on the thirteenth day of a simulated 14 day space mission.	An overloaded electrical circuit under the instrument panel that overheated and caused ignition. Contributing was lack of adequate planning and specification for equipment used in 100% oxygen environment.	Designate all manned tests in 100% oxygen environments as safety critical and require a hazard analyses to be performed prior to tests. Ensure that all equipment has been specifically certified for use in oxygen environment. Avoid use of flammable materials and prohibit maintenance during tests.

SECTION III
FACILITY/GSE SYSTEMS

Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
1. During detergent cleaning operations on the interior of an LH_2 Booster tank at a test facility, the multi-spray head became detached from the adapter on the spray arm assembly and fell from an elevation of 49 1/2 feet above floor level, striking two gores of the tank forward bulkhead and causing major skin fractures and scratches. No injuries were sustained by personnel.	No detailed written procedure for assembling and testing the spray head assembly existed nor was there a specified requirement for QC inspection and verification. Contributing was the improper assembly of the spray head by the manufacturer causing the drive shaft of the spray head to loosen and disengage from the spray head assembly.	Require documentation control in ascertaining proper operation of cleaning apparatus used in end-item hardware, verification of assembly detail by QC and installation of safety wires, collars, clamps, etc. on rotating apparatus to prevent detachment.
2. During manufacturing welding operations on a stage LH_2 tank, a worker was caught between the tank and the tank holding fixture when the tank rotated in the wrong direction. The worker in trying to stop the rotating tank structure was carried into the fixture vertical support member and was seriously crushed.	Tank skins were being welded out of sequence, the tank weight counter balance was not installed, and only one "come-along" was installed instead of the required four. Contributing was the lack of a locking device or mechanism to prevent tank structure rotation when out-of-sequence welding was performed.	Require a pre-operations hazard analysis on all major assembly operations. Require formal detailed procedures for manufacturing assembly and prohibit out-of-sequence operations without formal supervisory approval, control and monitoring.
3. During a test checkout procedure on a vehicle at a launch facility, a GSE oxidizer service unit developed a small leak at a pump flange and subsequent tightening of flange bolts caused the heavily corroded bolts to break, releasing a large volume of N_2O_4 oxidizer. No personnel injuries.	CRS steel screws/bolts, cad plated, were used to fasten the stainless steel and flanges to the stainless steel body which had caused repeated failures of a similar nature. Contributing was the apparent failure to document and take corrective action when this problem was recognized previously.	Require frequent inspection of fuel propellant servicing units for corrosion. Ensure that all incidents involving fuel/propellant systems are reported to safety and carried as action items until corrective action is taken.

	Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
4.	During calibration of a flowmeter at a booster manufacturing facility, an elevated calibration standard slipped from holding brackets, and hit a work bench top and a mercury filled manometer, causing the glass manometer to break and resulting in a mercury contamination of work area.	The mercury use area was not controlled by procedures, precautionary measures, or monitoring equipment to secure and maintain a safe environment.	Ensure that manufacturing/calibration areas involving use of mercury devices are rigidly controlled and monitored to prevent potential damage due to mercury contamination.
5.	During spacecraft manufacturing operations, a workman on the top deck of a work stand knocked loose a 1 1/2" "C" clamp with an air hose. The clamp bounced to the work stand second level, and hit the vehicle's structural web, radiator and aft bulkhead. No hardware damage or personnel injuries resulted, however, the incident could have resulted in considerable repair costs.	Inadequate work control in that the work area was not properly reviewed and prepared prior to the operation and human error in that the employee was neglegent in not exercising adequate precautionary measures while working around end item hardware.	Require that personnel working on work stands above and around vehicle structures be certified and properly trained in tool handling procedures and precautions to prevent tool droppage.
6.	During manufacturing assembly operations on a booster stage, a tank entry ladder was lowered into a tank without the forward wheels positioned against the stops, causing the ladder to scrape and gouge the flange of the gas distributor. No personnel injuries.	No positive indicating device or means was incorporated to show when the ladder wheels were correctly positioned against the stops. Contributing was a cramped space and poor lighting which made visual verification of stop engagement difficult.	Require that all manufacturing support tooling and fixtures and procedures established for their usage involving critical end-item hardware undergo a hazards analysis prior to release. Require all entry ladders to have a positive means of identifying full engagement position and have a positive locking device to lock into position.
7.	While attempting to install a section of a pre-shaped catwalk on the top level of a vehicle work stand, the catwalk slipped and punctured a 1 1/2 inch gash in the top of the vehicle bulkhead. No personnel injuries.	Established installation practices and procedures were not followed and untrained, uncertified manufacturing personnel were used.	Ensure that adequate manufacturing controls are established that permit the use of only properly trained personnel on critical end-item hardware and require verification of personnel certification on each shift.

SECTION III
FACILITY/GSE SYSTEMS (Cont.)

	Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
8.	During preparation of a booster stage for shipment, the skin of a fuel tank was dented and gouged when rammed from below by the top of a "C" Channel on a lift-a-loft truck mobile work platform. No injury to personnel.	Procedural in that action had not been taken to provide pre-marking of stand position or to provide stops to prevent positioning too close to the vehicle. Also there were no proximity or override control devices provided to warn the operator or to cut off power to prevent collision and no padding was installed on the work platform.	Ensure that the use of ground handling equipment, in the proximity of end-item hardware, is operated by two or more personnel under the direction of a qualified supervisor to guarantee that all moving parts are under constant visual control. Evaluate the utilization of handling equipment to determine where remote override or disabling controls can be used. Perform a hazard analysis on all stage maintenance and inspection activities requiring the use of mobile ground-handling and ground support equipment.
9.	During welding of an overhead gas line sparks from the welding ignited filters in adjacent fabrication and assembly units and endangered spacecraft equipment in the units. A two week schedule delay was incurred when vacuum was lost during shutdown.	Inadequate work control procedures in performing welding near critical equipment without providing protective shields to prevent damage from falling slag. Contributing was lack of procedures for determining potential hazards prior to work.	Designate all welding operations as safety critical in test areas and require pre-operations safety approval. Require use of protective blanket to protect adjacent equipment during welding operations.
10.	During cleaning of a 5000 gal. oxygen tank using trichloroethylene, a flash fire occurred in the tank when a piece of plastic fell into the tank and onto the heater element rod. One man received minor injury.	Procedural in not exercising adequate control of the area during hazardous cleaning operations, to prevent contamination. "Housekeeping" was marginal and area inspection lax.	Require positive area control procedures to prevent contamination of fuel/propellant tanks. Require periodic inspection of all fuel storage areas.

SECTION III
FACILITY/GSE SYSTEMS (Cont.)

	Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
11.	A booster stage stored outside a vertical checkout building at a manufacturing facility, sustained damage when the building door came in contact with the stage roof protective cover and caused the stage assembly to shift (rotate) on its supporting bases, and resulted in misalignment of mating dimensions. No personnel injuries were sustained.	Procedural in that the material handling procedure did not adequately cover storage and did not require verification of measurements and clearances when positioning stage assemblies in a storage position. Contributing was lack of supervisory action to ensure proper planning and verification of end item storage.	Ensure that storage areas used for end item hardware storage is prominently marked and designated and require verification of correct positioning. Facility doors adjacent to hardware storage areas should be opened only by authorized personnel.
12.	During manufacturing operations on a booster stage, involving rotation of the stage for painting and packaging, rattling noises were investigated and drill bits and a screwdriver were found in the forward skirt area.	No procedures were in effect for positive control of tools and materials used in the stage. No "checkin" and "checkout" was being performed to prevent leaving of tools in the vehicle and there was no requirement for tethering of tools.	Require maintenance of a checkout of all untethered tools and materials taken into an end-item assembly area, and ensure that tools and materials are accounted for or removed.
13.	During manufacturing modification work, personnel on an engine test stand at a test facility dislodged a piece of unsecured plywood from a second deck which fell through the deck opening striking the engine manifold and resulted in a dent of approximately 2" long x 1" wide x 1/8" deep. No personnel injuries were sustained.	Procedural in that the piece of plywood was not authorized for use on the test stand. The normally used plywood platforms which provide stage and engine access for modification work had been removed for a previous test and were not replaced. There was also a lack of work control procedure for verifying status of equipment prior to the next test.	Ensure that only secured decking sections are permitted on test/work stands. Require QC verification of work stands prior to use.

	Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
14.	Auxiliary derrick on vehicle test stand failed catastrophically during facility test stand loading test and fell to the ground resulting in major damage to pilot deck house. One of two primary attachment points between derrick and tower failed due to assembly with incorrect bolt size. (1 3/8" x 6 TPI instead of 1 1/4" x 7 TPI)	Weakness in operational procedures to insure and assign facility inspection responsibilities and lack of resident inspector's cognizance of total facility assignment. Contributing causes were inadequate work control procedures for control parts issue and design deficiency in that use of tapped nut plate for critical connection point precluded visual inspection of threads after installation.	Safety checklists of critical inspection points should be required to insure verification and conformance to safety requirements, for facilities involved with test or handling of Flight Systems. Critical connection points of any superstructure test stand or similar facilities should utilize a bolt and nut arrangement in lieu of a tapped nut plate.
15.	During manufacturing, a booster fuel tank bulkhead was damaged when a special ladder, being removed from the tank, broke and fell into the bulkhead.	The ladder had not been proof-load tested, was not being used correctly and formal procedures were not being followed. Contributing causes were a poor weld on the ladder and inadequate inspection of welds.	Proof check all equipment used in or adjacent to flight vehicles, and formally qualify it for use, prior to operation. Use detailed test procedures for all work on flight vehicles and ensure that inspection techniques are adequate on all support equipment. Ensure that all crew members are formally certified to perform work on flight vehicles.
16.	Stage damaged during test installation when a guard rail section fell against the stage and caused a 3" by 2" hole in the radiator. Rail had been removed and temporarily leaned against the stage and was bumped by a workman.	The required protective cover was not on the stage and work control procedures were not adequate. Contributing causes were lack of training and pre-operational briefing of crew.	Ensure that procedures are established requiring certification of all crew members handling flight systems. Provide positive measures to ensure that flight vehicles are protected from adjacent equipment. Prohibit placing any equipment against a vehicle. Require that protective covers be used at all times for flight vehicle.

SECTION III
FACILITY/GSE SYSTEMS (Cont.)

	Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
17.	During a Qualification Test of a main booster tank bulkhead, a fire occurred resulting in considerable damage to the test item and Test Facility. Ignition apparently resulted from heat of a "Sun Gun" on flammable hydraulic lines or electrical lines.	Failure to prepare test and safety procedures prior to the test. Contributing causes were poor housekeeping in the test facility.	Detailed test and safety procedures should be prepared prior to any tests of fuel or pressure systems. Test areas should be analyzed for flammable material and heat sources, such as "Sun Guns," should be prohibited for use where flammable material such as hydraulic fluid is exposed.
18.	During facility handling operations, a crane hook was being lowered to zero level, guided by controller at zero level with sound powered phone to operator at the 300 ft. level. At approximately 8 ft. above zero level, a failure in the controller's headset discontinued communications and the hook continued downward striking swing arm latch assemblies resulting in considerable damage.	Lack of pre-planned caution and warnings in procedural instructions to handle contingency situations when communications were disrupted.	Hazardous operations dependent upon continuous guidance and instructions via powered voice communications should require procedures including backup communications by visual means, possibly utilizing a second operator capable of visual guidance communications in vicinity of zero level.
19.	During purge operation of oxidizer transfer/conditioning unit, the 450 psig flex hose furnishing GN_2 purge was overpressurized to 3000 psig causing hose failure. Unrestrained end of hose struck and injured two maintenance personnel.	Even though a test procedure was followed, work control procedures were inadequate and allowed a low pressure hose to be used in a high pressure system. Contributing causes were inadequate identification and marking of the hoses and inadequate inspection.	Quality Control should be required to verify all flex hose installations after work is performed. Flex hoses should be color coded and marked on both sides of connections to show pressure rating and function.

	Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
20.	During removal of a damaged "T" section in a 3000 psi GN_2 line, workmen inadvertently cut a line in the oxidizer low point drain which ran parallel and adjacent to the GN_2 line. The oxidizer line contained only residue freon flush from the system, and no fire occurred. However, this was a potential accident.	Inadequate identification, marking or coding of adjacent pressure lines and failure to perform a pre-operational hazard analysis. Contributing cause was inadequate training and briefing of crewmen working on potentially hazardous pressure systems.	Ensure that proper identification of fluid piping systems are performed in accordance with program standards. Establish rigid training requirements for personnel maintaining high pressure systems and require all personnel to be certified for such duty. Perform a pre-operational hazard analysis and crew briefing prior to any disconnection of fluid systems.
21.	During a facility maintenance/repair of a crane main hoist, the bell housing was removed from the motor and improperly secured by suspending with a come-a-long attached to an overhead beam. Attempt to use the crane by the second shift operator caused the motor housing to fall to the floor of the vehicle assembly building and be destroyed.	Lack of information transfer between shifts. Contributing causes are the failure of the operator to inspect the crane for safe operating conditions at shift change over, and failure to tag out controls of the crane for the non-operational hazardous condition that existed.	Ensure that shift change-over practices and procedures require each crew member to be briefed by his counterpart, procedures to be established for placarding support equipment as "out of commission" until maintenance work is completed. Require "tag out" of controls at all times when not operable.
22.	During maintenance checks of GN_2 purge of electrical switch and terminal boxes on a test facility, the top of an elevator was being used as a work platform. The elevator was inadvertently activated while work was in progress, injuring the workman's arm.	No provisions were in evidence to preclude possibility of inadvertent activation of elevator. Contributing cause was lack of communication between elevator and elevator control room, and design error in not locating GN_2 purge valves for accessibility from platform level.	Procedures should delineate requirement for establishing rapid communications when performing checks at remote or isolated locations. Ensure that power source is deactivated when power equipment is being used for a work platform and relocate hardware to permit checks from non-hazardous locations.

SECTION III
FACILITY/GSE SYSTEMS (Cont.)

	Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
23.	An optical target tool used to align a stage fuel tank when joining to a thrust structure was not removed and was sheared off as tank entered thrust structure, resulting in minor damage to a fuel Y-ring and splice area at one position of the thrust structure.	A breakdown in communications between Quality Control inspection and facilities handling personnel.	Ensure that adequate continuous communications, both verbal and visual, are required and maintained between work groups performing critical assembly operations and procedures. Require verification by inspection of all steps preparatory to mating large structures.
24.	In the process of tightening a longitudinal turnbuckle during attachment of a transporter to a booster stage, a pinch bar slipped when excessive pressure was applied, causing the bar to slip out of the hole in the turnbuckle and injuring one person. No damage to booster stage.	The unauthorized use of a pinch bar as an alternate for a spanner wrench.	Ensure that alternate tooling used in place of primary tooling around end item hardware is authorized and documented in operating procedures and that supervisory surveillance is present.
25.	During preparation for removal of a booster stage from an assembly area, hinged platforms were being elevated to upright positions. A normally electrically operated solenoid hydraulic valve which was inoperative, was manually activated to raise a work platform, however, the spring loaded valve stuck and permitted the platform to be raised uncontrollably to a point where it struck and damaged antenna outrigger sections on the stage.	Failure to follow preparation procedures which required the antenna sections to be folded back prior to raising main platforms. Contributing causes were failure to tag inoperative equipment and to provide precedures and precautions governing use of electrically controlled equipment when operated manually.	Ensure that established disassembly steps and procedures involving work stands around end item hardware are monitored and supervised and procedures include contingency provisions for abnormal conditions.

SECTION III
FACILITY/GSE SYSTEMS (Cont.)

	Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
26.	Maintenance personnel working on plumbing of a manufacturing facility above a stage LOX tank, dropped a crescent wrench which caused a gouge in tank weldment.	Failure to use proper safety precautions in that tools were not tethered to prevent droppage. Contributing is lack of area access control by the area supervisor.	Ensure that test conductors of specific hardware areas exercises rigid area access control wherein only mandatory authorized facility maintenance is performed in areas surrounding end item hardware. Supporting maintenance shop practices/procedures should ensure tethering of tools.
27.	A 220 V AC GSE Unit was inadvertently connected to a 440 V AC facility power outlet damaging the GSE.	Installation of the wrong electrical cord and plug on the GSE. Contributing was lack of identification of the voltage on the facility outlet.	Require all facility outlets to be identified as to voltage. Require Quality Control verification of proper electrical plugs on GSE prior to plug in to facility power.
28.	The high pressure industrial water system to a test stand failed when the operating pump ran out of fuel and pressure drop occurred before the standby pump could be brought in. System surges occurred when the standby was brought in too fast, causing considerable damage to test stand vacuum breakers.	There was no formal procedure for co-ordinating depressurizing and re-pressurizing of the water system between the test stand and facility. Contributing cause was inadequate servicing inspection which permitted fuel to run low and procedural errors in bringing in the standby pump.	Ensure that a formal procedure is prepared for emergency depressurizing and re-pressurizing of the water system to test stands and require thorough briefing of test and facility people on this plan. Require periodic verification of fuel quantity gauges and low-fuel warning devices.
29.	During booster stage rotation from a vertical to a horizontal position, two common 16 D nails fell out of the stage aft skirt area, apparently left by facility personnel while dismantling wooden platform/scaffolding, following completion of stage modifications.	Clean-up procedures following modifications did not exist and there were no requirements for 100% inspection coverage of all work.	Ensure that stage removal procedures include Q.C. verification/inspection of no loose objects. No work should be allowed in critical stage areas following inspection.

SECTION III
FACILITY/GSE SYSTEMS (Cont.)

	Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
30.	A booster engine was damaged on a test stand during removal of a facility hydraulic cylinder on the 8th level. A cable hooked a metal protective cover, tipped it over on the engine and caused it to fall to the next level.	Failure to anticipate hazards of the operation and failure to require restraining devices on loose equipment on the stand.	Require all protective covers and other loose equipment on stand and platforms to be restrained. Require a pre-operational hazard analysis of facility maintenance near end item hardware.
31.	During movement of a work gantry at a stage facility, one of the extended platforms struck two quick disconnect lines on a booster stage aft umbilical, and caused minor damage.	Failure of operator to verify that all platforms were in a retracted position prior to movement. Contributing cause is the lack of a positive braking system on the gantry.	Ensure that formal operating procedures instructions are established for operating equipment around end-item hardware which require operators to verify safe conditions. Q&RA should additionally be required to verify this step. A micro-switch interlocking control system should be incorporated into work stands with extendable platforms which would prevent gantry movement until all platforms are in the proper positions.
32.	A LH_2 feedline environmental hut and a booster stage sidewall insulation were damaged at a test facility when left unattended during a weekend. Gusty winds caused a service tower to roll, striking the hut and stage.	Facility planning was lacking in not providing stops or checks for securing tower wheels. Contributing cause was a design deficiency in not providing positive braking devices for service towers.	Ensure that provisions are made for securing wheeled structures when left unattended and facility planning considerations include environmental factors and effects. Provide braking devices for all mobile equipment used with end item hardware.

SECTION III
FACILITY/GSE SYSTEMS (Cont.)

	Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
33.	A filter in a high pressure missile grade air line burst in an observation bunker during the night when unattended and scattered fragments over the floor.	A filter had been installed in a higher pressure system than the pressure rating of the filter. Contributing cause was a malfunctioning pressure regulator and inadequate installation inspection.	Require Q.C. verification of pressure ratings of all components installed in high pressure sytems. Perform frequent inspection of pressure regulators and replace any chattering or malfunctioning regulators.
34.	While disengaging sling after lifting operation on the 19th level of a test stand, the choker cable broke allowing clevis and cables to drop, hitting the upper LOX tank bulkhead of a stage.	The choker cable was not an authorized component but had been "klugged." Contributing cause was the lack of proof testing of the sling and cables and inadequate training of operators.	Require formal engineering approval of all sling and lifting devices used with flight hardware. Require proof-loading of all components to 150% of anticipated loads. Ensure that all handling operators are qualified and formally certified for duty.
35.	During routine inspection of a test stand auxiliary derrick, major damage to the derrick was discovered.	Operation of the derrick when limit switch was bypassed. Bypassing of limit switch in 5th gear was caused by a misadjustment of the control levers during installation and assembly.	Require Q.C. verification of all control lever adjustments on auxiliary derricks.
36.	A potentially hazardous situation occurred when primary facility power was lost followed by backup power loss to an entire test stand. This resulted in spurious signals to stage sytems. No damage to stage resulted.	Material failure when primary transformer was burned because of a defective insulator.	P erform a hazard analysis of potential hazards at all test stands under condition of loss of facility primary and backup power.

SECTION III
FACILITY/GSE SYSTEMS (Cont.)

	Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
37.	During welding operations on the 10th level of a test stand, LOX lines caught fire on 4 1/2 level, due to falling welding slag which ignited foam rubber covering of lines.	Failure to control welding operations and failure to provide protective devices to prevent failling slag.	Require all welding operations on a test stand to be designated as safety critical and require a pre-operation hazard analysis and safety approval.
38.	During post test cleanup, two men were sent into the forward skirt area immediately after GN_2 purge to pick up equipment. They encountered inert atmosphere and were temporarily incompacitated.	The men entered the area without taking air samples and without air-pacs. The stand talker was not familiar with safety rules and the men had not received safety briefing prior to work assignment.	Require air samples to be taken prior to entry into confined areas on a test stand. Require formal safety briefing of all personnel prior to assignment to duties on a test stand. Require formal training and certification of test stand talkers.
39.	During installation of booster strain gauges on 9th level, the technicians tool bag and tools were destroyed by fire from welding slag falling from an upper level.	Failure to coordinate work being performed in the area and failure to brief personnel of other work. Contributing cause was lack of protective devices for welding operations to prevent falling slag.	Designate all welding operation on or near flight hardware as safety critical and require safety approval prior to initiation. Provide protective devices to prevent falling slag. Ensure that all personnel are briefed as to concurrent work in an area.
40.	During disconnection of a butane line for a steam boiler used for cleaning on a test stand, an explosion and fire occurred damaging the tank, trailer and lines.	A butane fuel tank cart was too close to heat source and no controls or warning signs to prevent smoking. Workman was smoking a cigarette while disconnecting butane line. Contributing was a design deficiency in the installation in that main fuel tank was too close to heat source.	Require no smoking zone within 50 ft. of butane storage and lines. Require butane tanks to be a minimum of 25' from heat source.

SECTION III
FACILITY/GSE SYSTEMS (Cont.)

	Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
41.	During routine maintenance, workman was working above a stage and dropped a pair of wire twisters which damaged the stage engine and required replacement of the engine.	Inadequate work control. The hand tools being used above a stage were not restrained to prevent inadvertent dropping and protective covers were not installed on the vehicle.	Require all hand tools to be restrained when being used over end item systems. Require protective covers over flight vehicles or program equipment when work is being performed adjacent to or above the items.
42.	During operation of an air fan in a fuel disposal unit, located in the fuel transfer and conditioning area, the impeller assembly failed structurally causing particles of steel to penetrate the expanded metal guard. No injury to personnel.	A design deficiency in that the structural limitations of the stud bolts in the fan were not adequate and failed. Also, the protective shield for the fan was not adequate to prevent parts from penetrating it.	Require all fan units to be examined radiographically on a periodic basis. Require ultrasonic testing and static and dynamic balancing after any repairs or replacement of parts. Require structural testing of all protective shields to ensure containment of fragments in event of fan failure.
43.	Use of improvised tool for torquing of turn buckle on an engine thrust chamber resulted in six dents in the chamber tubes.	Inadequate work control procedures which permitted the use of unauthorized tools. The tools authorized for this job had been proven inadequate but had not been replaced by a suitable design. Workmen improvised their own tools, resulting in damage to the tubes.	Require all special tools and equipment used on end item hardware to be specifically approved and certified for use. Require all identified discrepancies in tool design to be documented by inspection and the tool "tagged out" until a suitable replacement is provided.

SECTION III
FACILITY/GSE SYSTEMS (Cont.)

	Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
44.	A construction worker on a test stand was exposed to electric voltage and injured while carrying a drill motor to an upper level. He received the electric shock while holding the drill in one hand and holding on to a stand beam.	A two wire jumper had been used to connect a three wire power souce to the three wire drill motor. Inspection of the jumper installation was apparently not conducted or authorization approved to use an ungrounded jumper.	Require all power tools used on a test stand to be of three wire grounding type and require all extension cords or jumpers to be of three wire grounding type. Require Quality Control verification of all temporary jumper connections.
45.	During a laboratory calibration test at - 100°F, Freon TF was inadvertently used to fill a calibration bath instead of alcohol. The test was discontinued at -40°F when ice crystals formed. No damage or injuries but serious hazards could have been encountered with other fluids.	Failure to properly mark or identify the contents of storage drums and failure to require written requisitions. Also, no control was exercised over issuance of chemicals. In this case, a driver was told to get methyl alcohol from the storage area.	Require positive marking and identification of all storage drums. Require written work orders for release of fluids in drum storage and require positive control over all issues from drum storage.
46.	During a leak check of a steam line of an altitude simulation system, the system was pressurized to 50 psi without the tie bars installed behind the expansion joints and resulted in movement of the joints and striking of the main steam line.	A previous crew had removed the bars and had not placarded the system console. The test crew was not aware of removal of the tie bars.	Require all operating consoles of systems to be placarded as "out of commission" whenever work is initiated on a system.

SECTION III
FACILITY/GSE SYSTEMS (Cont.)

	Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
47.	A spill of a passivation fluid (nitric acid 60% and water 40%) occurred when a locally fabricated tank made of two teflon lined 55 gallon barrels welded together, failed at the welds.	The tanks were not fabricated in accordance with an engineering design and the welding destroyed the teflon lining at the weld joint. The epoxy paint used on the weld was not adequate to prevent corrosive action of the acid.	Require all tanks for toxic or corrosive liquids to be constructed in accordance with approved engineering specifications. Ensure that tank linings are adequate for the liquid to be used in tanks.
48.	During proof pressure testing (20 psig) in a pressure test facility used as a flash and fire test chamber, the glass viewport shattered after a 4 1/2 minute pressure hold. There was no other damage to equipment and no injury to personnel.	A design deficiency in that the chamber port glass was sealed with a metal-to-metal seal which permits overstressing of the glass in torquing of the fastening bolts and does not allow for expansion. Contribuing cause was inadequate inspection to determine warps.	Test chamber checkout procedures should specify and be verified by Quality Control that chamber doors are checked for distortion and that viewports are checked for flaws prior to each operation. Ensure that viewports are designed to be secured with floating seals to eliminate metal-to-metal contact, and that viewports are bolted to pre-established torque values.
49.	During manufacture of booster stage, hydrogen tank horizontal frame was broken by use of an improvised work platform.	Proper work control procedures were lacking and there was not adequate pre-planning of work.	Require all tools and equipment used around or with end item hardware to be specifically approved and certified for use.

SECTION III
FACILITY/GSE SYSTEMS (Cont.)

	Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
50.	During counter balancing operations in preparation for a centrifuge test, the counter balance weights tore loose from mounting plate, shearing enclosure skin bolts, damaging mounting plate bolt holes, and slightly damaging counter weight plate. No injury to personnel.	The bolts used to attach the counter balance weights to the base plate were not in accordance with the specifications and were of insufficient length to permit sufficient thread engagement to support weights under acceleration load conditions.	Ensure that controls are established to ensure only proper parts as called out by the drawings or procedure are installed. Require Quality Control verification and sign-off on all materials and components, prior to installation. Require all replacement parts for test installation to be documented by written material requisition and work authorization.
51.	During repair of LH_2 tank liner, excessive temperatures were developed in curing the heating pad, damaging the liner and the heating pad.	Failure to specifically prepare a procedure for conduct of the work and failure to design a tool specifically for this job. There were not adequate temperature sensors and the one being used was marked by the "jury rigged" heater arrangement.	Ensure that formal work procedures are prepared for all repair work on flight vehicles. Require all special repair tools to be designed by tool engineering or approved by them. Install automatic heat cut off devices on "patch curing" heaters when critical temperatures are reached.
52.	A crane at an engine test stand was improperly secured at the end of a work shift, permitting the boom, in a horizontal ground level position, to be moved by high winds, striking a pressure gauge stand pipe on a GN_2 storage tank.	Failure to follow established procedures in securing of heavy handling/lifting equipment. Contributing was the apparent lack of verification/check-off monitoring by test conductor or other responsible personnel at the close of operation.	Established shutdown/securing practices or procedures for heavy handling/lifting equipment in proximity to test stands and storage areas should require verification of critical lock-up points.

SECTION III
FACILITY/GSE SYSTEMS (CONT.)

	Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
53.	During changing of a fluorescent tube in the ceiling of a high bay test area, the technician took the tube out of its container and laid it on the crane. It rolled off and shattered over the test stand and flight vehicle, causing glass and possible mercury contamination.	Failure to take necessary precautions to prevent falling objects from striking the vehicle when work was being performed over it. Contributing was carelessness of the technician in handling of the tube.	Require catch nets to be installed over a vehicle whenever work is being performed above it. Brief all personnel on the hazards of mercury contamination when handling fluorescent tubes near flight vehicles.
54.	During plug demating operation, a workman fell through the top-deck of a test facility, went through a debris net below and fell to the second level. He received minor injuries and the vehicle skin was damaged in several sections.	A plate on the top-deck was removed for other work and was not barricaded or properly placarded to prevent such an accident. There was no personnel net below the hole and no guard rails erected.	Ensure that all operations involving upper levels of test stand are analyzed for safety hazards prior to initiation. Require guard rails and placards to be placed around openings in decks. Require personnel safety nets to be installed beneath decks in addition to debris nets.
55.	A test facility high intensity search light was damaged by fire when the fabric cover was ignited while unattended.	Inadequate maintenance and inspection procedures. The cover had been allowed to deteriorate to the point where it was torn by high gusty winds. The tear was not detected and subsequent reflection of the sun from the light lens ignited the cover.	Require monthly inspection of all covers for GSE or flight hardware. Establish age life criteria for covers on critical equipment. Require inspection of all equipment following unusual weather conditions.

	Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
56.	During receiving inspection of a spacecraft, cleaning up of "dusty and dirty" conditions in the food locker area resulted in the discovery of a cotton swab stick stuck into a wiring bundle which could have resulted in damage to the wiring and a potential fire.	Lack of control procedures for controlling materials taken into a spacecraft. Contributing to this incident is inadequate inspection of the spacecraft after work is performed.	A log should be maintained of all materials taken into a spacecraft and all materials should be accounted for at the completion of each operation. Quality Control verification of the condition of the spacecraft and material logs should be required after each operation.
57.	Two spacecraft were contaminated with a residual cleaning solution of nitric acid and sodium nitrate which dripped from plumbing line holding fixtures positioned above the vehicles during manufacture. The fixtures fabricated of welded tubing were sent through a chemical cleaning immersion cycle prior to use. Bay areas, decks, and fuel tanks required extensive decontamination and cleanup.	Inadequate manufacturing supervisory control to ensure that cleaning procedures were properly applied. Contributing was the absence of manufacturing planning to insure vehicle protection against spillage or drippage of corrosive materials.	Ensure that manufacturing planning considerations include adequate safeguards for end-item protection from corrosive materials. Manufacturing procedures should include specific controls and requirements for tool cleaning.
58.	After installation of Xenon Lamp in a thermal radiation laboratory, the lamp exploded 30 seconds after power was applied. No injuries. The reflector lens and filter were damaged.	Material failure of the bulb. Bubbles were found in the quartz envelope, although there was no indication of stress concentration.	Require a ten hour burn in time for Xenon lamps without lens or reflector installed. Ensure that precautions are taken to provide protection of personnel and equipment from flying fragments in areas where xenon lamps are used.

SECTION III
FACILITY/GSE SYSTEMS (CONT.)

	Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
59.	While exiting Lunar Receiving Laboratory through ultra violet airlock, a spill alarm was sounded causing personnel to remain in the airlock until "all clear" was given resulting in burns to personnel's eyes from exposure to ultra violet lights.	Personnel did not know that two other doors from the airlock were unlocked from which egress could have been made.	Provide warning signs in potentially hazardous areas delineating procedure to follow when emergency conditions arise. Written procedures should be established specifying potentially hazardous conditions during a test, mode of egress to follow, and ensure that all personnel using facility are instructed and made cognizant of same.
60.	When power was initiated to the solar burn in a solar chamber, an electrical fire broke out damaging cables and cable tray.	The cables had been exposed for some time to normal traffic and covers had been installed to protect them. In installing the covers, the trap had been "forced" to allow installation of covers, apparently causing bolts to damage the cables.	Require installation of protective covers over all cables exposed to traffic prior to facility activation. Require Quality Control verification of work performed on electrical systems in test facilities.
61.	A mobile crane in movement with a driver and two riders experienced a ruptured radiatior hose which spewed hot water on the two riders. One rider jumped to the ground clearing the vehicle and avoided injury. The other rider jumped landing on the right front wheel which in revolving forced his body downward between the wheels and front portion of vehicle's metal frame resulting in a fatal injury.	**Violation of a documented company rule prohibiting riding on a vehicle without a seat or handrail. Contributing was a frayed and badly worn fan belt which broke and caused rupture of the hose.**	Safety rules and regulations applicable to movement and operation of heavy mobile machinery and equipment should require only personnel necessary for safe movement be permitted on board. Maintenance, procedures and inspection schedules should be formally established for all facility support vehicles.

SECTION III
FACILITY/GSE SYSTEMS (CONT.)

	Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
62.	During cleaning of a LH_2 tank, one of the four dual jet washers became disconnected from the rotor and dropped 40 to 50 feet inside the tank, damaging the forward bulkhead.	Improper assembly and securing of the dual jet washer to the washer assembly. In addition, there was no positive locking mechansim to prevent disconnection of the jet washer and counter-clockwise rotation could loosen the spray nozzle.	Inspect all jet washer rotor motors to ensure that the motor rotor is oriented to rotate clockwise. Require positive locking devices on all rotary auxiliary equipment used with end item hardware to ensure that removable heads are positively secured.
63.	During decontamination of lunar samples in a laboratory, using perasetic acid, personnel were exposed to toxic fumes and forced to evacuate the area when the air movement motor failed. No damage to samples.	Failure/malfunction of the motor. Contributing cause was a design deficiency in the exhaust systems in not providing devices to prevent back flow exhaust fumes when a malfunction occurred.	Require formal designation of unsafe conditions and maintenance of a safety corrective action test to ensure follow up action. Perform a hazard analysis of all areas where personnel are exposed to toxic fumes to ensure redundant exhaust features and positive means of preventing exhaust backflow.
64.	During welding operations in a test chamber, cleaning mops were ignited from arcing from the welding, and subsequent smoke caused fire alarm, evacuation of building, and loss of valuable work time.	Improperly grounded arc welding equipment and inadequate area inspection prior to welding operations.	Require adequate grounding of all arc welding equipment. Require an area inspection for flammable materials prior to welding.

SECTION III
FACILITY/GSE SYSTEMS (CONT.)

	Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
65.	During pre-test installation and maintenance of a flight vehicle prior to chamber tests, critical pressure lines and electrical cables were damaged by work traffic and required replacement.	Inadequate supervisory control over operations and inadequate inspection of work areas. Protective devices were not provided for critical lines and cables and periodic area safety inspections were not performed by supervision.	Require weekly supervisory safety inspections of work areas and monthly inspection by the safety office. Require all critical lines and cables subject to work traffic to be provided with protective covers.
66.	During pre-test installation and maintenance of a flight vehicle in a test chamber, valuable time was lost when the fire alarm system was activated by welding operations causing evacuation of personnel.	Failure to coordinate simultaneous work in the area. Welding was unknown to test personnel and smoke from welding was pushed up by air handlers and activated alarm.	Require prior notification of all agencies in test area of planned welding operations. Notify all agencies when planned work may activate the system.
67.	During pre-test maintenance on a space vehicle, a workman fell while exiting the cabin and was injured when he struck the vehicle. No steps had been provided for the 3' space to the floor.	Inadequate planning and supervision. Supervision had not performed a safety inspection prior to the operation and had not performed necessary pre-planning of support and safety equipment required.	Require steps and hand rails for all exits from flight vehicles during installation and maintenance. Require supervision to perform a daily and a pre-operational safety inspection. Require maintenance of supervisory safety inspection log.

SECTION III
FACILITY/GSE SYSTEMS (CONT.)

	Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
68.	After conduct of a test in a test chamber, a vacuum cleaner was left in the chamber and a hole was burned in the hose during the night due to being too close to a high intensity light.	Lack of adequate work control procedures. Equipment was not removed and secured after the operation and inspection of the area was not made to ensure safety of the facility.	Require all unused support equipment to be removed from test chambers after each operation. Require a safety inspection by supervision after each operation to ensure safety of the area. Replace high intensity lights where possible and place warning notices of fire hazards of high intensity lights.
69.	During welding operations in a flight vehicle test chamber, a hole was burned in a facility instrument air line, presenting a major fire hazard.	Inadequate work control procedures. The workman was not using protective devices for adjacent facility lines. Supervision did not inspect work area prior to operation.	Designate all welding operations in test facilities as safety critical and require pre-briefing of welders. Require supervisory inspection of work areas prior to welding operations to ensure use of protective asbestos blankets on adjacent lines.
70.	During a manned chamber test of a flight vehicle, a lightning strike caused loss of primary facility power, resulting in unloading of computers, circuit breaker disengagement, loss of trim control and loss of vehicle power.	Failure to ensure availability of back-up power prior to initiation of test. Contributing was failure of the emergency power for the trim control unit.	Require verification that back-up facility power is in idle condition prior to initiating manned tests. Emergency generator should always be on standby during tests. Require checkout of vehicle systems emergency power prior to each test.

SECTION III
FACILITY/GSE SYSTEMS (CONT.)

	Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
71.	During ascent to the access platform of a space vehicle at a test facility, a workman lost his balance and fell 8 feet to the floor, suffering multiple injuries.	Inadequate design of the ladder and access platform. The ladder was 8 feet high and set at a 70° angle from horizontal. The distance from the top of ladder to work platform was 14 inches and no handrails provided. Contributing was lack of daily safety inspections by supervision.	Require that work platforms and access ladders to space vehicles be provided with hand rails and constructed in accordance with approved safety specifications. Require safety inspections and approval of all work platforms and ladders. Require daily safety inspections of work areas by supervision and maintenance of a safety inspection log.
72.	During development testing of a flight vehicle, a freon supply tube to a supporting air conditioning unit broke filling the area with freon vapor under pressure. Though no serious damages were sustained, this condition could present a serious personnel hazard. Further extensive cleaning of the interior/exterior surfaces of the vehicle was necessary.	Lack of an adequate Preventive Maintenance Program, and age life records. Periodic inspection of refrigerant lines was not being conducted. The supply lines had exceeded age life limits and had no records to reflect they should be replaced.	Require preventive maintenance programs to be established for all supporting equipment or facilities for flight vehicle tests. Ensure that age life limits are established for critical materials and that inspection cycles and replacement times are identified and tagged on each component.
73.	Technician backed into GSE unit and broke glass sight gage. Unit was non-operational until gage was replaced.	Failure to provide protective devices for critical instrumentation located in areas subject to work traffic. The gage was located in a confined work area with no protective guards installed.	Require a hazard analysis to be performed of work areas to ensure that critical equipment is protected from work traffic. Perform periodic inspections of work areas and require that warning signs be placed in critical work areas.

SECTION III
FACILITY/GSE SYSTEMS (CONT.)

	Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
74.	Upon completion of testing in a vacuum chamber, glass was found shattered with glass fragments contaminating the flash reflectors. As a result of this incident, the tracking light shield was shattered, and the tracking light reflector was contaminated with glass particles.	Facility maintenance installed the wrong lights. (Incandescent rather than seal beam). Contributing was lack of inspection verification prior to vacuum tests.	Require facilities personnel to notify test engineering of any work performed in a test chamber and require a written log to be maintained and provided to test engineering. Require that Quality Control verify all chamber installations.
75.	While attempting to repair the temperature gage on an operating nitrogen cart, freon vapor was seen coming from the unit's vents. Subsequent damage required replacement of components in the cart before return to full operation.	Lack of procedural instructions associated with repair of GSE. The technician was attempting to replace components in the unit with power "on". Additionally, he failed to monitor the temperature and allowed the flow of coolant to decrease to a dangerous level.	Repair instructions for electrically operated equipment should direct that component replacements must be accomplished with power "off" and equipment should be placarded or "locked out" until work is completed.
76.	During development testing, a portable x-ray unit fell and contacted a flight vehicle. Subsequent investigation indicated a stiffener in the vehicle had been cracked (2 1/2" long x 5/8" wide) and required replacement.	X-ray unit was not placed in its proper cradle. The test plan did not adequately describe the equipment types to be used, nor specify test equipment setup. A contributing factor was the entrance of unauthorized personnel into the test cell who were not familiar with the equipment, and who were responsible for causing the equipment to fall.	The test plan should identify equipment configuration by type that is compatible with the facilities that are available. Subsequent inspection prior to test should be accomplished to ensure test equipments are properly set up and secured. Entrance to the test facility should be restricted to certified personnel involved in the actual testing.

	Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
77.	During manufacturing, approved GSE protective covers were not installed and flight cover used in a space vehicle cabin was stepped on and crushed by workmen.	Inadequate work control procedures and inadequate inspection. Supervision did not inspect cabin prior to work initiation to ensure that protective covers were installed.	Require protective covers to be designed and installed over critical flight equipment when work is being performed or when the vehicle is being handled, moved, or transported. Ensure that protective covers are marked for "no step" areas and include alignment markings.
78.	During manufacturing assembly, a work platform was not properly secured, and fell, striking the aft equipment bay of a flight vehicle.	Failure to attach the hold down screws on the work platform. Contributing factors were failure to inspect the platform after re-installation and failure to require a formal engineering work order for all structures used around flight vehicles.	Require all platforms and structures used around flight vehicles to be formally approved by engineering. Require Quality Control sign off after installation or reinstallation of any structure or platform used near flight vehicles.
79.	A workman on a test stand fell 50' through an opening in the top level into a safety net.	Failure to provide protective guards and railings around the stand opening during work on the top level. The prior installation of the safety net averted a fatality.	Require all openings on test stands to be provided with protective barricades. When working near open areas on test stands, install nets below, both to protect personnel and to protect equipment from falling objects.

SECTION III
FACILITY/GSE SYSTEMS (CONT.)

	Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
80	A spray booth failed and fell during final checkout, injuring a technician and causing extensive damage to equipment	Failure to properly operate the jack screws resulting in overstressing of the screws and material failure. The jack screws were at maximum heights at time of failure. Contributing was a design deficiency in that the safety cutoff switch was located in a position where it could not be cut off. Operating procedures were not adequate.	Proof test all lifting mechanisms with dead weights prior to installation on manned equipment. Require detailed operating instructions to be prepared and followed for operation of mechanical lifting equipment. Ensure that safety switches are located in a manner to preclude inadvertent over-extension of lifting screws.
81.	During manufacture the walkway of a workstand being positioned by workmen struck and damaged a vehicle.	Inadequate work control procedures and employee carelessness. The position of the workstand was not premarked and insufficient men were available for moving the heavy stand which moved too far when additional force was applied to move it.	Provide protective stops whenever heavy equipment is being positioned near vehicles and ensure that sufficient personnel are available to control movement. Ensure that sharp corners and edges of equipment are padded to protect from striking the vehicle.

SECTION III
FACILITY/GSE SYSTEMS (Cont.)

	Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
82.	A stage common bulkhead aft facing sheet was damaged ("canned") during the lowering of a vacuum bell tocl, when the inner bag contacted and came to rest against the sheet.	Performing work on the third shift which was abnormal to the normal duties of the crew in order to expedite work for the tooling department. Although work was performed properly, the vacuum bell, was not normally lowered over the aft facing sheet. Contributing was performance of simultaneous operations by two departments.	Ensure that simultaneous operations are properly coordinated and that abnormal tasks assigned to crews are pre-analyzed to identify potential anomalies that may occur. Ensure that all crews are properly briefed on hazards of assignments.
83.	During manufacturing assembly of a vehicle, a workman fell into the spacecraft when the protective cover slipped. Minor damage to the spacecraft and minor injuries resulted.	Design deficiency in the protective cover in that proper tie-down devices were not included in the design.	Ensure that all protective covers and work platforms used with flight hardware are properly secured.
84.	While changing socket slings on a hoisting spreader bar, the sling socket struck the LH_2 tank forward bulkhead spray foam causing minor damage.	Employee carelessness and failure to follow prescribed procedures. Work should not have been performed over the vehicle but was performed to save time. Supervision was not present.	Prohibit maintenance work on support equipment over end item vehicles. Require member of supervision to be present when work is performed above vehicles.

SECTION III
FACILITY/GSE SYSTEMS (Cont.)

	Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
85.	A workman was performing maintenance on an overhead crane when the shaft bearing housing broke and fell to the floor brushing a flight stage. No damage incurred but potential was high.	Inadequate planning and supervision. The work should not have been performed over a flight vehicle without protective devices for falling objects.	Prohibit maintenance of cranes or other support equipment adjacent to or over flight systems. Require supervision inspection of work areas prior to work above flight vehicles.
86.	A stage was damaged during pre-launch checkout when a 6" piece of soldering rod fell from an upper level and embedded in an LH_2 tank insulation.	Failure to exercise control over loose equipment and material above a stage. Apparently the rod had fallen from an overhead crane which had been moved over the stage.	Require daily inspections of areas above stages to ensure no loose equipment. Inspect all mobile equipment for loose items prior to moving on upper levels.

SECTION III
FACILITY/GSE SYSTEMS (Cont.)

	Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
87.	A commercial truck driver backed his tractor into a helium trailer, knocking it over the wheel chocks and into the storage manifold damaging lines, valves, and manifold.	The driver was attempting to hook up to the trailer without an outside observer present and misjudged distance.	Require an outside observer for all vehicles in gas storage areas.
88.	During installation of a spool on the LH_2 vent line of a stage, a workman dropped a 4" extension and socket causing a 5/8" gouge in the side of the vehicle skin.	No restraining devices were being used on tools over the vehicle and no protective covers were installed to prevent damage from falling objects.	Require that tools be restrained when used over end items. Require protective covers to be installed on vehicle whenever work is being performed above it.
89.	During X-ray of weld seams on a booster tank, a workman was subjected to radiation when X-ray operations were initiated while he was in the tank.	Inadequate communications. Walkie-Talkie was being used and a garbled message was misinterpreted by the X-ray operator and operations initiated prior to clearing personnel from the tank.	Require use of hardline communications for X-ray operations. Require positive verification by QC prior to X-ray operations that area is clear.
90.	During test checkout of ECS/GSE, a quick disconnect 1" alcohol bypass line was not connected, resulting in a spill of alcohol on the test stand when pumping was initiated from tank farm.	Failure to include hookup of the quick disconnect in the test procedure and failure to require QC verification of all quick disconnects prior to iniation of operations.	Require hook up of all quick disconnects to be included in the test procedure and require QC verification of these steps.

SECTION III
FACILITY/GSE SYSTEMS (Cont.)

	Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
91.	During fuel line draining of a vehicle at a launch facility, a fan blade on a facility oxidizer vapor disposal unit failed due to fatigue/stress corrosion and a blade section was thrown through the fan outlet at the top of the unit and traveled approximately 50 feet. The control panel and other fan blades were damaged from fan section impact. No personnel injuries were sustained, however, the disposal unit required replacement prior to vehicle propellant loading.	The lack of an established periodic inspection and/or replacement schedule for the fan blades. Contributing was the apparent lack of a facility hazards analysis prior to activation of the launch facility oxidizer vapor disposal unit.	Require that facility support equipment be verified for continued usage through an established periodic inspection and/or maintenance program.
92.	During pre-launch checkout, a technician on an upper level dropped two wrenches tethered together and they struck a stage on a lower level causing minor damage.	The primary cause was improper tethering of tools. The technician had tethered them together and hung them over his neck resulting in both tools falling.	Require all tools to be tethered to the person or a structural member.
93.	A 6000 psi helium supply line was damaged when the helium trailer was moved with the disconnected line draped over the trailer access door.	Inspection of the area was not made prior to movement and no outside observer was present during movement.	Require an outside observer at all times when vehicles are being moved in test or storage areas.
94.	After transfer of helium, the helium trailer was driven away with the transfer line still connected to the trailer causing extensive damage to the line and facility manifold.	The driver did not run a check list prior to movement and no outside observer was present.	Require checklist to be run prior to moving trailer after the transfer. Require outside observer to be present when trailers are moved from or to storage areas.

SECTION IV

FUEL/PROPELLANT SYSTEMS

Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
1. During welding of electrical grounding straps below stage thrust chamber area, a fuel leak developed which leaked through open grating into immediate area of welding operation. Although no fire or explosion occurred, the potential for such was in existence at the time.	Lack of coordination of other work performed in the area, failure to properly inspect the area prior to welding operations, and poor work control procedures in permitting welding operations under or adjacent to fuel systems without depressurizing or detanking the system.	Perform a pre-operational hazard analysis of the stage and area prior to welding operations to ensure compatibility of other operations. Require fuel systems to be isolated near welding operations and the isolated section drained and depressurized prior to welding. If this is impossible, ensure that protective devices are provided for potential leaks.
2. During fuel tanking operations of a stage, the plastic transfer line from tanker to the stage, broke free causing spillage of 5000 gals. of JP-1.	Failure to properly coordinate maintenance work with fuel transfer operation. Maintenance of the GN_2 System caused loss of GN_2 facility pressure and malfunction of the fuel check valve. Contributing cause was the use of plastic tubing for transfer rather than metal flex hose.	Ensure that all other simultaneous operations are reviewed and an analysis made of potential interface problems prior to fuel transfer operation. Use only flexible metallic covered lines for fuel transfer operations in order to avoid damage from exterior sources or failure under fire exposure.
3. During a freon flushing test of a pad oxidizer Service Propulsion System (N_2O_4), the waste tanker ruptured damaging the tanker and tractor. Three workmen received minor injuries.	Overpressurization of the waste tanker due to a procedural error in that a non-pressure tanker was used when the procedure called for a 50 P.S.I. pressure tanker. Contributing causes were lack of supervisory monitoring of the operation, out of configuration connections to tanker, lack of maintenance plan for cleaning of waste tanker, and inadequate Q.C. support.	Require formal maintenance procedures for cleaning and care of propellant waste tanker. Require Q.C. verification of equipment used and interface connections on propellant flushing operation. Designate all propellant flushing operations as safety critical and require a member of supervision to be present.

Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
4. Following draining of N_2O_4 from a Spacecraft Reaction Control System, the drain drum exploded causing minor facility damage. Explosion resulted from mixture of fuel with contaminants in the drum.	No formal procedure was being followed and the drain drums had not been properly maintained, controlled or cleaned to prevent contamination. Contributory causes were inadequate marking and identification of lines, drain drums, and contents of drums.	All drain drums for oxidizers and fuels be positively marked and identified as to their contents. All fuel and oxidizer drain lines be color coded and connections be sized or keyed to prevent interconnection with the wrong drain drum. All drain drums be emptied after each drain operation, cleaned, sealed, and positively controlled.
5. While flushing and cleaning drain tanks, a large spill of N_2O_4 occurred. Workman assumed tank to be empty when in fact it contained 190 gals. of N_2O_4.	There was a formal procedure to be followed, but it was "back in the office." In violation of procedure, workman applied 30 - 40 psi GN_2 purge without prior flushing with demineralized water. Contributing cause was lack of quantity gauge on tank.	Provide quantity gauges on all drain tanks and require identification of contents at all times. Require Safety monitoring of all drain tank flushing and cleaning.
6. After a purging operation, a workman was exposed to toxic propellants while removing a pressure transducer from the fuel system of a flight vehicle. The system had 8 - 10 psig pressure and propellant particles were trapped in the system.	Failure to properly control bleed down of the pressure as the transducer was removed. Contributing causes were increase of the hazard level by performing additional work under a deviation to the procedure and failure to wear protective clothing throughout the operation.	Provide system pressure bleed down prior to removal of parts whenever possible. Wear full protective clothing at all times when opening propellant lines since particles of propellant are known to be trapped despite thorough purging. Perform safety analysis whenever hazard level is changed by work deviation.

	Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
7.	During prelaunch checkout of a booster, a fuel tank was partially collapsed due to inadvertent drainage of 7000 gals. of RP-1 fuel when a large Tygon tubing from the drain manifold ruptured. Fuel flowed over the service platform and created a potentially hazardous situation.	Temporary outage of the 6000 P.S.I. GN_2 which caused the pneumatically operated valve to revert to the open position, resulting in failure of the Tygon tubing. The partial tank collapse did not cause permanent damage and was reshaped by repressurizing. However, rapid drainage of the tank could have resulted in a major fire and tank collapse.	Ensure that all service platforms under stage tanks are kept clean and that no ignition source is in the area when boosters are tanked. Provide positive means for venting tanks in event of inadvertent draining.
8.	N_2O_4 vapors inadvertently released on a launch pad, exposing two men when the relief valve malfunctioned due to lack of facility pressure.	Failure to coordinate simultaneous operations. The GN_2 facility pressure had been shut off for repairs on the line and this caused the fuel vent valve to open. Contributing cause was failure to vent the fuel system through the TVD Unit which was not operational.	Ensure that a pre-operation hazard analysis is conducted prior to all fuel and propellant operations to ensure that simultaneous operations are compatible. Provide a redundant pressure source for fuel relief valves to preclude opening in event of loss of facility pressure.
9.	Oxidizer vapors were inadvertently dispersed on a launch pad during draining of fuel, preparatory to disconnection of Hypergolic propellant lines.	The oxidizer and fuel drain barrels had been placed in the wrong drain pits and the oxidizer was drained to the fuel drain barrel. Barrels were not color coded and identified as to fuel and oxidizer.	Ensure that all drain barrels and connecting drain lines are color coded and marked to prevent draining of oxidizer into fuel barrel and vice versa.
10.	A large release of N_2O_4 vapors inadvertently occurred on a launch pad when the facility pressure was turned off, allowing the vent valve to malfunction. Although there were no injuries, personnel could have been exposed.	The "K" bottles used to keep the valve closed were not adequately pressurized due to depletion of supply and lack of a redundant manual valve for closing vent in event of loss of facility pressure.	Provide a manual back-up valve for toxic fuels to keep vent closed in event of facility pressure loss.

SECTION IV

FUEL/PROPELLANT SYSTEMS (CONT.)

Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
11. During simultaneous venting and draining operations of Reaction Control Systems and Service Propulsion Systems, the oxidizer liquid separator barrel blew up in the toxic vapor disposal unit. The drain barrel was contaminated with 15 gals. of water and 5 gals. of neutralizer.	Conduct of simultaneous incompatible operations and lack of coordination by test conductors. Contributing cause was lack of adequate control over drain barrels to provide positive record of contents.	Provide sight gauges for all fuel drain barrels to show quantity contained. Perform a pre-operational hazard analysis to determine compatibility of simultaneous operations and ensure that test conductors are aware of other operations. Outlet lines of fuel drain barrel should be larger than inlet lines.
12. While replacing a faulty valve in a fuel system on a facility engine test stand being activated, two (2) maintenance personnel were injured by release of nitrogen tetroxide under pressure.	Maintenance crews were not adequately briefed as to hazards of the operation, exchange of information at shift change was not effected and supervision failed to ensure that pressure was released prior to the operation. Contributing causes were inadequate inspection and work control procedures.	Positive procedures should be established to ensure that pressure is relieved prior to maintenance work on pressure systems. Establish procedures for briefing of crews prior to each maintenance task on hazards of the operation and establish formal procedures to ensure exchange of information at shift change.
13. A test facility hydrogen vent line exploded during an inactive period (lunch) destroying 150 feet of the line. The vent flare stack was on at the time and ignition occurred either from the flare stack or from static charge.	Proper purge procedures had not been followed after removing and installing a vent valve in the system. Contributing causes were use of an unqualified vent valve, failure to follow formal installation procedures, and failure to close a drain valve in the vent system.	Require that only qualified components are installed in fuel systems. Perform installation and maintenance only in accordance with formal procedures. Prepare safety checklists for checkoff when performing maintenance or installation on fuel systems. Require purging of fuel systems after any installation or maintenance in which the system is opened.

SECTION IV

FUEL/PROPELLANT SYSTEMS (CONT.)

Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
14. During a test in an altitude chamber containing self-igniting fuels, the system was over-pressurized causing fuel spillage and a fire which caused extensive damage to the chamber and a four-week delay in schedule.	Formal written test procedures were not followed. The test engineer attempted to perform the tasks specified for two men and left the pressure valve open while he was performing another task. A design deficiency in the water deluge system contributed to the damage since the fire rendered the deluge system inoperative.	All tests with hazardous fuel should be designated as Safety Critical and should require safety approval prior to operations. A hazard analysis should be conducted of all fire extinquishing installations to ensure their functional capability will not be impaired by emergencies. Detailed test procedures should be prepared and followed for all hazardous tests.
15. While flushing a valve during Development Test, small amounts of fuel and oxidizer mixed, causing a flash fire.	Flushing without positive fuel and oxidizer shutoff. Contributing causes were lack of procedure review by management or QC prior to operation and use of an incompatible flushing agent.	Procedures used on cryogenic and monopropellant systems should be reviewed and approved by Quality Control and Safety prior to conduct of tests. A list of approved flushing agents and materials should be prepared for all fuel and propellant tests.
16. During development test of a booster, a 3000 psig relief valve actuated at normal line pressure releasing GH_2. The GH_2 combined with air resulting in an explosion which damaged the test facility.	Improper setting of relief valve and inadequate inspection resulting in setting relief valve to open at line pressure. Contributing cause was poor design of the venting system which was installed in a horizontal position causing inadequate venting and buildup of static electricity.	Test procedures should specify tolerances for relief valve settings. Vent stacks should be vertical to prevent development of static electricity. Quality Control should verify all pressure relief valve settings prior to tests of propellant systems.

Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
17. Fuel heat exchanger ruptured during a Mission Duty Cycle test, spilling fuel in the test chamber. Resulting fire caused major damage to the vehicle structure.	Overpressure of fuel system caused by design deficiency. Internal helium leak caused by manufacturing process deficiency and inadequate inspection. Contributing was the chemical reaction of fuel with heat exchanger material, caused by inadequate investigation of materials compatibility, and poor brazing control during manufacture caused by inadequate inspection. Also, failure to prepare contingency shutdown procedures and failure to perform a pre-operational Hazard Analysis.	Emergency procedures should be based upon a Failure Mode/Effects Analysis of vehicle, test rig, environment and interface factors. Shutdown procedures should cover possibility of propellant spillage, fire and explosion. Fuel system heat exchangers design should include a non-destructive method of determining voids in fin-to-case braze. Rigid inspection procedures should be established for periodic verification of structural/pressure integrity.
18. Fuel and oxidizer were inadvertently mixed during a Development Test causing extensive damage to the engine and test instrumentation.	Inadequate test procedure which permitted the operator to open a valve out of sequence. Contributing causes were lack of safety interlocks on valve hardware and operators not certified for the test procedure.	Test procedures should be verified for correct and detailed operating requirements. Personnel should be trained and certified for critical operations. Safety interlocks should be provided to prevent inadvertent hardware operations.
19. During changeout of engine actuators on a stage engine; one end of manual actuator gear housing became bound up on thrust structure and in attempting to free it by hand, it dropped approximately four inches striking a Hi-Press Fuel intake duct causing considerable damage. No personnel injury, however the duct required replacement.	No changeout procedures existed and proper safety precautions and hardware protection techniques were evidently not established. Contributing to this accident was the lack of installation tooling to support hardware until secured.	Operating procedures covering installation or removal of hardware on end items systems should assure that proper safety precautions are established, and that provisions are made for protection of hardware in proximity of change-out part.

Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
20. During oxidizer transfer from storage area to the contractor's ready and conditioning storage units, the transfer system was left full of oxidizer at completion of transfer per procedure. Some time later, a gross leak occurred in a pipe flange at the oxidizer storage area. No injury to personnel but the gasket had to be replaced.	The oxidizer caused eventual break-down of fluor-green gaskets, and pressure build-up could have occurred from thermal radiation of the trapped fluid in the transfer system. The transfer procedure was incorrect in allowing the transfer system to be left full.	Develop preventive maintenance procedures requiring scheduled replacement of gaskets subject to deterioration, to prevent creation of potential hazards.
21. During fuel topping operations at a static test facility, a fire occurred at the regulating valve when the valve malfunctioned and relieved the system. No damage, although a major fire and explosion could have occurred.	A malfunctioning of the relief valve. Contributing to the accident was failure to take preventive action for the valve was known to be leaking on previous operations. The test was continued with the leaking valve because there was no available replacement and the schedule was pressing. No temporary catch basin was provided for spill but a standby water hose in event of fire was provided.	Require discontinuance of tests with fuel and propellant systems, when any malfunctions of components is detected. If potential fuel spills are anticipated, provide temporary fuel spill catches and standby water hoses.
22. During disconnection of a line to an oxidizer transfer tank, residual N_2O_4 vapor escaped resulting in burns to both hands of technician. Technician was wearing an acid suit, hood, and goggles but did not have gloves.	Verification was not made that residual pressure in the line had been relieved. The line did not have a relief valve for bleeding off residual vapors. Contributing to personnel injury was failure to require personnel to wear full protective clothing.	Ensure that supervision is fully cognizant of potentially hazardous operating conditions and insist that personnel wear fully protective equipment for same. Provide means for detecting and bleeding-off residual hazardous vapors prior to maintenance operations.

SECTION IV

FUEL/PROPELLANT SYSTEMS (CONT.)

Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
23. During venting of N_2O_4 to atmosphere through a facility vent stack at an engine test stand, the immediate area and a nearby engine test area was enveloped with vapors during a temperature inversion when the wind direction suddenly changed. No personnel injuries, however a potentially hazardous situation existed briefly.	Procedural in that venting was accomplished under adverse weather conditions and adequate instrumentation was not available. Contributing was a design deficiency in the location of Delta T and wind indicators in the blockhouse rather than at the test stand.	Require burners to be installed in oxidizer vents and prohibit venting without burners. Require test stand weather instrumentation to be located near vents in order that accurate readings are available.
24. During drilling of a small hole in a 1" closed line of a liquid level oxidizer probe (normally sealed and containing a vacuum), N_2O_4 liquid struck the man in lower portion of the face. Technician was wearing a splash suit and protective gloves and goggles.	Supervision did not insist on personnel wearing proper equipment to safeguard personnel in a potentially hazardous situation. Contributing cause was pressurization of oxidizer probe due to change in temperature outside the tank, causing slight buildup of pressure in the line.	Require that personnel be briefed on the hazards for any job involving fuels and propellants prior to work performance. Require that supervision verify the suitability of protective clothing and equipment prior to each operation involving fuel and propellant systems. When breaking lines, require splash suits with full face cannister or a scape suit.
25. During an engine orifice installation and leak check on a test stand, an inadvertent firing occurred and vapors were released due to an inadvertent ball valve opening on the engine. Vapors caused expeditious evacuation of personnel resulting in an injury to a technician who jumped from the stand.	One sequential step in the procedure was not completed prior to initiating the next step. The "K" bottle GN_2 valve was opened prior to connecting a flex hose to a regulator, allowing the ball valve to open and fuel to flow through the ball valves into the engine diffuser orifices. Contributing cause was a leaking "K" bottle regulator.	Require positive verification of completion of critical sequential steps in the procedure prior to initiating the next step. Prohibit propellant system tests with any known component deficiency. Require pre-operations verification of of functional integrity of regulators.

Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
26. During fuel sampling operations on a facility engine test stand, an oxidizer sample "hoke" bottle inadvertently was issued and used for taking fuel samples in violation of established safety practices. No personnel injuries, however failure of the sampling device could have occurred as a result of excessive overpressure developed by exothermic reaction between the fuel and residual contamination in the cylinder.	Established safety practices were violated and positive control was not exercised to prevent use of oxidizer container in fuel sampling.	Ensure that inspection practices for all propellant vessels and containers are established. Require Quality Control verification of proper identification of proper type containers for all fuel/propellant sampling operations.
27. During open loop oxidizer transfer of N_2O_4 from facility storage to an engine test stand tank, liquid N_2O_4 spilled out the vent stack when the test stand tank overfilled.	Liquid level indicator was erratic during transfer, and no formal calibration schedule had been established for the instrument. Sight-glass indicators should have been used rather than liquid level indicator to provide positive measurement of fuel level.	Require installation of sight glass indicator rather than liquid level indicator.
28. A technician proceeded on his own initiative and hooked up stage purge lines without authorization. The hook-up was incorrect and resulted in cross-connection with RP-1 and LOX systems and caused contamination of the systems.	Personnel error in performing work without authorization. Contributing cause was inexperience of workers.	Ensure all personnel are properly trained, qualified and certified for duties.

Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
29. During UDMH fuel enrichment operation, a 55-gallon UDMH drum burst due to overpressurization. The drum was destroyed and contents of UDMH spilled causing contamination of the area.	Design deficiency in the system which allowed 120 psi facility pressure entrapment in the line and when the source valve was opened, the drum was over-pressurized by facility back pressure. No positive pressure gauge was provided in the facility line and no check valve.	Require positive identification of facility pressure through appropriate gauges prior to opening source valves on the fuel drums. Require drums to have a minimum pressure rating of 60 psig. Require facility lines to have check valves installed to prevent back pressure.
30. An explosion occurred approximately 5 minutes after personnel emptied 3 UDMH hoke bottles into a drain barrel and left the bottles attached to the barrel to drain. Hoke bottles and barrel were destroyed.	The exact cause was undetermined, however the probable cause was due to residual calcium hypochlorite oxides or static electricity in the barrel.	Require all drain barrels to be cleaned after each operation. Ground and bond drain barrels and hoke bottles. Require rust be removed from all fuel propellant containers and dump hoke bottles into waste pond.
31. During a stage fuel loading test, recirculation of fuel to obtain clean fuel samples using the emergency drain system created a negative pressure and resulted in collapse of the fuel emergency drain duct.	A special verification test conducted with appropriate instrumentation after the incident verified that a negative pressure could be created in the fuel transfer system using the approved pressure. A second test using a vacuum breaker and GN_2 purge, verified that positive pressure could be maintained on the fuel transfer system by a change in the test procedure.	When performing fuel recirculation operations, using the emergency drain system, perform a pre-operational hazard analysis to determine potential vacuum hazards. Ensure that test procedures are redlined, revised, and redistributed to all concerned after any engineering changes, modifications, or after significant test results are received. Provide positive pressure readouts in all critical pressure systems and provide relief vents in areas where vacuum can be encountered.

Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
32. During routine calibration activity for a facility test cell, inadvertent actuation of fuel and oxidizer valves caused fuel and oxidizer to be spilled onto test cell floor causing a fire. Three test cell personnel escaped injury, however, minor equipment damage occurred.	Hand and signal communications resulted in the inadvertent actuation of two valves. Contributing causes were lack of proper protective equipment in the test cell and lack of written procedures for operating the control console.	Ensure that a positive facility communication system is established in lieu of hand signals to prevent misunderstanding. Written procedures should be prepared for operation of the control console for all phases of the operation. Ensure that a control console is always properly manned with operators during testing. Ensure that test personnel exposed to a potentially hazardous environment utilize the proper protective equipment.
33. During fuel tests in a chemical laboratory of a test facility, men were exposed to aerozine vapors when the facility exhaust hoods malfunctioned and vapors were drawn into the room rather than out. Men were unaware of when the exhaust hood malfunctioned.	Mechanical malfunction of the exhaust hood. Contributing cause to hazard exposure was lack of a vapor detection unit and lack of visual or aural warnings of toxic vapors.	Require pre-operations inspection and verification of functional integrity of exhaust systems where fuels are being tested. Require all fuel test labs to be equipped with vapor detection units with both visual and aural warning devices. Provide redundant mechanical exhaust backup system where toxic fuels are tested.
34. During disassembly of a fuel system valve in a valve shop, workman was exposed to N_2O_4 vapors.	Residual fuels in the valve after decontamination. The valve had been subjected to complete decontamination process, but residual fuels still existed.	Mark and identify all components removed from fuel systems as hazardous. Ensure that all components are controlled and warning tags attached indicating hazards of potential residual fuel after cleaning.

Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
35. Several persons exposed to aerozine 50 fumes in a photo lab when aerozine 50 contaminants from the chemical lab venting system contaminated the air conditioning unit of the photo lab.	Inadequate precautions were taken to ensure that propellant vapors could not contaminate the area. Hazard analyses of the area was inadequate and inspection and detection for fuel contaminants inadequate.	Require all facilities and areas where propellants are used to be designated as hazardous areas. Require frequent inspections for potential contamination of adjacent buildings and require a pre-operations hazard analysis of fuel vent systems.
36. During preparation for vacuum drying operations on a flight configuration ball valve package, following cleaning operations, a puff of N_2O_4 fuel was released when GN_2 pressure and electrical power was applied to the valve. Personnel received minor nose and throat irritations, however a potentially hazardous situation existed.	A design deficiency in that the electrical harness used to operate the valve during cleaning operations allowed only one half of the valve to operate resulting in incomplete cleaning and N_2O_4 entrapment.	Electrical and indicator circuit boxes used for cleaning operations on toxic fuel hardware should incorporate provisions for visual indication of valve operation and positions.
37. During facility maintenance, ten men were exposed to water-diluted aerozine 50 when a spill occurred on an upper level.	A fuel line cap was removed without clearing personnel working below, and trapped fuel in the line caused a spill. Fuel was washed down and personnel were splashed with the fuel/water mixture.	Require that lower levels of test stand be cleared of personnel when disconnecting propellant lines.

Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
38. During simultaneous hydrogen venting operations of two H2 trailers adjacent to one another, hydrogen was ignited at one and then ignited hydrogen venting at the other. No personnel injury occurred and damage was minor.	Inadvertent ignition of the GH_2, either from static charge or impact from contaminants and the presence of O_2 in the vent line. Possible contributing cause to the ignition was an inadequately grounded vent flapper and contaminated or unclean fuel trailers. Also contributing to this incident was the simultaneous hydrogen venting from two adjacent trailers which permitted spread of the explosion.	Prohibit simultaneous venting of adjacent systems. Ensure that all hydrogen trailers are purged, cleaned, and warmed up at least once per year. Inspect all hydrogen vent lines periodically to ensure that all sections are properly grounded. Ensure that vent lines are purged prior to venting.
39. During a changeout of a pressure safety valve in a fuel storage tank line, a small pressure was released from the line followed by a small amount of liquid fuel which dripped on the fiberglass insulation of the line and ignited. No personnel injury. The insulation was removed and replaced.	Attributable to failure to exercise safety practices when opening fuel/propellant lines. Verification was not made of pressure release in the system prior to disconnection and bleed down of the line was not accomplished.	Require positive verification of purge and bleed down of lines prior to disconnection of any fuel or propellant system. Require Quality Control sign-off prior to initiation of maintenance. Provide protective devices to catch any residual fuel that may exist in the system.
40. A fire broke out on a test stand during fuel topping operations. ;Fire occurred near a fuel regulator valve causing minor damage.	Continuation of operations with a leaking regulator valve. Operations were continued because no replacement valve was available.	Require tests to be discontinued on fuel and propellant systems, when any leaking or malfunctioning component is detected.

SECTION IV

FUEL/PROPELLANT SYSTEMS (CONT.)

Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
41. During an R&D auto ignition test, a person was exposed to fuel spillage, when the test conductor vented the system without clearing the area.	The test conductor deviated from the procedure because he thought the area was clear.	Require positive area clearing practices prior to any fuel venting. Require strict adherence to written test procedures.
42. During a stage fuel fill operation, failure of a monitor light to indicate "fuel tank full" caused tank to be overfilled and fuel was pumped out through the vent valves. No injury to personnel.	A probe cable to the monitor lights was inadvertently left unconnected during installation. Contributing to cause was lack of Quality Control verification after work was performed and critical instrumentation was not checked out prior to test.	Ensure that "fuel tank full" light indicators are installed in such a manner that the light is "on" until the tank is filled.
43. During purge of a propellant loading system, a tapered connection installed to attach a flex hose was not properly tightened and when valve was opened, a workman was sprayed with trapped oxidizer.	The scape crew had failed to tighten the tapered back-to-back and there was no inspection verification prior to valve opening. Trapped oxidizer from a leaking valve had been previously drained from the line.	Require all connections in propellant systems to be verified by Q.C. prior to activation. Require strict adherence to procedures for valve sequencing and require Q.C. verification of valve positions at each sequential step.
44. During transfer of waste alcohol from storage to a transfer truck, a 3" reinforced rubber hose burst due to overpressurization causing a spill of 100 gals. and a potentially catastrophic fire. Ignition sources were in the area and adjacent to a vehicle assembly area.	The driver failed to open the valves in the right sequence causing overpressurization. Contributing was an inspection deficiency in that the hose had exceeded age life requirements and should have been replaced. Contributing to hazard potential was locating fuel storage near an assembly building and failure to provide adequate drainage for spills.	Require preparation of formal procedures for all fuel transfer operations. Ensure that personnel are qualified and certified for fuel transfer duties. Require hazard analysis to be made of all fuel storage areas to insure there are no ignition sources and that area is isolated from critical systems. Ensure drainage is provided for major spills and fire standby for transfer operations. Require age life standard for all transfer hoses.

Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
45. During manufacturing checkout of the fuel and propellant system in the high pressure test facility, the fuel and oxidizer orifices did not flow in accordance with specification, requiring complete disassembly and analysis of the system. This analysis revealed a plastic cover in the oxidizer line downstream of the orifice, reversal of the fuel and oxidizer orifices during installation and damaged lines, strainer and orifices.	Inadequate work control procedures during assembly, packaging, installation, and cleaning. The plastic cover was identified as a type used to seal line ends during cleaning or packaging. The oxidizer orifice had been installed on the fuel line and vice versa during assembly and the strainer, lines, and orifice had received minor damage during installation. Contributing cause to this incident was inadequate inspection of critical work and failure to exercise positive control over materials used in assembly and packaging of critical flight systems.	Require all materials used in sealing critical fuel lines to be of sufficient size to preclude inadvertent stowage in lines. Require detailed manufacturing work order for all assembly, packaging and cleaning operations on propellant lines. Require warning notes and inspection sign of points to be included in work orders. Size or key fuel and oxidizer connections to preclude inadvertent reversal of orifices. Require "one way" waste cans in packaging and assembly areas to preclude reuse of plastic materials. Require inspection accounting of plastic materials after each operation.
46. A thrust chamber purge was inadvertently applied to a stage without the LOX dome purge being "on" resulting in contamination of the LOX System and blowing off of engine exit covers.	An erroneous verification to the operator that the RP-1 simulator had been installed. Contributing cause was an engineering deficiency in not preparing an E.O. change requiring the installation of the simulator.	Require engineering review of test procedures and set up prior to propellant tests to ensure proper configuration of test system. Require Q.C. configuration verification prior to each test.
47. During routine training for Astronaut Egress teams performing simulated rescues in a hypergolic fire environment, a detonation occurred in the low point area of the burn pan. No injuries occurred but the burn pan was damaged.	Using a water curtain to separate hypergolic propellants which upon removal allowed oxidizer to surge into the burning fuel and cause detonation. Contributing causes were lack of personnel training and understanding of potential hazards, and lack of warning notes in simulation test procedure when using hypergolic propellants.	Ensure that potential hazards are identified and suitable warning notes included in the procedures for operations involving use of hypergolic fuels. Do not use water as a separator for fuel and oxidizers. Designate all operations involving hypergolic fuels as safety critical and require prior safety approval of plans and procedures.

FUEL/PROPELLANT SYSTEMS (CONT.)

Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
48. One fuel tank was collapsed and another was destroyed when an explosion occurred during transfer operations due to formation of an explosive mixture in the receiving tank.	The two tanks were not adequately inerted during the operation. Air entered the receiving tank forming an explosive mixture and the source tank was imploded by rapid evacuation after the explosion.	Require both receiving and source tanks to be blanketed with an inert gas during transfer operations.
49. A propellant system was damaged by an explosion when components of the oxidizer and fuel system were inadvertently exchanged during maintenance.	A design deficiency in the test setup since the oxidizer and fuel system were composed of identical parts. Contributing was lack of work controle procedures for requiring color coding and marking of components to prevent mis-installation after initial use.	Require a hazard analysis to be performed of propellant systems to determine parts that are interchangeable between oxidizer and fuel systems. Parts identified as interchangeable should be placed on a control list and color coded or otherwise identified to prevent wrong installation. Q.C. should be required to verify all components on the controlled list after installation.
50. An explosion occurred during a test when N_2O_4 and ethylene/glycol water solution were inadvertently mixed when a leak occurred in the ethylene/glycol system.	A design deficiency in the test installation in that incompatible systems were located in a manner which permitted inadvertant mixing.	Require specification for ethylene glycol system to contain caution and warning notes to avoid locations where contact can be made with propellants as a result of leaks, spills or overflows.
51. An open air explosion occurred on a test stand when explosive vapors accumulated in an engine compartment and ignited.	Failure to provide explosive mixture detectors in the test area.	Require vapor detectors to be installed in all confined areas of a test stand where vapors may accumulate from propellant systems.

Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
52. A fire and explosion occurred during transfer of propellant from a storage tank to a servicing unit due to build up of static charge in a plastic hose and ignition of the propellant.	Use of plastic hose for fuel transfer. The hose was not grounded and was non-conductive, resulting in numerous pin hole leaks from static discharge.	Require the use of only conductive hose for fuel transfer operations and ensure that all lines are grounded when rubber or plastic type hoses are used.
53. A propellant system exploded during a test when N_2O_4 was introduced to the system due to residual cleaning fluid in the system (Halogenated Carbon solvents)	Failure to properly purge the system after using cleaning solvents and failure to determine compatibility of solvents with N_2O_4.	Prohibit the use of halogenated carbon solvents in N_2O_4 systems and ensure that all systems are properly purged after use of cleaning solvents.
54. An explosion occurred in a test installation due to incompatibility of a dye penetrant used to check leaks in a weld seam.	Action had not been taken to determine the compatibility of dye penetrants used to inspect weld seams. There was residual LOX in the seam and the explosion occurred when the dye penetrant was used to check the weld. Contributing was inadequate cleaning or purging of LOX components.	Require all dye penetrants used in LOX systems to be verified for compatibility. Require thorough precision cleaning and purging of LOX components or systems prior to leak checks.
55. A test was terminated prematurely when a propellant tank standpipe came loose and fell to the bottom of the tank, requiring special operations to drain the tank.	The lock washers were not installed on the standpipe, allowing the standpipe to work free during down-loading. Contributing was inadequate inspection of tank installation and lack of Q.C. signoff.	Require Q.C. verification of all internal tank installations. Ensure that written work orders are employed and that required components are specified in the work order.

SECTION IV

FUEL/PROPELLANT SYSTEMS (CONT.)

Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
56. During a thermal oscillator test an inadvertent H_2 leak and fire occurred while dumping from 75% to 50%. Fire was extinguished with minor damage to valve and lines.	LH_2 was dumped through the Control Console rather than by passing the Console to the roof vent. Dumping through the console resulted in freezing of valves and resultant leaks Fire and damage was minimized by safety shutoff valves previously installed which permitted shutoff of the leak.	Use manual dump valves for LH_2 dumping and dump directly to the Vent system rather than through control consoles since leaks will be imposed as a result of cryo temperatures.
57. During spacecraft RCS fuel system electro-mechanical checks, a solution of alcohol (isopropyl) contaminated with fuel (less than 1%) was discharged into the face and eyes of an employee from a "taped-over" transducer port pressurized to approximately 25 psig. No personnel injuries were sustained.	Lack of communications between personnel or work teams as to the hardware configuration during simultaneous work operations. Calibration personnel had removed the transducer for calibration and taped-over the open port, without documentation of a "non-operational" configuration.	Ensure that the configuration of end-item hardware is documented at all times to alert personnel performing simultaneous work in hazardous conditions. Open ports in pressurized systems should be covered with threaded caps instead of tape to maintain cleanliness integrity.
58. Remnants of a cleaning pad and plastic container were found in the screen and bottom of LH_2 tank on a booster during routine inspection. Complete re-cleaning of system and a 2-day time loss incurred.	Inadequate work control procedures during installation and assembly, lack of adequate work inspection during installation and excessive pressure on test crews due to schedules.	Establish positive area control procedure during activation, installation, and assembly of test systems to prevent contamination of systems. Keep all lines capped when open and account for each piece of capping and taping material when system is connected.

Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
59. During preparation for static firing of a booster, a workman entered the annular space of the LH_2 tank to replace light bulbs. The tank was pressurized while he was in the tank, resulting in minor hearing injury.	Inadequate area Control procedures. The "buddy" system was being used but the "buddy" did not know his co-worker had entered the tank and no warning was given to the man inside when the tank pressurization was announced over the public address system.	Require positive headcount of stand personnel prior to pressure tests. Provide workmen inside enclosed areas with visual and aural devices of conditions requiring evacuation.
60. During a human factors analysis of a stage fuel system, a potential for cross-connecting the fuel test line flex hose and the LOX sensing flex hose was discovered. Corrective action prevented such an event, however the potential for a major explosion existed.	Lines had been designed in assemblies of flex lines of the same length and size which included both fuel and LOX lines. The lines were not color coded and were of the same length, permitting cross-connection.	Ensure that all adjacent, critical flex lines are properly coded, marked, or sized to preclude inadvertent cross connection of lines. Test procedures should require Quality Control verification of critical flex line connections.
61. An open-air hydrogen explosion occurred at a test facility storage area when a relief valve prematurely relieved causing extensive damage to the facility, lines, gauges and electrical systems.	An erroneous regulator setting caused by cumulative errors of valve operating tolerances ($\pm$ 3%) and pressure gauge readability tolerances, allowed relief at 2800 psig on a programmed 2900 psig test. Contributing cause was the use of a 4" x 6" relief valve which allowed the development of a high volume explosive mixture. The ignition source was apparently by static discharge from the vertical stack tip using a horizontal diffuser plate.	Limit GH_2 relief valves (3000 psi systems) to 25,000 maximum SCFM to limit buildup of explosive mixture. Require vent stack tips to discharge vertically without a horizontal diffuser plate. Vent all GH_2 systems to the main facility vent stack when possible.

SECTION IV

FUEL/PROPELLANT SYSTEM (CONT.)

Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
62. During preparations for removal of the mass propellant utilization probe from an LH_2 tank, a valve was inadvertently left open allowing a clear path for flow of He or GH_2 into the open tank. No damage or injuries resulted but a high hazard potential existed.	Failure to verify valve positions prior to initiation of work and tank entry. When gas was reported in the tank, the area was cleared and sniff checks were negative. Investigation revealed that the transfer shutoff valve, precooler fill valves, precooler vent hand valves, and the helium transfer hand valve were all open to purge the LH_2 transfer line.	Require a valve and purge checklist be instituted as part of a vehicle tank entry procedure and ensure by verification that all sources of gas have been shut off prior to tank entry.
63. During post-test inspection immediately following stage static firing, fuel was observed leaking from the heat shields around a booster engine. Source of leakage was traced to a calibration valve on the sensing line leading to a Fuel Differential Pressure Switch, located under a fuel tank. No damage to equipment or injury to personnel resulted but a potential fire hazard existed.	The gland nut, which retains the valve stem in the valve body, vibrated loose and fuel pressure forced the valve stem out of the valve body because the gland nut had not been safety wired. Inspection of work was inadequate and personnel were not properly trained.	Ensure that Quality Control verify safety requirements of all fasteners specified by procedure prior to delivery of stage to static test. Ensure that all personnel are properly trained, qualified, and certified for duties.
64. During servicing of the Oxidizer Supply System for a stage auxiliary propulsion system at a launch facility, two hoses, a vent and a recirculation hose, were cross-connected at the hand valve on the valve panel. The cross connection did not cause any equipment damage or personnel injury however significant delay of oxidizer loading resulted.	Personnel errors made during the installation and verification steps since the hoses were properly identified. The use of one find number and one part number led to the assumption that if the first line was correct, the second was also.	Require that identical hoses which may be cross-connected be designed with differently keyed connectors to prevent wrong installations.

SECTION V
LIFE SUPPORT SYSTEMS

	Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
1.	During repair/installation of a defective cold plate on a vehicle in manufacture, a screw driver used in removing an armored joint made nine tool marks on an adjoining cold plate and necessitated scrappage.	Lack of overall planning on the part of repair/installation personnel in that protective provisions, both tooling and procedural, were not adequate for safe removal/replacement of vehicle hardware in unaccessible areas. The armor joint removal tool normally used could not be used in the small work area.	Ensure that manufacturing planning and procedures include analysis of hardware configurations and locations. Quality control should verify usage of tool and procedures for repair operations on end-item hardware.
2.	During test of a life support system, one man was injured and the system damaged when an oxygen source valve caught on fire and melted. The oxygen source consisted of two six (6) cylinder K-bottle assemblies hooked into a common manifold at 2200 psi. The fire occurred when the valve was turned on to stablize the manifold pressure.	The fire apparently started in the valve seat which was made of penton (a polyether) which is an unsafe material for oxygen systems and had not been tested and approved for oxygen compatibility. Also, procedures for cleaning and inspecting of oxygen system components were not adequate. The system contained numerous contaminants consisting of aluminum chips, rust and organic materials. Additionally, there were no filters installed between the source and inlet valves and lines were of stainless steel with teflon parts.	Require all high pressure test installations and tests to be designated as safety critical and require design approval by safety or oxygen systems groups. Prohibit use of stainless steel and teflon material in high pressure oxygen systems wherever possible and specify usage of copper or copper alloy lines. Require flushing and inspection ports on oxygen system manifolds and remotely controlled shut-off valves for emergencies.

SECTION V
LIFE SUPPORT SYSTEMS

	Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
3.	During proof testing of a spacecraft O_2 control Module on an environemntal control system, a fire occurred which blew off a cap boss when an O_2 ring seal failed permitting a subsequent 1400 psig pressure surge.	The O_2 ring seals were being reused on subsequent tests in lieu of installing new seals. Also, Dri-Lube 822 was being used for thread lubrication which was not compatible with oxygen and thereby caused ignition when the pressure surge occurred.	Ensure that only materials proven to be compatible with oxygen and authorized for usage on an approved materials list, be used in oxygen systems. Prohibit usage of hydrocarbon or organic materials for thread lubrication in O_2 systems. Require installation of new pressure seals for each O_2 system test.
4.	During qualification testing of a spacecraft fuel cell power system, the test was prematurely terminated by an electrical failure caused by carbon deposits from cleaning fluid residuals left in the system.	The cleaning procedure being used was inadequate to ensure complete removal of all cleaning fluid residuals. Contributing was failure to establish by analysis and test, the compatibility of the cleaning agent (Trichloroethane PMC 9056) which has a propensity for carbon deposits in reaction to oxygen system electrodes.	Require analysis and test of cleaning fluids used in oxygen systems for compatibility with system materials. Prohibit use of high carbon cleaning agents such as Trichloroethane PMC9056 (PMC 9004 is a recommended alternate). Require preparation of detailed cleaning procedures for oxygen systems.
5.	During acceptance test of a spacecraft emergency oxygen system, the test was discontinued when an out-of-specification pressure condition occurred due to a damaged "O" ring seal. No hardware damage resulted; however, a leak occurred requiring replacement of the seal and test rerun.	Inadequate work control procedures during cleaning, handling and assembly of the O_2 system. The back-up ring of seal had been damaged prior to installation and the "O" ring was extruded into the damaged part causing the leak. The internal damage was not detected by visual inspection.	Require formal manufacturing procedures to control handling, cleaning and assembly of non-metallic seals and parts to prevent damage. Require re-inspection/verification of non-metallic parts acceptability for usage immediately prior to installation. Personnel involved in handling and assembly of seals and associated parts should be instructed on careful handling techniques.

SECTION V
LIFE SUPPORT SYSTEMS

	Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
6.	During an underwater leak test of a spacesuit excessive leakage occurred in one glove due to the reverse installation of a pressure seal. Under mission operational conditions this could have presented a critical crew hazard.	Maintenance procedures were not formally prepared. The seal was assembled backwards during maintenance disassembly and reassembly operations preceding the leak test. A contributing cause was the lack of QC verification of proper assembly of critical components.	Require detailed, formalized maintenance and assembly procedures be prepared and utilized in development of life support equipment. Require QC verification of proper assembly criteria. Where feasible, require identification of proper assembly direction on pressure seals or design seals such that reverse assembly is impossible.
7.	During a design verification test on a spacesuit the shoulder restraint cable failed resulting in test termination and necessitating refabrication of the cable.	Essential reference dimensions were not completely incorporated into design drawings and resulted in out-of-specification fabrication.	Ensure that design drawings and specifications be verified for accuracy, and inclusion of all essential dimensional information prior to release.
8.	During a pressure test using a biosattelite bleed and fill tool to pressurize an O_2 system vessel to 3500 psig and bleed down to 500 psig, a fire occurred in the fill line when bleed down was initiated, resulting in damage to the system and injury to one operator.	Inadequate cleaning procedures and specifications for O_2 components. The test article had received only standard cleaning at the manufacturer, and it was certified for use in O_2 systems; however, aluminum chips and rust were found in the system. Neoprene was used for the regulator diaphram, which was found unsafe for O_2 systems and there was no filter on the inlet side of the regulator. Ignition was apparently caused by impingement of contaminants against the walls of the lines.	Require procurement orders to specify approved cleaning requirements for O_2 systems components and hardware with QC certification/verification of cleaning operations prior to acceptance and installation. Require test setups using compressed gas service lines to incorporate protective shrouds and restraining devices. Oxygen farm supply systems should be inspected and cleaned of contaminants on an established schedule. Prohibit usage of organic materials, including teflon, in oxygen systems.

SECTION V
LIFE SUPPORT SYSTEMS

	Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
9.	During a closed loop test of a spacecraft water-glycol system for fuel cell cooling, the test operator inadvertently left the system heater on and overpressurized the system, resulting in bursting of a glass tube flow meter rated at 32 psia.	The test operating procedures did not specify continuous monitoring of system pressures and temperatures. A contributing cause was the lack of a relief device or critical temperature/pressure warning devices in the closed loop test setup.	Require pressure/temperature monitoring and recording at specified intervals during closed-loop pressure tests. Require relief and warning devices be incorporated for system protection when critical conditions are exceeded.
10.	During a post lunar flight-proof test of a spacesuit, which functioned properly during the mission, a water hose burst at 31.5 psig due to an improperly installed hose clamp. The improper installation could have created a critical hazard potential for crewmen and possible mission abort had failure occurred during the lunar mission.	The assembly drawing for the part did not adequately describe dimensional requirements for assembly resulting in the water hose being improperly installed, creating load stresses and eventual rupture. Inspection verification of assembly dimensional requirements also had not been accomplished.	Ensure that all design specifications and assembly drawings of life support systems require an engineering hazard analysis to identify essential assembly information and criteria. Require that all detailed dimensional requirements critical to life support systems pressure connections be verified by QC inspection following assembly/installation operations.
11.	During tests on a single fuel cell of a spacecraft life support system, the gaseous hydrogen heater was inadvertently left on, resulting in system temperature exceeding critical limits, test shutdown and cracking of the heater housing.	The system monitoring requirements were inadequate resulting in failure of the operator to continuously monitor system conditions. Contributing was the lack of an automatic temperature control and shutoff device to prevent the system from exceeding critical temperature limits.	Require all tests involving gaseous hydrogen be controlled and performed to detailed formal procedures which includes continuous monitoring and recording of critical data at specified intervals. Provide automatic shutoff of heater elements used in conjunction with gaseous hydrogen systems.

	Accident/Incident Description	Causes	Recommend Preventive/Corrective Action
12.	A mercury atmosphere was detected in a Spacesuit Test chamber following a spill, and resulted in contamination of a test vacuum chamber which had drawn mercury vapor from a "U" tube manometer.	Controls were not exercised to prevent exposure of "U" tube manometer to a vacuum source.	Prohibit use of instruments containing mercury wherever possible. Exercise strict control over instruments used and prohibit use of open end manometers near vacuum sources. Enclose and segregate mercury containers and processes. Perform periodic tests of areas for mercury contamination. Use electro-mechanical type gauges in lieu of mercury manometers.
13.	During a flush of a lunar vehicle water management system with a 10% chromic acid, a spill occurred due to two leaking quick disconnects causing minor contamination of the vehicle.	Pre-operational leak checks did not include quick disconnect matings. During mating, an "O" ring seal was left out of one QD and the other was not properly mated. Contributing was inadequate inspection verification.	Require pre-operational leak check of quick disconnects when toxic or corrosive fluids are involved. Require QC verification of all quick disconnect matings prior to and after mating.
14.	Spacesuits were found to be contaminated with mercury in storage in sealed plastic bags. All suits required complete analysis, disassembly and cleaning.	Adequate control procedures were not in effect to control instruments containing mercury. The source of contamination was a tube manometer used with a test vacuum chamber. The suit packs were in turn contaminated from the test chamber.	Prohibit the use of instruments containing mercury wherever possible. Establish rigid procedures for control and inspection of instruments before, during, and after use. Design instruments containing mercury in such a manner that open ends cannot be exposed to vacuum sources.

SECTION V
LIFE SUPPORT SYSTEMS

	Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
15.	During a proof pressure test of an oxygen panel, the low pressure side (210 psig) was inadvertently subjected to pressure from the high pressure side (1500 psig) when the high pressure shutoff on a common "T" connection was not closed.	Procedural error in failing to close the high pressure side of the "T" connection. Contributing was lack of adequate verification of test installation prior to tests and failure to include adequate warning notes in test procedures.	Require position of all valves to be verified prior to high pressure tests. Prohibit "T" connection of high and low pressure systems without check valves and relief devices to protect the low pressure system.
16.	During a space simulation test, an explosion occurred in the oxygen system of a test chamber causing system damage.	A design deficiency in that Delrin seals used in the ball valves were subject to impact ignition with oxygen. Subsequent impact tests confirmed this incompatibility.	Do not use Delrin in oxygen systems. Prohibit the use of Delrin in oxygen ball valves. Replace Delrin seals in oxygen systems with Teflon.
17.	During test of the Environmental Control System (ECS), problems were encountered and during subsequent troubleshooting, the heater switch was left on for 12 minutes. This caused melting of solder joints, leakage of water glycol, and system contamination.	During troubleshooting, the technician turned the switch on and inadvertently left it on when his attention was diverted. There were no warning notes in the procedure and the procedure was in error. Contributing cause was a connector that had been disconnected by the first shift which caused the secondary heater to activate.	Require warning notes to be placed in procedures where critical switch sequences are involved. Require all critical switches to be placarded with warning notes.
18.	The oxygen supply system of a vehicle environmental control system was contaminated with mercury during replacement of a solenoid valve. Mercury was discovered in the cold trap of the leak detector during subsequent leak checks. Incident required complete analysis and cleaning of entire system.	Lack of adequate procedures for the control of instruments containing mercury in the manufacturing and test facilities. Mercury was apparently introduced through a solenoid bypass valve which had been replaced in the system.	Prohibit usage of instruments containing mercury in or around flight vehicles. An exception is "blacklight" devices; however, when used, adequate padding and screening should be required. Where mercury containing instruments are required, exercise strict control over instruments and require inspection before and after each use to ensure no mercury loss. Provide protective devices with mercury instruments to catch any spillage.

SECTION VI

ORDNANCE SYSTEMS

	Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
1.	During a full steam test run at a static firing stand the shutter valve squib inadvertently fired when the Arm key was armed, causing the shutter valve to close. No damage resulted.	Procedural in that the squib valve was armed out of sequence permitting inadvertent firing.	Require strict adherence to procedures during tests involving ordnance devices. Require inspection verification of critical arming sequences to prevent human error.
2.	During preparation for test firing of a dual drogue disconnect utilizing a shaped charge, a stray pulse amplified by modified circuitry caused one of two squib initiators to be fired by the firing system, and subsequent electrical firing of the drogue disconnect. No personnel injury; however, the sound level was equivalent to a shotgun six feet away.	Following circuit modifications, an update of circuit and test set-up hazards analysis was not conducted. Contributing was an original design deficiency, in not providing a means of preventing premature firing.	Test procedures on ordnance devices should reflect the results of a comprehensive hazards analysis, including safety precautions and the proper use of safety devices. Test circuit design of ordnance devices should incorporate an external arm plug whenever possible.
3.	Stage damaged by inadvertent firing of ordnance device.	Explosive components were being received and used without historical data required to maintain accurate shelf life records.	Ensure that service and shelf life historical data are included with shipments of explosive components. Do not install items when an accurate shelf life record is not available.
4.	Vehicle hardware damaged by fire as a result of an explosion of hand grenades in the same car.	Hand grenades were not properly identified or properly packaged resulting in their being erroneously shipped with the flight hardware.	Maintain positive inspection and control over ordnance packaging to ensure that all items are properly packaged and marked as "explosives".
5.	During a training class an instructor was demonstrating a component of a destruct system when it exploded causing damage to equipment.	Human error in that the instructor connected the power to the wrong terminals causing inadvertent activation.	Require checklists to be used at all times when working with explosives. Color code or otherwise provide positive matching of circuits with terminals.

SECTION VI

ORDNANCE SYSTEMS (Cont.)

	Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
6.	During installation and checkout of an ordnance device, it was inadvertently fired causing damage to the system.	An unauthorized standard multimeter was used which provided sufficient energy to fire the device. The circuits to the device had not been disconnected prior to the check.	Establish a list of authorized equipment to be used in the checkout of ordnance devices. Ensure that all ordnance devices are disconnected prior to resistance checks.
7.	An ordnance device was inadvertently ignited due to static electricity generated from use of plastic covers.	A design deficiency in that the covers being used were non-conductive, allowing static charges to build-up.	Ensure that only conductive type plastic covers are used with vehicles having ordnance devices installed. Ensure that covers are adequately grounded at all times.
8.	An explosion occurred during checkout of an ordnance device when the device was inadvertently fired from voltage generated from test equipment.	The crew was not properly trained and unauthorized resistance-measuring equipment was being used which provided sufficient voltage to ignite the device.	Use only battery powered test equipment for checkout of ordnance devices and ensure that facility power is disconnected. Prohibit the use of facility powered test equipment.
9.	Equipment was damaged and personnel were injured when an explosion occurred during test of the ordnance devices.	Crews were not properly trained and certified. The test procedure was not adequate, and unauthorized test equipment was used which caused inadvertent firing of the ordnance device.	Require all ordnance test personnel to be formally qualified and certified for test duty. Establish a formal list of approved test equipment to be used for ordnance checkout.
10.	Equipment was damaged when an ordnance device was inadvertently ignited by static electric charge.	A design deficiency in that static eliminators were not installed in the system and the ground was not adequate. Contributing cause was procedural since crews were not wearing static-proof clothing and test procedures were not adequate.	Design all ordnance systems with static eliminators and ensure that all grounds have been verified as adequate. Require all test personnel performing ordnance tests to use static-proof (conductive) clothing and covers.

SECTION VI

ORDNANCE SYSTEMS (Cont.)

	Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
11.	During checkout of ordnance devices, the system was damaged when premature ignition of the device occurred due to stray voltage.	"Safe distance" requirements related to R.F. energy were not adhered to. Design deficiency was a contributing cause since shielding for the ordnance device was not adequate.	Require that RF distance standards are established for each test of ordnance devices and for all maintenance or installation activities. Ensure that RF energy checks are made prior to each test.
12.	During receiving inspection, vendor shorting caps were left on an ordnance device and it exploded during storage due to corrosion.	Inspection procedures were not adequate. Contributing cause was corrosion between the shorting cap and connector pins.	Use shorting caps of the same metal as the pins and with a positive locking device. Establish positive inspection cycles for corrosion during storage.
13.	Stage damaged when an ordnance device prematurely ignited during countdown.	Loose and uninsulated terminals and the use of black powder which served as a conductor causing premature ignition.	Ensure that all connectors and terminals for ordnance devices are fully insulated and are securely fastened.
14.	Stage damaged when squib was inadvertently detonated.	Inadvertent ignition of the squib from "stray voltage".	Ensure that an analysis is made of potential stray voltage sources prior to all tests with live ordnance devices.
15.	Stage damaged by premature firing of an ordnance device during checkout prior to launch.	A short circuit between the cable shielding and the inner wire, allowing 115 volts to be applied to the circuit, during electrical checkout of the circuits.	Use low voltage devices such as minature flash bulbs for checking out electrical circuits for ordnance devices.

SECTION VI

ORDNANCE SYSTEMS (CONT.)

	Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
16.	During maintenance on ordnance devices, the device was inadvertently activated by communication circuits and loose tools which provided a live circuit to ground.	Electrical current was available to the device through communication's circuit even though the operational circuits had been disconnected.	Ensure that protective devices are provided to prevent inadvertent shorting to communication's lines during ordnance maintenance or checkout. Require all loose hand tools to be stored in their containers when not in use during work with ordnance devices.

SECTION VII
PRESSURE SYSTEMS

	Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
1.	During GSE validation testing at a launch facility, a stage disconnect was not disengaged prior to pressurizing the LOX tank prepress line. This allowed He gas to bypass the energized (closed) He pressure solenoid valve and backflow into the positive pressure line causing overpressurizing of a pressure gage. The gage was damaged internally and was replaced.	The test procedure did not specify verification of disengagement of the stage disconnect prior to LOX prepress line pressurization.	Require QC inspection and verification of pressure systems valve positions and hardware configuration prior to pressurizing operations.
2.	During pressurization retest of a vehicle H_2 tank following replacement of a transducer, the tank was pressurized to 196 psig (49% of DB) with personnel still in the chamber. Serious injury to personnel was averted by quick action on the part of Control Room Console personnel, who stopped tank pressurization and vented the tank.	Complete closure of the pressure regulator by test personnel was not performed as required and an out-of-sequence step was conducted. There were no positioning or directional markings on the valve box to indicate the direction the screw adjustable pressure regulator should be turned to increase/decrease pressure.	QC inspection should be required to verify valve positions in high pressure test set-ups. Require all pressure control valves to be placarded to show direction for decrease or increase of pressure.
3.	During preparation for purging of a welding machine connected to a stage engine in manufacture, a flowmeter glass tube and protective glass cover ruptured when a 3000 psi helium supply line was opened. Incorrect connection to the flowmeter was made wherein the supply line was connected to the outlet low pressure side of flowmeter. No personnel injuries.	No calibration tag or marking appeared on the flowmeter, no marking existed to differentiate source or regulated pressure side and no hook-up/operational procedures and precautions existed. In addition, there was no pressure relief valve downstream from the regulator and no QC verification of the installation.	Ensure that high pressure regulating devices are controlled and verified through a formalized calibration and tagging program. Ensure that inlet or outlet ports are properly identified. Require that high pressure systems hook-ups and procedures be verified as specified, prior to system activation.

SECTION VII
PRESSURE SYSTEMS (Cont.)

	Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
4.	During proof pressure testing on a metal flex hose in vehicle manufacturing, excessive pressurization of the hose to burst pressure rather than proof pressure resulted in hose rupture at 4500 psig. No personnel injuries, however, schrapnel caused damage to facility lighting fixtures and a work-bench.	The lack of a formalized procedure for accomplishing hose tagging. The tag attached to the hose was essentially indiscernable for identification of operating/proof pressure. Contributing was lack of QC verification of test pressures prior to the test.	Require QC to verify working and test pressures by inspection of test procedures, part numbers, and part tagging information prior to activation of tests on high pressure components.
5.	During manufacturing replacement of a leaking test port in the umbilical area of a vehicle above an RCS quad, water glycal contamination was noted on the primary fuel tank and adjacent areas. Contamination was found to be due to a leaking connection between the umbilical hose and the umbilical panel. No vehicle damage, however, a thorough decontamination process was necessary.	Poor workmanship in installation of a relief device between the hose and umbilical panel. Also an inadequate design of the modification kit connections, receiving container, etc. wherein loosening of the connection was possible during decabling or quad removal and/or spillage from the receiving container.	Ensure that installation procedures for temporary modification kits incorporate protective provisions for end-item hardware from contaminating fluids and require QC verification of the installation.
6.	During calibration of a pressure gauge on a vehicle fuel panel, a technician connected 3000 psi facility GN_2 through a flex hose to a calibration panel "outlet" port instead of the "inlet" port which subjected a 100 psi gauge to full facility pressure and resulted in rupturing disc and gauge blow-out.	The calibration procedure did not specify a step-by-step sequence for test set-up and operation. The lack of positive identification of outlet and inlet ports on the calibration gauge panels and lack of QC verification.	Require that formalized test set-up and operational procedures be established for calibration/testing of high pressure components which includes precautionary warnings and verification by QC personnel. Non-interchangeable disconnects should be designed into equipment and facility pressure sources to prevent damaging end-item hardware.

SECTION VII
PRESSURE SYSTEMS (Cont.)

	Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
7.	During warmup of a large LH_2 sphere at a stage engine test facility, the annular space was overpressurized and perlite insulation was expelled through the evacuation nozzle and the burst diaphram. Air leaking into the vacuum annular space had apparently solidified and during tank warmup, the air again returned to a vapor state causing a pressure buildup. Two personnel received minor injury and the vessel sustained minor damage.	Lack of design considerations for monitoring/evaluating the tank conditions during warmup. Contributing was the failure to identify the potential hazards involved in making temporary repairs in the evacuation system. Leak points had been found and sealed with duct seal approximately six weeks prior to this accident.	Require that pressure vehicles be designed with check valve/pressure relief devices to provide annular space relief commensurate with burst pressure of insulation used. Vacuum/pressure/temp. monitoring devices should be provided for vessel and annulus areas to aid in evaluating tank conditions during tank operations.
8.	During conduct of pneumatic tests on a stage, an 8' flex line failed at 2000 psi and subsequent whipping damaged adjacent GN_2 hard lines and propelled fragments for 75ft.	Material failure of the flex hose. Contributing to the extensive damage that resulted was the lack of restraint of the flex hose.	Require all flex hoses to be restrained at connections and each six feet. Use hardlines in lieu of flex lines when practical.
9.	In preparation for an O_2 subsystem checkout test of a flight vehicle, an incorrect hookup of a flex line to a water line instead of an O_2 line resulted in rupture of the potable water tank and damage to the waste water tank and water panel when 250 psig GN_2 was applied to the H_2O system. No personnel injury, however both tanks required replacement and the water panel required repair.	The flex lines of the vehicle system were incorrectly tagged and no procedural instructions or verification methods were used prior to application of GN_2 pressure.	Require formalized procedures for end-item hardware hookups for pressure system checkouts and documented verification by QC inspection.

SECTION VII
PRESSURE SYSTEMS (Cont.)

	Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
10.	A flex hose from the pressure checkout and calibration panel of a booster manufacturing tower was used to activate a stage LOX prevalve to a closed position so that installation of a LOX low pressure duct could be performed. Second shift manufacturing personnel unaware of the flex hose installation, pressurized the panel to 100 psi for engine purge operations on another vehicle and consequently the prevalve actuator was subjected to approximately twice its operating pressure.	The flex hose was installed without formal documentation or procedural authorization and failure to pass information from one shift to another as to the panel configuration.	Require that all unusual temporary hookups are performed by authorized procedures, and ensure that work shift operational logs include information pertinent to temporary conditions and configurations.
11.	During leak check tests on a LOX valve, following maintenance and cleaning, laboratory pressure of approximately 2000 psi was applied through an unsecured flex line causing it to snap and in so doing, forcing the valve in an unmounted vise off the table. No personnel injuries.	The flex hose used was of excessive length and was not restrained. The test article was not properly secured prior to test, test procedures were not adequate and there was no inspection verification of the test setup.	Ensure that all high pressure hardware components and flex lines are securely mounted and constrained during testing. All flex hoses used in high pressure applications should be verified for proper length prior to tests.
12.	During receiving inspection test, convoluted flexible ducts of the "Y" GOX collector were damaged when a test fixture was improperly installed. No injury to personnel.	There were no warning notes in the test procedures and there was no QC verification of the installation. The work was performed by inspection personnel rather than regular maintenance personnel and the clamps provided to restrain the duct were not used. Checklists for critical installations were not being used.	Quality assurance be required to verify proper installation of test fixtures prior to initiation of pressure tests. Ensure that design of test setups provide positive means to preclude occurrence of human error. Incorporate caution note in test procedure to preclude improper installation of test equipment.

	Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
13.	During a burst test of a titanium helium sphere for a booster using super critical water at 8000 psi as a pressurant and with the sphere immersed in a tank of boiling water, the facility was damaged when the sphere burst and parts were spread over a wide area.	The high energy release was due to the titanium acting as a spring when the tank burst, causing it to want to jump out of the tank. The movement of the tank was increased by the rapid volumetric expansion occurring when the water turned to steam. The sphere was not properly restrained in the tank cradle and no protective screen provided to prevent flying pieces.	Require protective screen for all destruct tests to prevent flying metal. Ensure that all destruct test articles are adequately restrained to restrict movement.
14.	During oxidation/humidity qualification tests on spacecraft components in a test tank, (ambient pressure of 7 psia, 95 ± .5% O_2, 95 ± 5% humidity and 90°F), an explosion occurred within the tank when polyurethane foam used under the water pan swelled, causing a suspended electrical immersion heater to touch the bottom of the tank. Sufficient localized heating was generated to ignite the O_2 saturated foam. No personnel injuries, however laboratory equipment sustained damage and test units required replacement.	A design deficiency in the test setup for conducting tests in high O_2 and humidity environments. The highly saturable polyurethane foam was not compatible with the test environment due to its proximity with the heater and susceptibility to ignition from heat generated by the heater. Also, there was lack of adequate safety analysis and QC verification prior to tests.	Require that teflon be used in lieu polyurethane/neoprene for electrical insulation in high humidity; O_2 rich environments. Ensure that electrical/pressure test setups be verified against a formalized test procedure by QC inspection prior to test initiation.
15.	GN_2 and O_2 facility lines at a test facility were inadvertantly cross connected on the roof at a junction header when the lines were disconnected to correct a leak. Test setups were contaminated and systems/lines required purging.	Procedural due to the lack of detailed maintenance/repair procedures and checklists. Also, there was an installation design deficiency due to lack of identification of lines, i.e., no color coding or connector sizing, and lack of adequate work inspection	Require QC inspection and verification of all facility line interface connections with test setups. Locate, size or key facility lines to prevent cross connections, and color code facility pressure lines in conjunction with established standards. Ensure that formal work procedures are utilized for all maintenance/repair operations involving facility lines interfacing with test installations.

SECTION VII
PRESSURE SYSTEMS (Cont.)

	Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
16.	During hydrostatic proof pressure test of pressure bottle for a spacecraft emergency oxygen system (13,250 psig), the bottle weld failed at 9000 psig due to a faulty weld. The pressure vessel was destroyed, however no personnel injuries were sustained.	Inadequate manufacturing control and inspection procedures. The weld seam failed due to incomplete fusion of the bottle half, apparently caused by either improper centering of the high intensity fusion welding on the seam or being directed at an incorrect angle. X-ray inspection of the welded seam did not reveal the discrepancy.	Require detailed manufacturing procedures and processes for performing high intensity fusion welding of pressure vessels. Require that development test programs establish the best possible techniques for detection of welding flaws and ensure that inspection methods are capable of verifying the location of faulty welds through non-destructive testing.
17.	After completing transfer of a CO_2/O_2 gas mixture from a "K" bottle to a small hoke-type cylinder, attempted closure of the cylinder needle valve resulted in the valve failing and the valve stem blew-out at a pressure of 1350 psig. No personnel injuries, however a potentially hazardous condition existed.	Material failure of the valve stem and the apparent lack of an established procedure for periodic hydrostatic tests or other controlled maintenance as evidenced by no inspection or test record stamp on the cylinder.	Establish a rigid inspection/maintenance program on reusable high pressure cylinders which includes disassembly and verification of the integrity of the internal parts of hand valves. Cylinder maintenance records should be inspected and verified prior to each usage.
18.	During fit check of facility GN_2 line, a workman inadvertently activated the valve with his foot and a man was injured by the release of 5000 psi blast.	Lack of any positive safety device on the valve to prevent inadvertent opening.	Ensure that all high pressure hand valves located in areas where exposed to personnel traffic, are provided with positive locks and/or shields to prevent inadvertent operation.
19.	During a system test involving pressurizing the hydraulic system, the hydraulic return line was not connected, and the flight vehicle was sprayed with hydraulic fluid.	Failure to verify system configuration prior to the test. QC support was inadequate and test procedures not followed.	Require that QC verify configuration of test setups prior to any pressure tests.
20.	During dewpoint sampling operation of a GN_2 facility system, the pressure gauge burst injuring 6 men.	The use of a 50 psi pressure gauge with a 2000 psi pressure source, and manually operated pressure regulation from the source. Contributing cause was an inadequate test setup and inadequate procedures for sampling.	Designate all pressure tests or operations as Safety Critical and require Safety Analysis and approval prior to operation. Require the use of automatic self-relieving pressure regulators or burst discs on all pressure gauges.

	Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
21.	Pressure relief valve on a spacecraft water glycol system ruptured, during checkout ejecting a solid piece of metal against the test chamber wall.	Improper maintenance procedures in that the relief valve had been modified to replace the pressure regulating spring with a piece of solid bar stock.	Prohibit the modification of pressure relief valves without prior engineering and safety approval. Require QC to verify prior to pressure tests that automatic features of pressure regulator are functional.
22.	During preparation for altitude chamber pump down for performing spacecraft purge and leak checks, the valves were misconfigured and the spacecraft was purged with 100% O_2 instead of 65% O_2 and 35% N_2 gas. Although no accident occurred, the 100% O_2 environment constitutes a potential fire hazard.	The pressure relief valve settings and panel configuration were specified in the test procedure but not adhered to. Contributing cause was the lack of required inspection verification of valve settings and panel configuration.	Quality Assurance be required to verify air pressure relief valve settings prior to pressure tests involving oxygen enriched environments. On all tests involving oxygen enriched environments, gas samples should be taken prior to entering the chamber or spacecraft.
23.	During a leak check of a stage instrument container, the container was inadvertently overpressurized and damaged a bulkhead and fuel tank.	A dust cap had been left over the instrument container quick disconnect for the pressure sensor, causing erroneous pressure readings. Contributing causes were malfunctioning of the pressure relief valve, procedural error in using a 900 psi pressure source on a low pressure system, and by-passing of the malfunctioning regulator in violation of test procedures.	Prohibit continuance of any pressure test when any malfunction of pressure regulators is noted. Prohibit the use of high pressure sources on low pressure systems. Require positive inspection verification for all pressure connections. Provide redundant pressure sensors in all pressure vessels when practical.
24.	During a pressure test, the relief valve failed to operate and the pressure vessel ruptured at a weld bead, seriously injuring a person.	Failure of the pressure relief valve and pressure sensors to function properly. Contributing cause was lack of positive procedure for precluding personnel from areas where high pressure tests were being conducted.	Areas where high pressure tests are being conducted should be designated as hazardous areas and all personnel be excluded from the area while tests are in progress. Relief devices should be verified for proper functioning prior to initiation of pressure tests.

SECTION VII
PRESSURE SYSTEMS (Cont.)

Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
25. A 3000 psig GN_2 facility supply line was attached to a gaseous flow meter to determine if this supply would furnish sufficient volume of gas for a subsequent test. Flowmeter exploded when GN_2 supply hand valve was half opened. Three men were injured and flowmeter destroyed.	No action was taken to verify the adequacy of the exit line from the flowmeter prior to the operation, and the explosion resulted from inadequacy of the 1/2" line to handle the pressure, thus causing a pressure build-up in the flowmeter. Contributing cause was high-pressure flex lines were not properly chained or sand-bagged and no pressure gauge downstream from the facility GN_2 supply. Also, four people were in vicinity of test setup.	Ensure that all flex pressure lines are restrained at all connections and at frequent intervals as required by facility standards. Personnel safe distances should be established for all pressure tests. When connecting unqualified parts to high pressure sources, a relief valve should be provided downstream of the source.
26. During decontamination, following a static firing test, a GN_2 flex line rated at 300 psig, ruptured and whiplashed, injuring three workers. The line was overpressurized to 2750 psig., because it had been inadvertently connected to a high pressure system.	There was not adequate exchange of information at shift change. Test procedures were not adequate and were not followed. Control procedures and inspection practices were inadequate which permitted connection of 300 psig line to high pressure system.	Color code all pressure fittings and "key" connections to prevent inadvertent cross connection of high and low systems. Designate all pressure operations as Safety Critical and require a hazard analysis to be performed prior to each operation. Ensure that detailed test procedures are prepared and followed. Require all test crews to be briefed prior to each hazardous operation and at each shift change.

	Accident/Incident Description	Causes	Recommended Preventive/Correction Action
27.	During pressurization of stage fuel tanks prior to static firing, the LH_2 fill ducting line was overpressurized causing damage to the line, upstream bellows and the LOX tank. Overpressurization occurred when a worker inadvertently closed the fill and drain line allowing purge gas to enter the LH_2 system.	Simultaneous pressurizing of both LOX and fuel systems was being performed in violation of procedures. Contributing causes were failure to transfer information at shift change and inadequate design of the pressure relief valve to handle maximum pressures.	Establish positive procedures for exchange of information at shift change. Schedule critical pressure tests so that work can be completed by the same crew when practical. Ensure that all pressure relief valves are adequate for potential maximum pressures. Provide interlock valve in fuel systems to prevent inadvertent pressurizing by the purge gas when fill drain valve is closed.
28.	Booster stage burst during fuel tank leak check. The tank was overpressurized because pressure sensors were disconnected by first shift and the second shift was not notified. Stage was destroyed. Seven men injured and minor damage to the facility.	Failure to transfer information from one shift to another and lack of overall integrated test procedures for the test. Contributing causes were use of unqualified vent valves, overstressing of the stage during test installation and inadequate training of test conductor and crew.	Ensure that individual test procedures are integrated through a total system sequential test procedure. Establish positive procedures for transfer of information at shift changes. Prohibit use of unqualified components in a test setup. Establish procedures for the formal certification of all test crew members.
29.	During pre-launch checkout, a helium tank pressurization line ruptured when it was overpressurized due to failure of the LH_2 purge valve. Concurrent tests were in progress and failure of the valve permitted pressure from the LH_2 system to enter the GN_2 system. The helium line, LOX dome and electrical harness were damaged.	Failure to properly integrate concurrent test procedures, failure to coordinate concurrent pressure tests, and failure to follow test procedures. Contributing causes were malfunctioning of the purge valve after rework and failure to requalify the valve after rework.	Require that all concurrent pressure tests be analyzed for potential interaction and test crews be briefed on concurrent activities. Require all reworked components to be requalified prior to operational tests. Ensure that individual test procedures are sequentially integrated for major system checkout. Require prior engineering approval for any deviation from test procedures.

SECTION VII
PRESSURE SYSTEMS (Cont.)

	Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
30.	Vehicle was destroyed in a test during pre-operational pressure test when a titanium pressure tank exploded. The titanium tank had been weakened by the use of methanol, which is incompatible as the pressurant with titanium.	A design deficiency in permitting the use of methanol with titanium. A complete investigation of the compatibility of methanol with titanium had not been conducted and a list of compatible materials for use with titanium had not been established.	Preclude the use of methanol (methyl and alcohol) with titanium. Assure that a formal list of compatible materials have been prepared for use with titanium components. Require formal materials compatibility studies to be performed for all new structural alloys or materials used in fuel and propellant systems.
31.	Stage glycol radiator was ruptured during tests, due to inadvertent connection of 2200 psi GN_2 system with the 120 - 130 psi glycol system. The radiator ruptured at 1900 psi.	A design deficiency in the test set-up which provided adjacent incompatible pressure systems with the same connection fittings. Contributing causes were lack of color coding of line, inadequate test procedures and inadequate inspection procedures. Training and briefing of crewmen was also inadequate.	Insure that design of test setups provide positive means for precluding inadvertent inter-connection of high and low pressure systems. Provide different size connections or key connections so they cannot be inter-connected. Color code all pressure lines on both sides of all connections and identify the function of the line. Designate all pressure tests as safety critical and brief all crew members prior to the test.
32.	During preparation for a reliability test on a GOX duct assembly of a booster stage, a six inch "hot" line ruptured under pressure of 3200 psig at 610 degree F. and damaged adjacent piping. Uneven heating of the pipe caused it to overstress locally. The system was being pressurized with gaseous nitrogen.	A design deficiency in the test setup. The heating element on the line permitted uneven heating and caused hot spots which weakened the line. The instrumentation provided "average" thermocouples readings and did not provide local temperature of hot spots. Unauthorized substitutions were utilized and thermocouples were of a different size. Contributing causes were inadequate procedures for control of parts purchases and inadequate work control procedures.	Establish work control procedures to assure use of only authorized parts and test equipment. Require a formal engineering specification to be prepared for each test installation. Conduct a pre-operational hazard analysis prior to each test.

	Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
33.	One person was injured when a pressure gauge burst during calibration. Line was pressurized from a 1600 psig bottle and had an 18 psig relief valve.	Inadequate calibration procedures and inadequate inspection which permitted an 18 psi valve to be used with a 1600 psi pressure source. Contributing causes were inadequate test procedures and lack of pre-test hazard analysis. Relief valve was not adequate to vent fuel pressure and personnel were not certified for test operations.	Prohibit inter-connecting high pressure lines with low pressure components. Identify all pressure tests as safety critical and perform a pre-test hazard analysis. Establish a formal program for certifying test and maintenance personnel for their assigned duties prior to participation in hazardous operations.
34.	During development tests, a GH_2 test tank was overpressurized and ruptured, resulting in destruction of the tank dome and fatal injury to two personnel.	Pressure relief valves were set too high. Contributing cause was failure to depressurize tank while working on it, and failure of the test conductor to be aware of activities in his scope of responsibility. Procedures for personnel safe distances during pressure tests were not followed.	Designate all pressure tests as safety critical and require QC verification of safety relief pressures prior to the operation. Prepare procedures for personnel safe distances during all pressure tests. Prohibit the conduct of maintenance on pressure tanks and vessels when under pressure.
35.	A facility helium actuator valve rated at 500 psi was used in a 3000 psi system. It failed during a facility test and caused an explosion which destroyed the valve.	Inadequate planning and inspection procedure that permitted a high pressure system to use a low pressure valve. Contributing causes were lack of inspection during the system installation, no list of equipment approved for high pressure use, and no relief device to prevent overloading the valve.	All pressure systems should have an established list of approved components. Inspection and Quality Control procedures should verify that only approved parts are installed. All valves should be provided with relief devices to prevent overloading.

	Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
36.	While removing cap from facility pressurized water supply stub-up interface, maintenance worker was fatally injured when cap blew off.	Lack of procedural direction and instructions for relieving trapped gas in the water system or verification of absence of pressure build up. Contributing causes were lack of personnel training and certification wherein precautionary and awareness factors applicable to pressure systems are stressed and the absence of a pressure relief vent on the water systems.	Procedural instructions should contain caution and warnings for hazardous operations, require verification of absence of pressure buildup in liquid-water systems prior to opening or disconnection of any closed system component. Water systems should provide a means of venting to relieve gas pressure buildup and interface connections should be coded and labeled HAZARDOUS.
37.	During stage tanking securing operations, a fire occurred in an engine compartment GN_2 purge unit on the stage test stand. The fire damaged the unit. No injury to personnel.	The loss of cooling provided to the heater chamber as a result of a chain coming off a sprocket wheel which supplies cooling to the heater. Contributing cause was lack of temperature sensors for automatic cut-off of heater when loss of cooling occurs.	Provide temperature sensors for automatic cut-off when loss of cooling occurs. Chain design installation should incorporate an idler gear to prevent chain slippage.
38.	During second shift, unscheduled venting of stage LH_2 tank occurred, creating a hazardous condition for personnel and creating a potential explosion/fire.	After previous venting operation of the LH_2 tank, the flex hose from the "K" bottle was left connected to the LH_2 vent valve control valve. Seepage through the regulator probably occurred and the regulator control or "K" bottle control valve may have been inadvertently opened.	Require QC verification of test setups prior to and after each test. Require verification of disconnect of He "K" bottles from LH_2 vent control valve when not in use.

	Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
39.	During replacement/installation of an air compressor stage cylinder in a high pressure facility system, using an overhead hoist and chain rigging, the stage tilted and uncontrollably swung while making a rigging change. Two personnel received minor injuries and minor damage to the compressor hardware.	Personnel were not certified in rigging or material handling and no safety procedures existed for operating hoists or handling material in this area. Contributing cause to this accident was that the supervisor allowed and directed the activity without ensuring that personnel were adequately trained.	Ensure that personnel performing hazardous rigging and handling operations are certified and operating procedures are required for handling and change out of high pressure system hardware.
40.	While performing a leak check of a GSE setup during a prelaunch systems checkout on a spacecraft emergency O_2 pressure system, a wrong flex line was disconnected and capped, allowing the O_2 pressure system to be inadvertently pressurized to 50% above the design burst level. No damage resulted but it constituted a potential accident.	Failure to follow test procedures which required the O_2 emergency system to be isolated from the GSE setup during leak checks of the GSE equipment. Contributing cause was inadequate Quality Control/supervision and surveillance during critical prelaunch checks.	Recurrence of such incidents could be prevented by ensuring that test procedures require QC verification of critical valve and switch positions before going to the next sequential step. Ensure that all lines are positively identified prior to disconnection.
41.	During pressurization of a stage O_2 system, it was inadvertently overpressurized to 570 psig when the specified pressure was 350 psig. No damage occurred but potential damage to system was effected.	Deviation from normal procedures to save time. The GSE regulator was increased to 750 psig to save time and when pressure reached 350 psi, the regulator was not reset until the pressure reached 570 psig.	Establish positive control procedures over pressure source regulators and require strict adherence to procedures on pressure tests.
42.	During fuel cell pressurization of a flight vehicle the O_2 system was overpressurized to 25% above design burst, when a new "K" bottle pressure source was added. Although no damage occurred, the system could have been damaged.	Failure to close regulator valve. The regulator valve on the "K" bottle source had been opened as the supply was depleted. When the new "K" bottle was added, the regulator valve was not reclosed, allowing a maximum of 2200 psig to be applied to a 350 psig system.	Establish positive control procedures for "K" bottle regulators. Require use of checklist when replacing "K" bottles.

SECTION VII
PRESSURE SYSTEMS (Cont.)

	Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
43.	The actuator of a pneumatically operated valve disintegrated into several pieces during initiation of a leak test. A technician had connected a high pressure hose to a wrong valve fitting and the valve was subsequently subjected to 600 psig, when the operating pressure was only 120 psig. No personnel or hardware damage.	Failure to connect the pressure hose in the manner prescribed in the test procedure. Contributing cause was the failure of supervision/inspection to verify compliance with test procedure and the limited experience and familiarity of test personnel with the component and procedure.	Formal training programs to certify operating personnel of high pressure systems should be formally established. Verification of test setups should be required in test procedures.
44.	A threaded tailpiece of a valve in a facility high pressure compressed air system failed while system was pressurized to 4900 psig. The valve had been replaced only two hours prior to accident. No personnel or equipment damage.	Torqueing requirements for the tailpiece were not provided in installation procedures and were apparently exceeded. Contributing to this accident is the marginal safety factor of thread fittings in the tailpiece which was aluminum bronze QQ-C-465 (alloy 642). Analysis following the accident determined that these thread fittings should not be used at pressures exceeding 1750 psig.	Ensure that torqueing valves for all high pressure components installation are established, specified and complied with in operating procedures. ASME rules for threaded parts permit a safety factor of 4 on yield, and should be verified by design analysis.
45.	During sampling tests on a facility LH_2 dock transfer system, the system was pressurized to 15 psig when an expansion joint ruptured. Technicians proceeded with the pressure cycle with the main valve closed instead of in open position as required. Minor damage to LH_2 transfer system.	The sampling was performed without checking the main valve which was closed and should have been open. Contributing factors were that personnel performing system repair had closed the main valve without tagging a critical valve.	All critical valves should be tagged when repair operations are in progress on pressure systems. All personnel performing work on pressure systems should be briefed on previous or concurrent work on the system.

	Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
46.	During start of repairs to the high pressure industrial water system, located on stage test stand, personnel used wrong valve sequencing and trapped water in a section of the line. When pressure was applied, the trapped water moved downstream as a hammer head and fractured the casing of a 30" gate valve.	The procedure for valve sequencing was not followed. Contributing cause was a design deficiency in the system in that adequate drains were not provided at the various gate valves.	System engineering should exercise tight control over this type of operation and also brief personnel in the proper sequencing of valves before draining system. Install bleed valves at gate valve locations to insure that vacuum pockets are not established between the valves.
47.	In preparation for gas sampling of a GN_2 facility system used for stage fuel tank pressurization, a blind flange blew from an auxillary pressurization duct caused by gas leakage past a valve in a "closed" position. Four persons were knocked off their feet and three received minor injury.	A hazards analysis had apparently not been performed to identify the absence of a pressure relief mechanism, a positive pressure display device or that the shut off valves required higher than normal torque to seat.	Require all pressure tests to be designated as safety critical and require a preoperational hazard analysis. Ensure that pressure relief devices are provided in pressure systems.
48.	During maintenance operations on a fuel tank auxiliary pressurization duct, located on a stage test stand, capped end of duct was blown off by overpressurization.	Apparently, 1500 psig leaked past the seat of an inlet hand valve and a " "normally open" solenoid valve on the service panel thus pressurizing the duct. A contributing cause was lack of a means for verifying whether pressure exists on the duct prior to work on pressure systems.	Positive verification should be made so that no pressure exists on a system prior to starting work on any pressure system. In addition, a pressure gauge and tap should be provided to ducts where this cannot be determined accurately otherwise.
49.	GN_2, GHe and GH_2 systems damaged on a test stand when the GHe relief valve relieved inadvertently causing whipping of the vent line riser and breaking of the line.	A material deficiency in that either the relief valve malfunctioned or the pressure control valves were leaking.	Perform periodic inspections of relief valves and pressure control valves for possible malfunction or leakage.

SECTION VII
PRESSURE SYSTEMS (Cont.)

	Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
50.	During preparation for a stage engine LOX dome flush procedure, the high pressure GN_2 facility valve was opened to pressurize the tank with regulated 500 psig and simultaneously regulated 500 psig GN_2 was introduced as back-pressure on a spring loaded vent valve on the tank. The vent valve blew out when the regulator supplying back-pressure stabilized at 2100 psig instead of 500 psig. No personnel injuries, however the vent valve was destroyed.	A hazards analysis of the facility installation and flush procedure was not performed prior to release and approval for use, which would have detected the need for relief capability in the system. Contributing was the failure of facility inspection to detect the absence of relief capability as specified in construction/installation drawings.	A facility hazards analysis should be performed in conjunction with initial design review of major facility installations. A checklist of critical hazards should be provided to inspection to assure installation verification of relief capability components in high pressure systems, and proper settings of regulators.
51.	During pneumatic test of a purge line on a test stand, a valve rated at 1000 psi, was over-pressurized and blew up.	The test was being run without a written test procedure, without formal approval of safety and a valve rated at 1000 psi had been installed in a 5500 psi system.	High pressure tests should be conducted only in accordance with a written test procedure. All components installed in high pressure systems should be approved by engineering and safety.
52.	During test checkout, three workmen were injured and equipment damaged when an improperly installed bleed valve in a helium manifold blew out at 3500 psi.	Inadequate procedures, inspection and work control. A valve with non-standard threads had been installed in the system and the threads were weakened by "forcing" during installation.	Ensure that work authorizations are approved by engineering for installations on high pressure systems and that QC verify part numbers and AN codes for all parts installed.
53.	During leak check of a facility high pressure air system, a control valve failed at 3200 psig and caused a relief valve to vent, injuring five men.	Material failure of a seal in the control valve. Contributing cause was failure to establish personnel safe distance for high pressure tests.	Establish personnel safe distances for all high pressure tests.

	Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
54.	During pressure application to a static load test fixture, the thermocouple seal failed in the pressure supply line. The thermocouple was ejected, and RJ-1 was directed into a ceiling fan, where it was atomized and spread over the test fixture and test room area. No property damage occurred.	A hardware design deficiency in that a lava type seal was specified which does not provide adequate assurance against blowout (failure).	Stainless steel thermocouple seals should be specified for use in test setups using RJ-1 hydraulic fluid, since the stainless steel seals are superior to lava seals for insurance against blowouts.
55.	During proof pressure test of check valve, GN_2 at 4800 psi was admitted through inlet port while the outlet port was capped. After removal of valve from chamber, overpressurization caused valve to rupture.	Trapped GN_2 between valve seat and capped outlet port. Difference in temperature of valve when in test chamber and room temperature caused gas to expand and explode.	Provide hand valve to ensure that pressure can be released while the test item is still enclosed in the chamber.
56.	During a stage functional flow test, a rope securing a 6" metallic flex line broke resulting in directing water on the stage engine. This caused an overhead ladder to become dislodged and it came to rest on the engine resulting in a broken stud and damage to preloaded gimbal joint. No injury to personnel.	The flex house was not properly restrained. Contributing cause was improper storage of overhead equipment or elimination of such storage in a hazardous area.	Ensure that restraining methods and materials are specifically designed by engineering and that all restraining installations are verified by QC. Require a pre-operation inspection of test areas prior to each static firing to ensure no loose equipment is stored in the area.
57.	During bench check and repair of a valve, the technician inadvertently disassembled a pressurized valve, instead of a defective, unpressurized valve and was injured by a piece of "O" ring.	Not using a checklist to determine total pressure shutdown. Contributing was lack of adequate identification of the function of lines and valves and inadequate panel schematics.	Ensure that all pressure bench check panels have all lines and components labeled as to function. Prepare checklists for "pressure up" and "pressure down" sequences.

SECTION VII
PRESSURE SYSTEMS (Cont.)

	Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
58.	During a test of a fuel prevalve, a technician on the control console misinterpreted instructions and applied 2000 psig pressure to a 750 psig system. No injuries.	Design deficiency in the test set up. The control console was located in the test cell under high noise level conditions. Contributing was lack of pre-operational hazard analysis for safe working distances.	Establish safe working distances for all pressure tests and keep all personnel out of the test cell during tests. Locate critical control situations out of high noise areas.
59.	During a bench check of pressure gauge, the pressure gauge was inadvertently overpressurized and burst.	Inadequate marking and identification of the pressure rating. It had two markings 3 -15 psi, and 0 - 10,000 psig meaning it must have a transducer with the higher pressure. The 3 - 15 psi was overlooked and 5000 psi source was applied.	Ensure that all pressure gauges are properly identified as to maximum direct pressure allowable.
60.	During decontamination purge, the tie down bolts on the dynamic cart failed, allowing cart to swivel,damaging the system.	Inadequate design and installation of tie downs.	Require inspection verification of adequacy of all tie downs in high pressure test facilities.
61.	During repair of a pump in a pneumatic/cryogenic test lab, a pressure line blew out when a workman loosened a nut, resulting in equipment damage and injury of one man.	The facility repairmen were not familiar with the system and were being briefed "on the job" by test personnel. Contributing cause was poor design of test setup in that pressure shutoff valves were not provided in the subsystems. Also preplanning and briefing of crews were inadequate.	Designate all pressure/cryogenic test facilities as hazardous areas and require pre-briefing of all personnel performing work in the area. Require QC verification that pressure has been relieved prior to initiating maintenance work on pressure systems. Provide pressure shutoff valves for all pressure subsystems.

	Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
62.	During production functional testing of pressure transducers, using a pressure transducer test bench, a pressure gauge exploded due to over-pressurization, inflicting minor damage to the test bench and moderately serious lacerations to the technician.	The technician failed to turn off a high pressure source to a low pressure gauge. Contributing causes were distraction, noise, and confusion at time of accident brought about by photographing the test operation while the testing was in process. Also, the externally connected gauge bypassed the inherent safety features of the test station.	Ensure that temporary hookups have the concurrence of system safety and that when work-approved agreements are obtained that the hazards are properly flagged in the test procedure. Operators involved with pressure type test equipment should be certified. Ensure that temporary hookups do not by-pass the inherent safety features of a test station.
63.	During a leak and functional check of a pressurization unit and a 1500 lb. GN_2 system on a test stand, a rupture occurred in a .035 wall thickness stainless steel tubing between shut-off valve to GN_2 supply and flex line to pressurization unit. This resulted in temporary loss of hearing to a technician due to explosion of failed part and damage to the line.	Procedural in that the tubing used was .035 wall thickness when specified thickness was .049. Also, the tubing was hydrostatically tested to 300 psig rather than 2250 psig and QC had erroneously accepted the installation.	Provide hookups which will permit only one system (i.e., GN_2 or He) to be in operation at one time. QC to verify and "buy-off" that specified materials and test procedures are used per drawing. Provide a relief valve where two systems use a common line or component and set at the lower of the two operating system pressures.
64.	During test operations on an engine test stand, oxidizer vapors in engine lines under higher pressure than a GN_2 test cart pushed oxidizer vapors into the test cart and were released by relief valve when valves were inadvertently placed in the open position rather than the closed position, permitting oxidizer pressure to be applied to the GN_2 system.	Design deficiency in that no positive indicating technique was used to show valve positions. Contributing factor was failure to determine and verify exact position of the valves prior to start of test.	Require all valves to be positively identified at the valve position and the controller position as to "off" or "on". Require positive verification of valve position by QC at each sequential step in the procedure. When high and low pressure systems are interconnected, ensure a relief valve is installed to relieve at the lower pressure limit.

SECTION VII
PRESSURE SYSTEMS (Cont.)

	Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
65.	During removal of a transducer from an air frame on an engine test stand, oxidizer vapors under pressure were released when the component was loosened. The transducer subsequently blew out, releasing additional vapors and exposing one person. No injuries resulted.	A hazards analysis and briefing of potential hazards was not accomplished prior to the removal. No action was taken to verify pressure relief and there was no pressure relief device in the system.	Ensure that all pressurized lines are provided when a means for venting residual toxic vapors and pressure prior to opening. Require briefing of crews prior to opening any propellant line.
66.	During setup for acceptance tests on a helium checkout unit test tool, modifications were made to accommodate a lower facility supply pressure than was required, resulting in two high pressure fittings of different sizes being mated. Failure of fittings occurred at 4800 psi with minor hardware damage, however a more hazardous situation could have resulted at higher pressures.	Shop operating standards for assembling high pressure systems were nonexistent. Contributing was the lack of inspection to verify modifications from normally used techniques.	Ensure that standard operating and shop practices are provided for repetitive setups, and require QC/safety inspections prior to test activation.
67.	During a verification run on a test stand altitude simulation system, an explosion occurred in the 24" steam bypass line, causing major damage to the system.	Accumulation of fuel residues and flammable substances in the line over several months of operation. Contributing was inadequate inspection procedures for the system and lack of drain devices for draining low points of the steam bypass line after firing. Propellants used were LOX and alcohol.	Install drains in exhaust lines for draining of residuals after each cooling. Require flush of exhaust lines after each operation. Require relief valves in all isolated sections of exhaust lines.
68.	During vacuum breaking of an altitude chamber after a test, two airconditioning ducts (24" and 30") were collapsed when turned on before ambient pressure was reached.	The test procedure was not followed due to a hurried operation. The chamber pressure was only 8psia when collapse occurred.	Require strict adherence to written test procedures during all pressure operations.

	Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
69.	During leak checks of high pressure helium lines (3000 psi), two swage-lock fittings pulled out and damaged lines and helium bottles.	Failure to properly torque the fittings due to a restricted and cramped work area.	Require specific instructions to be followed in torquing swage fittings to ensure that a "set" is obtained. When possible, have fittings assembled first in the lab to get a proper set. Stainless steel swage fittings require high torque valves for a proper set.
70.	During conduct of leak checks of a flash point material testing chamber, the chamber was inadvertently overpressurized with GH_2 and the glass port in the door burst, causing minor damage to the chamber, minor damage to the facility, and minor injury of one man.	Design deficiencies in the test chamber and installation. The pressure source was 150 psig and the chamber working pressure was 16.5 psia. There was no pressure regulator on the source and no pressure relief valve on the chamber. The pressure gauge was installed between two chambers with shutoff valves to each, thus allowing erroneous pressure readings under dynamic pressure conditions. Contributing was failure to follow formal procedure in the leak check and failure to close the gauge valve to the second chamber. The chamber had not been proof checked.	Require dual pressure regulators on all pressure sources to pressure chambers and pressure relief devices on all pressure chambers. Prohibit installation of cutoff valves between pressure chamber and gauges. Require proof test of chambers to 1.5 times working pressure. Require all pressure tests and operations to be performed in accordance with written procedures with QC verification of critical steps.

SECTION VII
PRESSURE SYSTEMS (Cont.)

	Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
71.	During test of a pressure regulator on a booster pneumatic console, the facility was damaged when a burst disc ruptured and overturned the test fixture.	A leaking source valve in the GN_2 facility source which allowed over-pressurizing of the system and rupture of the burst disc. Contributing causes were inadequate restraint (tie down) of the test fixture, allowing it to be upset, and lack of a pressure relief device up-stream of the burst disc.	Require all pressure installations to be adequately restrained and tied down to prevent upset in event of a pressure failure. Require pressure relief valves upstream of all burst discs.
72.	Installation of a wrong quick disconnect flex hose resulted in stopping of the test and recycling. During recycle, a test engineer inadvertently activated the wrong fill line valve resulting in venting through the open flex hose causing damage from whipping action.	Flex hoses were not color coded and marked to preclude wrong installation and were not restrained at the connectors. Contributing cause was failure to follow test procedures and checklists allowing inadvertent activation of wrong valve. Also, there were no lockout or guard devices on the switches to prevent inadvertent activation.	Restrain all flex hoses at connections and at each six foot intervals. Color code and identify flex hose as to functional suitability, design operating pressure, and design burst pressure. Install positive locking devices or guards on all critical switches.
73.	During pneumatic test of stage propellant tanks, a 2250 psig gaseous nitrogen flex hose failure occurred, although operating pressure was only 2000 psig at time of failure. No injury to personnel.	The test set-up design called for hard lines but flex hose was used to facilitate hook-up. Contributing causes were no evidence of proof pressure test of flex hose prior to use, and responsibility for proof testing not clearly established.	Review test set-ups to eliminate high pressure flex lines where possible. Provide relief vlave and/or rupture disc to prevent overpressurization. Ensure that pressure systems operating manuals require verification of proof test requirements before installation of pressure lines.

	Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
74.	A 30 psig test panel was overpressurized at the 168 ft. level of the umbilical tower, resulting in destruction of the panel and injury to four men.	The test installation was not properly configured and personnel were not adequately trained or briefed. There were no pressure relief provisions and no method of controlling inlet pressure.	Require external regulators with an output guage on all pressure tests and ensure that all test setups include pressure relief devices. Perform a pre-hazard analyses on all pressure tests and pre-briefing of test crew on potential hazards.
75.	During pressurization of a Helium pressure module on a flight vehicle, a high pressure line (3500 psig) was inadvertently connected to the low pressure (350 psig) side of the regulator resulting in overpressurization and damage to the system.	Failure to include caution and warning notes in the test procedure, failure to color code pressure lines, and failure to require inspection verification. Contributing was a design deficiency in not sizing or keying connections to prevent cross connection.	Require test procedures for pressure tests to include caution and warning notes to verify connections. Design all test installations so that inadvertent cross connections of high and low pressure lines cannot be made. Require all pressure lines to be color coded on both sides of mating connections.
76.	During purging operation, a facility nitrogen heater overheated and ruptured damaging the heater and lines. The thermocouple and controller failed to function and the relief valve did not relieve.	There was no formal procedure for nitrogen heater operations. Contributing was change in thermocouple and controller installation in deviation from original design. Also a design deficiency in not providing a bleed valve to allow gas flow during sampling.	Require formal engineering work order for all changes to facility pressure or electrical systems interfacing with flight systems. Require formal procedures for operation of facility support systems for test of flight systems. Install bleed valves to permit gas flow during sampling operations.

SECTION VII
PRESSURE SYSTEMS (Cont.)

	Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
77.	During test checkout of a stage, the area around the instrumentation unit of the environmental control system was inadvertently sprayed with water/methanol, requiring removal and check-out of equipment.	Procedures permitted an alternate routing and hook-up during the change from open loop cooling to closed loop cooling. This alternate was used and was incorrect, causing the incident. Contributing was inadequate training and briefing of personnel.	Require a pre-test hazard analysis and pre-operational briefing of personnel. Require engineering verification of all alternate routing or hook-ups of pressure system, prior to operation.
78.	During checkout of a check valve under cryogenic temperatures in a test cell, an explosion occurred injuring one person and causing minor damage to equipment. System was being pressurized to 3000 psi and explosion occurred at 2900 psi.	The operator failed to shut off the power and close the solenoid valves after a previous run, as required by the test procedure. Contributing causes were a leaking hand valve, lack of a pressure relief device in the test set-up and failure to provide operator with the latest revision to the test procedure.	Ensure that the latest revision to test procedures are available and verified by Quality Control to pressure tests. Provide pressure relief devices on all pressure tests. Establish personnel safe distances for all pressure tests.
79.	A mechanic removed a burst disc from the LH_2 pressurization line at the top of a stage LH_2 tank dome while an automatic checkout test was in progress. The program opened the vehicle repress control valve causing pneumatics to pressurize the pre-pressure flex line which was not secured at that time. The flex line whipped out of a technician's hand, striking the LH_2 non-propulsive vent duct making an indentation, and struck the technician's foot.	Lack of communications. The propulsion engineer, had previously observed the need to remove the burst disc to accomplish flow through the system, and a revision to procedures was prepared and approved by test programs. However, the test conductor was not informed, nor was he aware that the workman was removing the burst disc.	Ensure that checkout operating policies and procedures require vehicle changes or procedures changes are to be confirmed and signed-off by the test conductors. Ensure that all participants in critical tests are pre-briefed as to simultaneous operations and system changes.

	Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
80.	During charging of a facility helium storage tank from a trailer, a section of the trailer manifold and flexible hose ruptured when backflow from the facility tank caused the pump discharge pressure to be exceeded.	A design deficiency of the trailer system in that the flexible hose was found to be underrated by a factor of 4, and a weld flaw was found in the manifold. Contributing was the use of an under-rated relief valve on the upstream side of the trailer helium pumps.	Only properly certified hoses, hydrotested at 1.5 times operating pressure should be used in any application requiring flexible hoses. Hard plumbing should be used wherever possible. X-ray inspection of critical welds should be required for all pressure systems.
81.	During conduct of a water purge operation in a test preparation laboratory, the flowmeter burst when the flowmeter drain valves were opened resulting in severe damage to the flowmeter cabinet.	Failure to use the proper procedure. The technician used the procedure for freon purge rather than for water purge. Contributing was failure of Quality Control to verify position of the valves and failure of the flowmeter burst disc to function.	Require positive verification that the correct procedure is being used prior to pressure tests. Require Quality Control verification of all sequential valve settings. Designate all pressure tests as safety critical and require a pre-operational briefing.
82.	During a pressure test, a flowmeter ruptured when a dust cap was not removed from the exhaust port prior to the test. One man received minor injuries.	Failure to coordinate activities from one shift to another. The dust cap had been installed by a previous shift and the next shift was not aware of it. Contributing causes were failure to provide a pressure relief device in the test set up and procedural error in not requiring personnel safe distance during the test.	Ensure that pressure tests are designated as safety critical and that personnel are required to be briefed by the previous shift at shift changes. Require pressure relief devices in all pressure test set-ups. Establish personnel safe distances for all pressure tests and designate same in test procedures.

SECTION VII
PRESSURE SYSTEMS (Cont.)

	Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
83.	During leak and functional checkout of an engine at a test facility, a throat plug assembly which was left in an "unlocked" position, blew out through the engine throat and was found approximately 40' away. No personnel injuries or hardware damage; however accident potential was high.	The facility test procedures had not been updated to reflect revisions previously made in the manufacturer's test procedures which required that the ball lock pin remain installed in the throat plug assembly during the entire leak check procedure.	Ensure that positive procedures are established to update test procedures as changes are made in design and manufacturing. Special precautions should be taken where test procedures subject to revisions are generated and controlled at a location removed from the test facility. Require Quality Control verification of the test procedure prior to initiation of operations.
84.	During evacuation of the oxidizer and fuel tanks of the RCS system on a flight vehicle, the tanks were imploded when vacuum was inadvertently applied to the tanks.	The test engineer deviated from the test procedure due to misunderstanding the intent of the operation and hooked the facility vacuum to both the manifold and the tanks rather than the manifold alone.	Require strict adherence to test procedure sequential steps at all times. Require Quality Control verification of all pressure quick disconnect matings prior to each test.
85.	During checkout, a low pressure free standing frame with pressure rating of 0-300 psig and 0-1000 psig were inadvertantly left in the pressure circuit and pressurized to 3200 psig destroying one panel and damaging gauges, test cell wall, and test cell door. Three persons in the test cell received minor injuries.	Failure to update test procedures, failure to include essential change information in the specification, elimination of mandatory customer inspection points, "redlining" of test procedures in violation of procedures and using a trainee as a test conductor. Safety procedures were violated in having personnel in the test cell during pressure tests.	Establish strict control over all test variances or engineering changes to ensure that all related software has been properly updated. Prohibit "on the spot" changing of test procedures by engineering "redlining" without other approval and Quality Control verification.

	Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
86.	During maintenance changeout of air filters in a facility air compressor, the filter housing under partial pressure parted at the sealing joint, knocking one person to the floor and inflicting minor injuries.	A design deficiency of the filter system wherein no mechanism existed to provide visual means of actual pressurized conditions.	Require that all pressure systems incorporate a means of isolating specific segments, depressurizing bleed-down devices and pressure gauges up-stream of filters or other frequently changed hardware to provide means for relieving and indicating internal pressures.
87.	During operational testing, over-pressurization ruptured a pressure switch, when a high pressure line was inadvertently connected to a low pressure line.	A design deficiency in that the high and low pressure lines were the same size and color and had the same connectors. They had not been color coded and connections sized to prevent cross connection.	Ensure that high and low pressure lines of similar size and shape and in close proximity to one another are color-coded and sized or keyed to eliminate cross-connection. Whenever possible, high pressure lines should be routed in such a manner that they cannot be cross connected with low pressure lines.
88.	During propellant purging operations at a test site, using water through glass flowmeters, a flowmeter burst at 50 psi causing damage to the system.	Hammer effect of trapped gasses forcing a head of water when the tank return valve was opened. Contributing was a valve sequencing deficiency in the procedure and inadequate training of crews.	Fill fluid lines with liquid at reduced pressures prior to operating pressures. Verify functional integrity of relief valves prior to each operation. Perform periodic proof tests of burst discs. Require verification of valve sequences at each step in test procedure.

	Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
89.	During loading of a stage for static firing, a test was held due to a helium leak in the pressurizations system. To permit investigation, the chamber was brought to ambient using GN_2. When 2 workmen entered a personnel opening in the upper level, they were overcome by GN_2. A wind at the time was forcing GN_2 from the lower level out the top level opening.	The test conductor had deviated from normal purging procedures after GN_2 use. The break to ambient was not performed because the ambient air valve had been sealed off because of a leak. The ventilating fans were not used for fear of overtemping the tanks. No vapor detection units were used to check area before entry and no oxygen masks were used.	Require strict adherence to procedures during all propellant loading operations. Require vapor detection tests prior to personnel entry into potentially inert areas. When deviations from test procedures are required during propellant loading for repairs, require safety approval prior to personnel entry into the area.
90.	During a test run in a flight vehicle test chamber, a flex pressure line rated at 3000 psi burst at 1000 psi due to damage previously inflicted by welding operations.	Inadequate work control procedures and inadequate inspection. The welder had damaged the hose while welding adjacent structures and had not reported it. Inspection or supervision had not inspected the area after the welding operation.	Require formal test engineering work authorization for any welding operation near flight equipment. Require QC sign off after welding and require a member of test engineering to be present when welding operations are conducted.
91.	During checkout of stage engines for static firing, the propellant tanks were inadvertently overpressurized when a helium regulator malfunctioned, resulting in a schedule delay but no damage or injuries.	Malfunction of the helium regulator. Contributing cause was a design deficiency in the facility vent system in that a vent was not provided to permit venting to ambient under emergency conditions. Valve was contaminated as a result of previous rework on the system and the valve had not been functionally checked after rework.	Require positive verification of functional integrity of relief valves in propellant systems, prior to each test. Require emergency vent provisions for venting to ambient under emergency situations. Require functional recheck of relief valves after any system rework.

	Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
92.	During manufacturing test run of flight propulsion hardware, a primary burst disc in the He tank ruptured prematurely (1625 psig). The disc was rated at 1881 psig. Subsequent damage to the storage tank could not be determined until the tank was removed and inspected. Damage was noted on the disc mounting flange.	This failure occurred as a result of moisture entrapped in the system during storage. Components upstream of the disc were weakened by the moisture and contracted the disc, rupturing it. Additionally, material used in the system was susceptible to corrosion. Contributing cause was procedural. Components were stored without desicants, and the system was inadequately purged and dried prior to pressurizing.	Ensure that design specification for critical components of flight systems include essential cautions and warnings for corrosion prevention during storage. Require QC verification of packaging for storage of critical flight hardware. Require tagging of all parts critical to moisture corrosion prior to packaging.
93.	During manufacturing, flight vehicle systems were closed down during lunch break. Upon return to work, technician found excessive pressure build-up in the Heat Transfer System of the ECS. The heat dissipating fluid (alcohol) had been stored at temperatures of $-20^{\circ}C$. When introduced into the system and allowed to settle to ambient conditions, expansion of the alcohol created the over-pressure condition. In this situation, exhaustive investigation of the system was necessary to confirm that no damage had been suffered by the ECS as a result of exceeding allowable pressure limits.	Lack of pressure relief devices incorporated within a cloosed loop system. Contributing factors to the incident include the lack of pressure indicators in the system, and procedural instruction to maintain continuous monitoring of the system until thermal stabilization had been accomplished.	Design of any closed loop circuit of flight critical hardware should include appropriate pressure monitoring and relief components. Require warning notes to be included in design specs. Procedural instructions should provide "warnings" and "caution" notations to alert personnel to sensitive operations. Establish procedures requiring constant monitoring of active systems of a flight vehicle.

	Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
94.	During manufacturing checkout of a helium boost unit, the flex hose between the boost unit and storage tank failed at 3500 psi. Hose was rated at 3000 psi and system was rated at 6000 psi maximum. Restraining devices on line failed allowing line to whip until pressure shut down.	Inadequate work control and inspection. The flex hose was not properly identified as to pressure rating and the restraining devices on the flex hose was not properly installed allowing it to break free. The hose was four years old, had not been proof tested since manufacture and was 15' too long. The restraining device was not fastened to a primary structure.	Require all flex hoses to be stamped for date of manufacture or identified as to the proof pressure and date, rated operating pressure, and functional rating. Require Q.C. verification of flex hose rating prior to installation and require Q.C. sign off for all restraining devices for flex hoses. Prohibit use of excess length flex hoses.
95.	A supply of liquid CO_2 used in development testing was stored in an aircraft type, wire wound "K" bottle (oxygen bottle) in the laboratory. The bottle exploded causing damage to a metal storage cabinet, and producing a 3 foot hole in an interior wall of the laboratory. No one was in the area at the time of the accident, and therefore, no injuries were sustained.	Storage of liquid CO_2 in a flight type O_2 bottle, rather than in a hydrostrated CO_2 cylinder. Additionally, the storage container was overdue by 12 months for proof testing. A contributing factor in this incident was the lack of adequate procedures detailing storage requirements for materials.	An inspection program should be implemented to monitor the various types of containers being used to store materials. Design criteria should be provided to detail the specific storage requirements for materials. Inspection schedules should be developed and monitored to ensure storage containers are periodically examined to ensure structural integrity and compatibility with materials being stored.

	Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
96.	While calibrating a pressure gage on GSE, a 0-500 psi standard was inadvertently substituted for a 0-5000 psi reference unit. During the testing sequence, the 0-500 psi reference exploded and particles were thrown into the operator's eye.	Inadequate identification of the pressure rating of the unit and personnel error due to schedule pressure on the operator.	Establish procedures to tag calibration units for more accurate identification to prevent selection of improper standards.
97.	During suit loop checkout in manufacturing, the stage was contaminated by a spill of distilled deionized water, when the pressure was overshot and the relief valve vented at 25 psi.	A design deficiency in the pressure gauge and regulator to permit accurate control of the pressure. Contributing to the incident was a design deficiency in the location of the vent so that damage could occur from venting.	Ensure that instrumentation is adequate prior to any pressure tests to permit evaluation and control of critical pressures. Require a hazard analysis to be conducted on all pressure vents to ensure they are located where inadvertent venting will not damage equipment or are provided with protective shields.
98.	A waterglycol system of a spacecraft was damaged extensively when it was inadvertently overpressurized during conduct of an unscheduled leak check of a line which had been repaired.	The test conductor was not aware of the leak check and Q.C. inspectors present did not interfere even though the work was not authorized. The technician used a high pressure source "K" bottle for a 60 psi low pressure check, using a 3000 psi regulator which could not be controlled within 50 psi.	Require all pressure tests to be conducted only with approval of the test conductor and in accordance with written procedures. Prohibit use of high pressure sources for low pressure tests without adequate regulators.

SECTION VII
PRESSURE SYSTEMS (Cont.)

	Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
99.	During manufacturing checkout of a spacecraft, the inlet and outlet gages on a "K" bottle regulator assembly were inadvertantly reversed, resulting in failure of the gage when "K" bottle was turned on.	Improper installation of the assembly. Gages were reversed and installed with a seal nut which prevented proper engagement of threads.	Inspect all pressure gages, prior to installation, for proper assembly for thread engagement. Require QC verification of proper gage installation prior to tests.
100.	While removing a burst disc from an LH_2 flex line at the tank dome, an automatic program was initiated and the repress valve was opened causing the line to whip, damaging the vent duct, and injuring a workman.	Failure to coordinate concurrent operations on the test stand. The propulsion engineer authorized work without notifying the Test Conductor. The stand talker did not clear with the test conductor before allowing work.	Require all work on stand to be coordinated with the Test Conductor. Require all flex hoses to be restrained.
101.	During tank pressurization, a recirculation bypass line became disconnected, releasing a large amount of GN_2 and caused evacuation of 16 people from the aft interstage. No injuries, minor damage.	An erroneous installation and failure to follow installation procedures. LH_2 feed duct not properly connected to pump inlet duct blanking plate. Contributing cause was inadequate inspection.	Require strict adherence to installation procedures and require QC verification of all pressure connections.

	Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
102.	Three men were injured by whipping action of a pneumatic purge line to a camera lens, when it was overpressurized and burst.	An error in installing the line restriction orifice. The orifice had been installed at the camera side of the line rather than at the pressure source thus allowing full source pressure to be applied to the line.	Require inspection verification of all line restriction orifices, prior to test. Design orifices with sizing or keying to prevent wrong installation. Require all flex hoses to be restrained.
103.	During conduct of a high pressure test (3300 psi) in a development test facility, a gage shattered, striking one man but caused no injury. Serious injury could have been incurred.	The gage was a low pressure gage and had not been removed from the system after a previous test and no verification steps were taken prior to initiating high pressure tests. Contributing was a design deficiency in not providing a relief device and failure of the rubber blowout disc to function properly.	Require positive verification of installation configuration prior to high pressure tests. Require relief devices to be installed with low pressure gages. Do not depend on rubber blow out discs in gages.
104.	During troubleshooting of a pressure system, a test technician inadvertantly over-pressurized the system and a vacuum pressure gage exploded causing potential for personnel injury.	Troubleshooting procedures were not adequate and the relief device for the gage had been inadvertantly removed. Contributing to potential hazards was a lack of protective guards over the gage to prevent flying glass.	Require protective screens or guards on all gages. Ensure that written procedures are prepared and followed for all pressure tests or troubleshooting.

SECTION VII
PRESSURE SYSTEMS (Cont.)

	Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
105.	One man was injured when a hose was over-pressurized and burst as a result of connecting a 750 psi nylon hose to a 2200 psi GN_2 system.	The 750 psi hose was knowlingly substituted for a 3200 psi hose because the latter was too short. It was thought that the source system could be regulated to 300 psi. Neither the technician or engineer knew the system and connected to the GN_2 system when they thought they were connecting to the oxidizer system.	Ensure that all personnel are properly trained and formally certified for test duty on pressure systems. Prohibit any equipment substitutions without formal Engineering approval.
106.	During the night, while unattended, an LH_2 shutoff valve failed, scattering parts over a wide area, and destroying the valve and tubing. No injuries.	Failure of a regulator which allowed full facility pressure to be applied to the valve.	Perform frequent inspection for verification of functional integrity of pressure system regulators.
107.	While working on a pneumatic console, two workmen were exposed to helium gas when the console inlet valve was opened by a concurrent automatic program being run.	The workmen had removed a component from the console and had not safed the system. A test engineer initiated the automatic program without notifying the stand talker and without knowledge of the other work being performed.	Require positive verification of compatibility with other work prior to initiating tests. Require prior notification before conduct of any automatic program.

No.	Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
108.	During leak check of a stage engine, a quick disconnect was not connected prior to the test, causing venting to atmosphere rather than to LUT vent.	The inner engineer erroneously verified that the QD was connected when it wasn't. Contributing cause was poor communications and failure to use schematics and proper terminology. Also test personnel were changed during the test.	Require technicians to verify connection of Q.D.'s. Require Test Conductor to have drawings and schematics available to ensure use of proper terminology. Do not change key test personnel during a test.
109.	During mass decay check of an engine start tank, the start tank vent and relief valve were overpressurized when a quick disconnect hose was connected to the wrong Q.D. The valve required replacement.	A malfunction had occurred earlier and a decision was made to bypass the pneumatic console regulator. However, the Q.D. hose was connected to the wrong Q.D. Contributing cause was poor numbering and marking of adjacent Q.D.'s and poor visibility due to darkness and rain.	Require all adjacent Q.D.'s to be positively identified and color coded as to function. Size or key connectors to prevent inadvertent cross connection. Prohibit deviations from normal procedures without written Engineering approval and written procedures.
110.	During pre-launch checkout of a stage, pressure was inadvertantly applied to the turbopump purge system, causing schedule delay, system damage, and revalidation.	Several quick disconnects were located where they were subject to cross connection and the ground half of a Q.D. was cross connected to the stage half Q.D. Lines and connections were not properly identified to prevent cross connection.	Require all lines and hoses to be located, if possible, in a manner to make cross connection impossible. Identify and color code lines and connection to prevent errors in installation. Require Q.C. verification of all hook-ups at both ends of lines.

SECTION VII
PRESSURE SYSTEMS (Cont.)

	Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
111.	During pre-launch checkout, a forward umbilical purge system was found to be non-operational due to cross connection of an inactive misidentified line rather than the purge line.	White tapes with ink marking were being used to identify lines and tapes had been placed on the wrong lines.	Require color coding markings for identification of hoses and lines. Require Q.C. verification of all pressure connections. Size or key adjacent lines so they cannot be cross connected.
112.	During manufacturing checkout, the stage and engine service systems were inadvertantly subjected to penumatic pressure, causing damge to valves and regulators.	Technicians failed to follow the TPS and did not remove a piece of tubing, thus failing to completely isolate the pneumatic valve. A contributing cause was failure to require inspection verification of work performed.	Require strict adherance to written test procedures and work authorizations. Require Q.C. verification of all work performed on flight hardware.
113.	During LH_2 valve fairing purge flow checks, a "B" nut cap over the outlet part of a flowmeter was not removed resulting in overpressurizing the flow-meter, bursting of the glass, and injury to 3 workmen.	The test installation had been moved due to rain and the test setup could not be easily observed in the new location. Contributing was lack of warning placards for removal of caps and lack of a specific callout in the test procedure. Also, the test was interrupted by the morning break and certain key personnel were changed during the break. There were no relief devices for the flowmeters.	Require all outlet parts for flow-meters to be placarded for removal of caps. Use tape to cap outlet parts, rather than "B" nuts. Require specific callout in test procedure for removal of part caps. Design all flowmeters with a pressure relief capability.

	Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
114.	During test installations, a 300 psi hose was installed in a 3000 psi system and ruptured, causing extensive damage and injuring one person.	Identification of hoses was not adequate and resulted in the mis-installation. Contributing to damage was failure to restrain the flex hose allowing whipping after it burst.	Require all flex hoses to be identified as a function operating pressure, proof pressure function, and date of proof pressure. Restrain all flex hoses at connection and at 6' intervals between connections.
115.	A workman was injured when a pigtail vent installed with a 90° bend, straightened out and struck a workman standing nearby, as a result of unprogrammed venting.	A design error in the vent installation. When the system vented and pressure hit the 90° bend, the vent line straightened from the pressure forces. The line was not restrained and there were no personnel protective devices installed.	Require all high pressure vent lines to be located in areas where personnel cannot be injured. Do not use 90° bends in vent lines if they can be avoided and ensure that vent lines are restrained to prevent whipping.
116.	After an incident involving a fire in a high pressure service system, nylon seats of ball valves were tested and found to decompose and burn under high pressure conditions.	A design deficiency in specifying nylon seats for ball valves. Test results showed that nylon decomposed and burned due to heat of compression at high pressures. (Test pressures used were 1800 to 4000 psig).	Do not use nylon seats in ball valves in high pressure systems.

SECTION VII
PRESSURE SYSTEMS (Cont.)

	Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
117.	During simultaneous conduct of two tests, system checkout and umbilical leak check on a stage engine, the engine throat plug burst disc was ruptured when the engine helium control solenoid was energized	The throat plug was required to be installed for system checkout and removed for leak check, but had not been removed for the leak check. Contributing was the need for unscheduled vehicle propulsion subsystem testing at this stage of pre-launch checkout due to late approval of change procedures and parts delivery.	Preclude the simultaneous conduct of tests involving pressures on end-item hardware wherever possible, however when necessary to perform testing concurrently, physical verification of equipment configuration should be made to assure that tests do not conflict with each other.
118.	During an instrument compartment leakage test, the compartment was overpressurized and the top bulkhead of a stage fuel tank was buckled in a reverse direction causing removal and replacement of the tank. No injury to personnel.	Overpressurization of the instrumentation compartment through a procedural error which allowed a dust cap to be left over a monitor gage, obstructing pressure readouts. Personnel were not properly trained and certified and test setup was not verified by Q.C.	Ensure that all personnel are properly trained and qualified in the performance of their duties. Q.C. to verify removal of dust caps, etc., to permit readout of monitor guages.

	Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
119.	During transfer of potable water from a storage tank, using H_2 at 25 psi as a pressure source, an H_2 fire occurred when a line was loosened. One man was injured.	The technician was wearing a nylon jacket and was using an unsafe method of relieving H_2 pressure. When H_2 escaped, it was ignited by a static charge. There was no supervisory or safety verification prior to start of hazardous tests and work control procedures were inadequate. The test installation was not properly grounded nor was the operator using grounding devices.	Require all tests employing H_2 to be designated as safety critical and require safety verification and sign-off. Prohibit use of nylon clothing around H_2 systems. Require verification of pressure relief and system inerting prior to disconnecting H_2 lines. Ensure that test installations and operators are properly grounded.

SECTION VIII
PROPULSION SYSTEMS

	Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
1.	During third acceptance test of a booster engine, a turbo pump fire occurred as a result of LOX leakage into the pump gear box, resulting in an extensive damage to the engine and minor damage to the facility.	A design deficiency in that there was shaft-to-seal movements which impacted the seal against the mating ring and caused LOX leakage into the gear box.	Ensure that LOX turbo pump design provides for adequate clearances to prevent rubbing or impacting of internal components under all operational conditions.
2.	During a laboratory test for qualification of a LOX prevalve for engine shutdown of a booster engine, the test system exploded ten seconds after initiation, destroying the valve, and damaging the test facility and the test engine.	A design deficiency in that the pump developed an uneven two-phase flow and cavitation after closing of the LOX prevalve, which caused uneven loads on the impeller and ultimate failure.	LOX prevalve should not be used for redundant engine shutdown mode. A redundant shutdown mode should be provided other than a LOX prevalve system.
3.	Inadvertent engine ignition occurred on a stage during routine maintenance while tanks were loaded. Ignition occurred when a connector was disconnected which allowed mixing of fuel and oxidizers. The engine cooler and lines were damaged.	A design deficiency in that adjacent connectors were not properly coded and adjacent connectors were of similar size and design, although the functions were different. This contributed to error on the part of a crewman who disconnected the wrong connector. Contributing causes were inadequate training and briefing of test crews and inadequate procedures. Maintenance personnel were not certified or adequately trained.	Ensure that all adjacent critical control connectors or switches are properly coded, marked or sized to preclude inadvertent operation of the wrong connector. Test procedures should require Quality Control verification of critical control functions such as fuel connectors or switches.

	Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
4.	A static firing test was aborted and a three-day schedule delay incurred when one engine failed due to a piece of tape in a fuel line.	The tape had apparently been left in the line during installation and partially blocked the fuel line at the connecting flange between the manifold and the ASI fuel line. Contributing cause was inadequate inspection and work control.	Require QC verification of all fuel line connections to ensure the line is free of contaminants. Do not use loose plastic materials or tapes in the vicinity of open fuel lines.
5.	During static firing of a booster, the heat from the flamebucket ignited adjacent grass resulting in burning of TV cables and blast recorder wiring.	Failure to ensure that the test area was clear of flammable material prior to test.	Require pre-firing area inspection to ensure the absence of flammable material in the test area.
6.	During checkout of a spark igniter as part of a propulsion leak and functional test, a short occurred in an electrical connector causing arcing and failure of the burner spark to come on. Connectors were damaged when failure was not immediately recognized.	Damaged connector pins incurred during connection in a confined space, allowing a bent pin to ground to the connector case. A contributing cause was diversion of the test conductor by assisting inexperienced monitors, thus allowing the test to continue after malfunction was noted.	Require monitors for critical data readouts to be provided with specific parameters for observation. Test crew members should not be allowed to leave their stations during a test. Ensure that electrical connectors are located in such a manner that repeated connections can be made easily without danger of damaging pins.

	Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
7.	During acceptance test of a booster servo actuator, the midstroke locks were removed out of sequence, allowing the fixture to rotate and causing damage to the servo actuator.	Test procedures had not been updated after this potential hazard had been discovered by the previous crew and the new crew had not been briefed on the hazard. Contributing cause was inadequate planning for the actuator removal and lack of supervision during this critical operation by an untrained crew.	Require briefing of all workers prior to performing critical operations on flight systems. Identify safety critical operations and require supervisory personnel to be present when critical operations are in process. Place warning notations in the test procedure where previous trouble has been encountered and require quality control verification that test procedure has been updated prior to each operation.
8.	During pressurization prior to static firing of a booster, an explosion occurred in the hydrogen vent line resulting in complete destruction of the vehicle. At the time, the vehicle was tanked with LOX and LH_2.	Inadequate procedure for purging the hydrogen vent line. Adequate samples had not been taken prior to pressurization to determine the O_2 content was at a safe level. Contributing cause was a design deficiency of the burn stack at the end of the horizontal vent line which permitted flashback.	Purging operations on Hydrogen systems should not be conducted until samples verify the absence of O_2 in the vent line. Provisions should be made for sampling O_2 at several places along the vent line. A hazard analysis of each hydrogen vent installation should be made, prior to operations, to determine potential flashback and static charge hazards.

	Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
9.	During maintenance engine run-up on a space flight training vehicle, the fuel tank ruptured during pressurization causing destruction of the tank, and minor injury to two persons. An unauthorized high pressure source was used to pressurize the tank. The procedure being followed was not applicable to the configuration of the vehicle.	Overpressurization resulting from erroneous pressure readings caused by a "sneak circuit" and lack of pressure relief devices in the system. Contributing causes were inadequate test, quality and inspection procedures. Discipline and control were inadequate as evidenced by use of unauthorized high pressure equipment on low pressure systems and lack of certification of equipment operator.	All hazardous operations should be performed only with detailed test procedures for the configuration of the test vehicle. Relief provisions should be installed in all equipment used to pressure flight systems. Personnel should be certified for operation of critical equipment. High pressure equipment should be prohibited for use on low pressure systems. A pre-operations hazard analysis should determine potential "sneak circuits."
10.	During countdown for a hot-firing Acceptance Test a welded high-pressure titanium tank exploded destroying the stage and causing extensive damage to the facility.	Use of incorrect filler wire although sufficient documentation was available to alert the vendor to the problem of titanium welding. This improper wire caused hydrogen embrittlement which reduced the tank strength. Contributing cause was inadequate subcontractor control by QC.	Provide eddy-current non-destructive testing in addition to standard radiographic tests for acceptance inspection and quality control of titanium tanks. Assure that procedures exist for welding titanium vessels and are enforced, and welders are certified. Procedures prepared by vendors should be reviewed and approved by the prime contractor Quality Control.

	Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
11.	During engine electrical sequence section of a stage simulated flight checkout, the engine valves opened, due to residual pressure in the engine control bottle, causing numerous engine valves to cycle. This resulted in damaging five engine exit covers. No injury to personnel.	The helium control bottles were pressurized with residual pressure up to 100 psig while the strip charts indicated zero pressure. This difference can be due to the telemetry system tolerances.	Ensure that engine control bottles are vented through the use of helium control system or initiate helium tank vent control "open" prior to and during all electrical engine sequence tests.
12.	During installation of midstroke locks in preparation for a thrust chamber jacket flush, a stray signal caused inadvertent activation of the servo actuator and damaged the system. Heli-coils, engine gimbal controllers and servo actuator were replaced.	A stray signal, either from a short circuit or from stray voltage apparently actuated the servo-actuator causing hydraulic fluid to flow from the piston/actuator body area. Pre-operational checks had not been made of potential stray voltage sources.	Conduct a pre-operational inspection for potential shorts or stray voltages prior to installing electronically actuated components in propulsion systems.
13.	During removal and replacement of an accelerometer on a booster engine, unannounced closing of prevalves by test console operator resulted in propellant vapors being emitted which struck a technician in the face. However, the test conductor was congnizant of both simultaneous operations that were taking place.	The test conductor directed closing of the prevalves without announcing it to others in the area. Residual vapors, either in the solenoid valve or in the engine were apparently released by the vibration of the valve opening.	Require public announcement to be made on the test stand whenever fuel propellant systems are activated. Require positive verification of notification personnel on simultaneous operations prior to initiation.

	Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
14.	In performing shutdown operations after a steamline burst disc ruptured during a static firing, two unscheduled firings occurred causing miner damage to the heat shield.	A design deficiency in that the aspirator vent system back-pressure could actuate the ball valve, caused the first firing. The second firing was due to a procedural error in opening the propellant valves with 60 psia in the tanks blocking the engine valves partially open. Contributing to both was an incorrect wiring of the ball valve position indicators on the control console.	Ensure that a hazard analysis has been performed to identify possible sources of inadvertent activation of the engine ball valves. Perform a pre-operational verification of the position of all valves as indicated on the control console.
15.	During trouble shooting following an automatic engine shutoff, an unscheduled engine firing occurred resulting in minor damage to electric wiring. Propellant tanks had been left pressurized to conserve helium.	Failure of the GN_2 facility pressure to maintain 150 psi to the backside of the engine actuation valve. Pressure in GN_2 system was 27 psi due to trickle purge of engine injector. Contributing was the tape programmer override of the engine firing control circuitry.	During periods when propellant tanks are pressurized, assure that the facility pressure for the engine actuation valves is maintained at required level. De-pressurize fuel tanks whenever possible prior to trouble shooting.

	Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
16.	A series of inadvertent power applications to RCS engines during functional checkout resulted in replacement of several engines.	Inadequate warning and caution notes in procedures, running of concurrent tests, inadequate QC inspection, improper test installation, and operator errors.	Require all test procedures to have warning and caution notes included in steps where critical switches can be inadvertently activated. Require Q. C. verification of control switch settings in the test procedure. Prohibit running of concurrent tests, when potential hazardous conditions exist.
17.	During propellant loading, an unscheduled engine firing occurred when the engine bleed valves were opened. A 15" hole in the floor grating was the only damage but personnel in the stand were subjected to potential hazards.	A procedural deficiency which allowed the engine drain valve to be open and the vent valve closed when engine bleed was open thus permitting pressurizing of engine activator through the open (vented) leg of the engine solenoid valves. Pre-operational hazard analysis had not been run. Post hazard analysis revealed other unsafe modes.	Require pre-operations hazard analysis for potential unsafe modes prior to fuel loading for static tests. Keep engine drain valve closed during engine bleed. Keep engine actuator system disconnected from bleed system and reroute as a separate vent system.

SECTION VIII
PROPULSION SYSTEMS (CONT.)

	Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
18.	During static firing test on a stage, a fuel leak occurred and resulted in a fire which burned through measurement wires causing test shutdown. Configuration of the LOX system following shutdown caused rupture of a LOX interconnect line and approximately 50,000 gals. flowed into the stage thrust structure and on engines. Fire damaged engine harnesses and hardware.	A polyethelene shipping disc had not been removed from a fuel connection and caused the fuel leak. Contributing causes were design deficiencies in the shipping disc such that it was not properly color coded or identified as a shipping disc and was not sized or configured to prevent inadvertent installation on the operating system.	Inspection procedures should require Q&RA inspection and verification of removal of all packaging/shipping material prior to end-item hardware assembly, and require accountability and removal from the area. Protective covers should be designed with blind holes, oversized or color coded and marked to prevent inadvertent installation.
19.	During Acceptance Test of a stage, an operator removed a test fixture from the engine which slipped through his hands and dropped approximately 8 ft. onto bottom of engine thrust chamber. Impact caused minor damage in one of thrust chamber tubes.	One man was assigned a critical task when due to the awkward conditions two men were required. Contributing causes were poor housekeeping in that the fixture was greasy, making it difficult to handle and no restraining devices were provided to prevent dropping the fixture on the engine.	Ensure that an adequate number of men are assigned to critical work tasks to prevent induced safety problems. Provide handles on test fixtures whenever possible to facilitate handling in awkward positions. Require all items being removed above end item systems to be restrained or tethered to prevent inadvertent dropping.

	Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
20.	During installation of a low thrust engine for test runs, a small amount of hydrazine fuel found in the connecting fuel line was attempted to be purged. Failure to close-off the engine valve prior to purging with GN_2 permitted 30 psig GN_2 to be forced through the fuel scrubber, the engine valve, catalyst bed, and out the engine exhaust. Fuel residue and a mixture of gases was blown into an employee's face causing considerable injury.	Test operator's failure to follow established procedures which required closure of the engine valve prior to purging operations. Contributing cause was the absence of provisions and safeguards in operating procedures to protect operators during purging.	Ensure that a hazards analysis of test operations involving pressurized toxic gas or liquid systems be performed and procedures include safety provisions and warnings for out-of-sequence operations and steps.
21.	During crew training on a flight training vehicle, thrust was lost when helium pressure was depleted and the vehicle was destroyed. The pilot ejected safely.	A design deficiency in the helium pressure sensing system which turned on the red warning light too late to permit corrective action by the pilot. The windy conditions and poor communications with the ground were contributory causes because the pilot, being busy with controlling the flight vehicle, was not aware of the rate of fuel depletion. Ground control recorded this data but failed to communicate it to the pilot in sufficient time.	For all manned flight tests, detailed operating criteria should define safe flight limits. Specific communication procedures should be prepared in advance to ensure transmission of critical information from ground to air. Hazard analyses should be conducted, prior to flight, of all critical warning and detection systems to ensure adequate pilot response time to warnings.

	Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
22.	Crew training vehicle crashed during a routine training flight mission. A region of flight was entered where the aerodynamic moments overpowered the vehicle control system in use, such that attitude control was lost. The pilot ejected and the vehicle was completely destroyed.	Lack of pre-planning and establishment of safety rules relative to wind conditions at all flight altitudes. Contributing causes were design limitations of the vehicle with reference to aerodynamic control capabilities and inadequate flight display systems on the ground to permit warning of the pilot of impending dangerous conditions.	Aerodynamic limitations should be established for any manned flight vehicle by wind tunnel tests with verification accomplished during the flight tests. Operations manual should include specific descriptions of flight profiles and allowable wind/environmental conditions at all altitudes, such that flight envelops are well within previously established and demonstrated vehicle capabilities. Prior to manned flight tests, verification should be made that essential flight data displays are provided in ground control to permit warning of the pilot of any dangerous condition.
23.	During preparation of test procedure sheets on a vehicle's RCS engines, it was discovered that the engine's heater circuits had been actuated for two hours and 16 minutes, whereas, the specification's maximum firing time was 25 minutes. No hardware damage or schedule slippage other than loss of test time to investigate.	A series of procedural errors in communications between test personnel resulting in non-documentation of engine operating times and component configuration between delta modifications, propulsion panel retesting and integrated systems testing.	All vehicle, vehicle to GSE and thermal board disconnects should require that requests for connecting and disconnecting be coordinated or channeled through a central installation or configuration group, to ensure that exact vehicle configurations are always known, and operating times are recorded.

	Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
24.	An open air explosion occurred during development testing of a stage engine at a test facility. The test was terminated after 2.5 secs. of mainstage operation whereas the test was scheduled for 25 secs. The premainstage explosion caused extensive damage to the test stand facility, foundation, and instrumentation. No personnel injuries were sustained.	An incorrect plumbing installation for igniter gaseous O_2 and GN_2 used for oxidizer dome purge, making it impossible for the igniter-oxidizer to flow into the thrust chamber. This resulted in no flow of gaseous O_2 required for ignition during the start sequence. A large amount of unburned fuel flowed which resulted in an open air explosion.	Ensure that plumbing installations are performed to formalized configuration and procedural instructions, and verified by QC inspection prior to testing operations on propulsion systems.
25.	During an engine run in an altitude chamber a fuel leak developed and a fire occurred causing extensive damage to the test vehicle. Extensive damage occurred due to failure to quickly control the fire.	A hazard analysis had not been conducted on the operation and no backup or contingency plans had been developed to cope with unplanned events such as fuel leaks and resultant fire.	Require all altitude chamber tests to be designated as safety critical and require a pre-operation hazard analysis to be performed. Ensure that emergency backup and contingency plans are incorporated into formalized test procedures.

	Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
26.	While a polyethelene cover was being rolled down over a spacecraft the rocket motor inadvertently fired from static electricity, resulting in 3 fatalities and major damage to the spacecraft and facility when the vehicle careened around the building.	A design deficiency in selection of non-conductive polyethelene covers for the spacecraft. Movement of the cover generated static electricity which discharged and ignited the igniter. Contributing was a design deficiency in the igniter which permitted firing by a spurious energy source.	Prohibit use of non-conductive plastic covers on spacecraft or components. Ensure that all covers and mated assemblies are grounded. Require verification of safety of igniters from spurious energy sources prior to use.

SECTION IX
STRUCTURAL SYSTEMS

Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
1. Welded supports failed during hydrostatic structural qualification tests of a booster tank, damaging the vehicle.	A design and manufacturing deficiency in that the welds were not adequate. Inadequate inspection procedures contributed to the accident.	Use Chem milling manufacturing process whenever possible for major structural components and ensure that inspection techniques for tank welds have been demonstrated to be adequate for determining weld integrity.
2. While conducting hydrostatic structural verification tests of a booster, the stage failed and was completely destroyed causing major damage to the facility and property. The stage was loaded with 3,000,000 lbs. of water, under pressure.	Enlargement of rivet holes, after repeated loading of the stage to near ultimate loads; which resulted in ultimate failure of the tank. Contributing cause was lack of adequate instrumentation to determine loads and failure to perform thorough inspections between tests.	Ensure that adequate inspections are performed between tests when hydrostatic structural verification tests are being run. Ensure that adequate instrumentation is provided for hydrostatic tests to establish structural loads at critical areas.
3. During draining of a booster tank after a hydrostatic test, a polyethelene cover was inadvertently left over a vent manhole in the tank, resulting in collapsing of the tank from vacuum.	The test procedure called for installation of the cover prior to draining. Contributing causes were failure to transmit essential information during shift turnover and a design deficiency in that no positive standpipe vent provisions were made to prevent inadvertent tank collapse during draining. Procedures were inadequate and not followed by test crew.	All booster tanks be designed with positive standpipe vent provisions to prevent collapse during draining. Positive procedure be established for critical tests to ensure transfer of essential information at shift changes. Hydrostatic tests of Flight Systems be conducted only in accordance with a detailed written test procedure which integrates the entire operation.

SECTION IX
STRUCTURAL SYSTEMS (CONT.)

	Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
4.	During development drop tests at a test facility, a failure occurred on drogue parachutes when a test vehicle was dropped from an aircraft at 30,000'. Both drogue chutes, after deployment, prematurely disconnected from the test vehicle and failed catastrophically. Test vehicle impacted drop zone and was buried 5' below ground.	Lack of good pre-flight loads analysis and an error in the assumption used to determine the load capability of the reefing ring attachment. The safety factor on the design was slightly below the acceptable minimum of 1.35, but was approved for this drop.	Ensure that the results of preflight loads analysis are utilized to verify design load criteria and that safety factors are met.
5.	During destruct test of a space vehicle landing strut assembly, the assembly failed and unexpectedly shattered into fragments which were dispersed over a wide area at high velocity, creating a high hazard potential to personnel and equipment in the test area.	Procedural deficiencies in the test setup and area control. The test had not been reviewed and approved by safety, unnecessary personnel were present in the area, and no protective screens had been provided to restrain shrapnel. Test engineers assumed the failure mode would be a bending failure.	Require all destruct tests of components or assemblies to be designated as safety critical and require safety approval and a pre-operation hazard analysis. Require test area to be cleared of personnel and require protective screens for potential fragments.
6.	During pre-bonding operations in manufacturing, skin sections of a flight vehicle were damaged by corrosive action of an unreported spill of a cleaning agent, pasa-jell 105. Skin sections were pitted and discolored.	The spill had not been reported at the time, precluding proper cleaning and neutralizing of the chemical action which can take place if contact with aluminum exceeds 40 minutes. Contributing cause was an inspection deficiency and lack of control over corrosive cleaning agents.	Require chemical analysis of all cleaning agents prior to use on end item systems to determine potential corrosive actions. Require inspection of flight vehicles after any cleaning applications. Require warning notes/labels to be placed upon any corrosive agents used around flight hardware. Require any spillage on flight hardware to be reported immediately.

	Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
7.	During verification checks of a spacecraft antenna to determine clearances in moving antenna from the deploy to stowed position, the antenna was damaged when it was inadvertently permitted to travel to the full stowed position.	The test checkout procedure lacked necessary precautionary provisions and warnings to instruct personnel of potential hazards in performing verification checks on delicate flight equipment. Contributing was the absence of necessary supervisory surveillance.	Ensure that test checkout procedures for delicate flight equipment contain caution and warnings in sufficient detail and clarity to prevent damage to the equipment. Require all personnel performing work on delicate equipment to be formally certified for such duty and require supervision surveillance of all checkouts of delicate equipment.
8.	During hydrostatic test of stage fuel tank, a 4" hose connecting a standpipe to the tank pulled loose from a quick-disconnect coupling which caused an unplanned drain of tank. Approximately 218,000 gals. of "D" water with a chromate solution was dumped in sewer and in tank farm ground area.	A plastic hose was used for the drain line rather than a hose with a metallic sheathing resulting in in adequate clamping of the connection.	Require all flex hoses used for drain connections, to have a metallic sheathing to facilitate clamping action for quick disconnect couplings.
9.	Unscheduled entry into a stage fuel tank to determine causes of failure in electrical test during stage tests, discovered two gouges on fuel tank lower bulkhead. Gouges of approximately .200L by .110W by.020 deep indicated that gouges were caused by droppage of a sharp-pointed tool, pliers or wire cutters. The tank was accepted for use following rework, inspection test and cleaning.	Tools were probably dropped by previous work crews due to failure to tether tools.	Ensure that no tank entries are made on end item stage hardware except those authorized by approved entry requirements and procedures and personnel working in critical hardware should be under continual surveillance. Ensure that tools are restrained in or over flight hardware.

SECTION IX
STRUCTURAL SYSTEMS (CONT.)

Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
10. During installation of stage access platforms in the thrust area, an employee, while kicking a jammed vertical support, fell backwards onto a horizontal platform support when a diagonal brace he was holding onto gave way. Personnel injury was two broken ribs.	Inadequate supervision in that the employees were not instructed on the proper installation of the access platforms in a congested area. Contributing causes were the limited work space and potentially hazardous obstructions of the thrust area.	Assure that employees are briefed in the proper procedures for installing and removing access platforms where known potential hazardous areas exist. Employees must communicate with one another when confronted with a hazardous problem to prevent unsafe practices. Assure that proper hand tools are available to assist employees in the removal or installation of fabricating equipment.
11. During draining operation after hydrostatic test of a booster assembly, a facility check valve malfunctioned resulting in a partial vacuum and structural damage to the stage.	Failure of the checkvalve to function properly. Contributing cause was inadequate operating procedures in that rigid inspection check-offs were not required at critical points in the procedure.	Ensure that all check/relief valves are properly functioning prior to hydrostatic tests. Require positive standpipe vents in booster tanks to prevent vacuum during draining operations. Provide for inspection checkoffs in the test procedure for critical steps in the test.
12. Common bulkhead in a booster stage failed catastrophically during Qualification Test while under pressure. Bulkhead material contained cracks.	Inadequate inspection procedures. Use of standard dye penetrants failed to reveal cracks left by machining. Subsequent analysis indicated 6 of 11 cracks had not been detected.	Manufacturing inspection procedures should require a caustic etch as well as dye penetrant inspection after all machine operations.

Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
13. During manufacturing repair of a skirt adapter, for a vehicle, excessive heat applied to the adapter assembly caused the outer and inner sheets to buckle and/or warp out of contour which caused a void or debond condition in subjected areas. No injury to personnel.	Instrumentation malfunction in that the recorder rotary stamp did not register the heat cycle properly due to a loose cover inside the recorder, preventing the stamp from advancing beyond 160°F.	Ensure that the calibration lab check and verify that all instrumentation is in proper working order by scheduling periodic inspections and calibrations. Temperature recorders with an automatic heat controller should be utilized in critical areas where overtemperature conditions could prove detrimental to the hardware.
14. A vehicle's mid-section collapsed in the assembly jig during manufacture when bulkheads were removed from deburring with jig gates not in position to support the assembly. No personnel injury; however, structural damage by deformation was considerable.	Manufacturing procedures were not followed which required installation of jig gates and safety lines prior to structure disassembly. Contributing was the lack of a requirement for inspection of jig attachment points, prior to disassembly.	Ensure that QC/Inspection requirements specify verification of installation of safety lines and jig gate supports prior to end item structure disassembly.
15. During qualification testing of experimental equipment, damage was sustained by the unit as a result of accidentally imposing unscheduled shock transients. Subsequent actions included significant testing of the equipment, and necessary rework actions before it could be cleared for flight operations.	Lack of adequate procedures. The equipment under test was improperly positioned in the vibration table; the test schedule imposed was inadequately detailed, and a comprehensive test plan had not been developed and approved through engineering. Contributing to this incident was the lack of adequate security in the area during non-working hours. Unauthorized personnel had tampered with the test set-up.	Detailed qualification test plans should be provided and include schedule of tests, equipment layout, and limits of testing. Arrange for the formal test plan to be routed through appropriate engineering personnel for approval and comments. Inspection of test set up and schedule should be accomplished prior to initiating testing. Security in the test area should be implemented to restrict all unauthorized personnel from the test area during all qualification testing.

SECTION IX
STRUCTURAL SYSTEMS (CONT.)

Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
16. A space vehicle tank was imploded and had to be replaced when it was inadvertently evacuated by a grinding tool which employed a vacuum pump to a pick up metal chips.	Inadequate planning and work control. The main fuel line had been cut for removal of the tank for a pressure check and was not sealed. The vent line had been covered with a plastic bag, causing a vacuum to be created by the grinding tool vacuum pump.	Require all lines to tanks requiring positive pressure to be sealed when disconnected and provide a vacuum relief valve in the line. Ensure that tanks are vented to atmosphere during rework. When vents are covered, use filter material rather than plastic.
17. Several workmen were injured when a flange blew off of a GN_2 system port during sampling operations, when the wrong bolts were installed in the flange.	Inadequate work control procedures. Four bolts of smaller size than called for in the specification were installed and failed. Contributing was failure to ensure bleed down on the system prior to removing flange. Due to valve leakage in the system, pressure had built back to 1500 psi.	Require bleed valves in all isolated sections of pressure systems. Ensure that materials used in pressure systems are rigidly controlled and issued only against an engineering work order. Require Q.C. verification of "pressure safe" prior to work.
18. During a structural test of a booster fuel tank using methyl alcohol at 245 psig, the tank burst after a two-hour hold, due to stress corrosion of the methyl alcohol on the titanium tank.	A design deficiency in specifying the use of methyl alcohol with titanium without conduct of adequate compatibility tests. Methyl alcohol is not compatible with titanium 6A1-4V - STA, under stress conditions.	Require compatibility tests of all liquids or solvents used in titanium tanks. Prohibit the use of methyl alcohol with titanium 6A1-4V- STA.
19. Fuel tank of a space vehicle inadvertently collapsed in manufacturing when a vacuum cleaner hose was left over the open end of the tank pressurization line. Replacement of the tank was required.	Work and area control procedures were lax and adequate safeguards had not been provided to maintain a positive pressure on the tank. The vacuum cleaner caused evacuation of the tank and collapse. There was no vacuum relief valve in the line and no warning signs to protect from inadvertent evacuation.	Require that all tanks using a positive pressure atmosphere be provided with a vacuum relief valve to prevent inadvertent evacuation. When pressure lines are disconnected, ensure provisions are made for maintaining positive pressure and require open lines to have warning placards.

Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
20. A propellant supply line failed during fill operations, due to compression and shear stresses imposed by a 90° bend in the line. A major spill resulted.	A design deficiency in the installation. Shear and compression stresses had not been calculated and engineering criteria was based upon hydrostatic testing only. Useful life and inspection criteria had not been specified.	Avoid sharp bends in propellant supply lines. When bends are empoloyed ensure that shear and compression stresses are calculated and proof tested. Tests should include flex tests to determine useful life and inspection criteria.

SECTION X
TRANSPORT/HANDLING SYSTEMS

Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
1. During movement of a GSE recorder in a launch operations building elevator, the unit overturned, striking and breaking the elevator glass window. No personnel injuries; however, the unit sustained dings and scratches and required recalibration and operational reverification.	No instructions, cautions/warnings existed to direct personnel in safe movement of unwieldy delicate equipment. The unit was not placed in a cradle, or restrained.	Require delicate GSE equipment to be secured and prepared prior to movement and ensure that procedures/instructions cover equipment movement either by decals on equipment or formalized movement procedures. Use cradles for moving unwieldy, delicate equipment.
2. During preparation for unloading a spacecraft stage, the spacecraft radiator was damaged extensively when an improvised ladder on a forklift tipped forward and struck the radiator.	Inadequate work controls were employed. When the approved ladder could not be located, the crew chained a 25' ladder to a forklift for use as a substitute without formal authorization.	Require use of only approved equipment around flight hardware.
3. In preparation for movement of a booster stage from a work station, a movable second level floor struck and damaged an engine fuel feedline bracket. No personnel injuries.	Handling procedure in effect did not require verification by the move conductor of proper vehicle positioning prior to floor being raised.	Require that material handling procedures include verification by the move conductor that the vehicle is properly positioned prior to disassembly or activation of moveable floors on work stands.
4. During installation of a fuel pipe bridge at a launch facility using a stationary manual winch, the handle came off the hoist causing the pipe bridge to fall approximately 6 feet. No personnel injuries, and damage was confined to a broken link in a support chain.	The lack of scheduled maintenance/inspection on the winch since the handle locking pin had been installed 180° from its proper place and the cable on the winch drum was wound in the wrong direction.	Require the handling/lifting equipment used at launch facilities to undergo periodic schedule and maintenance and inspection. Require Q.C. verification of all hoisting equipment prior to lifting end item hardware.

SECTION X
TRANSPORT/HANDLING SYSTEMS (CONT.)

	Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
5.	During a load proof test on a main crane at a test facility, the 15,000 lb. load block assembly began turning as crane cables twisted, resulting in breakage of the single tag line and failure of the load cable. No personnel injuries. Booster stage removal from test stand was delayed.	Lack of emergency planning/procedures to reflect actions to be taken in the event of load spin. Contributing was a deficiency in test planning/engineering since only one tag line proved to be inadequate to restrain the load spin.	Ensure that procedures for proof tests on large facility cranes provide contingency actions in case of emergency situations. Require tag lines at 90° intervals when lifting heavy loads.
6.	During manufacturing assembly operations on a booster stage, a GSE forward nose cone being lowered onto a forward skirt struck the accelerometer mount shroud pin causing cracks in the shroud rubber cushion and laminate. No personnel injuries.	Insufficient clearance between the handling equipment and the stage skirt to permit the use of the tool and the lack of a tool try-out verification procedure.	Require that GSE support equipment be formally approved and verified for use by means of an established tool prove-in process, prior to release.
7.	During transfer of a booster stage from a ground transporter to a test stand, and rotation from a horizontal to vertical position, the aft handling beam (spreader bar) was permitted to come into contact with the stage LH_2 tank skin when the deck crane was allowed to traverse beyond allowable limits. The tank received minor paint abrasions. No personnel injuries.	Lack of communications between the lift conductor and crane operator/riggers. There was no inspection verification and monitoring of crane positions during handling operations and the observor was not positioned so that he could observe the load. One observor did not have a headset on.	Require all personnel responsible for movement and handling of end-item hardware to be within one communication loop via headset. Crane positions should be verified by inspection during each step of handling operations.
8.	During hoisting and movement of a stage common bulkhead with four eyebolts at four points on lower end of dome, two eyebolts broke and one side of the 1000 lb. dome fell on an employee's foot causing permanent injury.	A design deficiency in the type of eyebolts and rigging specified. Contributing was lack of established rigging procedures and standards for proof testing of hoisting equipment.	Ensure that rigging slings, fastening devices, transporting equipment, etc., used for heavy complex structures are adequately proof tested to verify design characteristics, and require that periodic proof testing schedules be established.

SECTION X

TRANSPORT/HANDLING SYSTEMS (CONT.)

	Accident/Incident Description	Causes	Recommended Preventive/Correction Action
9.	A flight vehicle helium storage and supply tank assembly was imploded and a 14" diameter dent incurred during placement in a holding fixture, when a technician inadvertantly leaned on the tank.	Lack of detailed procedures covering handling steps and equipment required. Contributing cause was lack of use of protective covers and lack of development and use of special tooling and handling equipment.	Require that detailed handling procedures be prepared for all fragile flight hardware systems. Require engineering specifications for special equipment required for handling flight hardware. Require use of protective covers for deliverable hardware during handling and storage.
10.	While rotating a stage from a vertical to a horizontal position for station move in manufacturing, the stage and hoisting sling were damaged when the sling malfunctioned causing the stage to pitch and roll.	The stage had an eccentric center of gravity and the aft hoisting block hook had been locked against the rotation of the stage. Contributing cause was a design deficiency in the hoisting sling in that it did not break and "elbow" as the stage rotated to the horizontal. Also, the work was being performed at night and a rope to assist in breaking the sling center link was not attached.	Require all major moves of flight vehicles be performed during daylight hours whenever possible. Ensure that material handling procedures are thoroughly reviewed for potential hazards prior to hoisting end items. Ensure that detailed procedures are followed for hoisting flight vehicles and require Q.C. verification of proper equipment prior to start of operations.
11.	A stage purge line was damaged during removal of the forward skirt, when hoisting equipment adapter bolts failed.	Inadequate work control procedures in that the first shift had installed out-of-spec bolts and inspection had not verified the use of proper bolts. Contributing was supervisory and workmen carelessness.	Require establishment of positive control over materials used in hoisting equipment used for flight vehicles. Require inspection verification of all hoisting installations prior to use.

SECTION X

TRANSPORT/HANDLING SYSTEMS (CONT.)

	Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
12.	A booster engine injector received minor damage when it was dropped 5 ft. to the floor during a transport operation in manufacturing.	The wrong bolt had been installed that held the hoist to the overhead trolley. It did not have a safety pin installed and had worked loose and disengaged allowing the hoist and load to fall. Contributing was inadequate inspection and failure to obtain safety approval of the hoist installation.	Require Q.C. verification of all hoist installations to ensure conformance to specs. Require safety pins in all hoist attaching points. Require safety approval of all hoisting equipment installations handling deliverable hardware.
13.	During move of an interstage from storage to assembly line, the interstage struck another interstage in an adjacent station causing minor damage.	Failure to perform adequate preplanning. The move conductor did not move other equipment in the area which would have provided increased clearance.	Require pre-position marking guides on the floor prior to moving large assemblies on the assembly line. Require inspection of the area prior to move to ensure removal of unnecessary equipment.
14.	While removing a panel from a spacecraft with an overhead crane, a 1/4" screw was inadvertantly left in the panel and was pulled through, causing extensive damage to the panel.	The technician performed the operation without a move conductor present and failed to remove one screw prior to lifting the panel. There was no inspection verification prior to the hoisting.	Require a member of supervision or a move conductor to be present whenever flight hardware is handled. Require inspection verification of move setup prior to initiating hoisting operation.
15.	During movement of stage forward skirt from a test stand to cribbing next to stand, the skirt was lowered too rapidly, striking the cribbing and damaging the skirt. Schedule was impacted.	A malfunction of the speed control on a 12 ton hoist being used. Contributing cause was a substitution of a 12 ton hoist for a 65 ton hoist and use of a hoist operator who was qualified but inexperienced in this operation.	Require use of only experienced operators when moving critical end item flight hardware. Do not permit deviations from or substitution of equipment in test procedures without supervision approval.

	Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
16.	A spacecraft umbilical assembly was damaged during transport on a fork-lift, when the forklift hit a dip in the road and the assembly struck the pavement.	Lack of a detailed procedure for transporting the assembly. Crews on regular shifts had discovered that the safest method was to transport the forklift backward. The second shift operator was not informed of this method.	Require detailed transportation procedures to be prepared and followed for transport of end item assemblies.
17.	During transport of an auxiliary propulsion system with loaded hypergolics, the vehicle struck the ground during an uncontrolled lowering of the boom to pass under overhead electric cables. The vehicle TCD limits of 1.5 G's was exceeded but no damage incurred.	A malfunction of the crane brakes due to moisture in the drums. Contributing cause was failure to check out the crane at equivalent loads prior to lifting flight hardware.	Require pre-operations checkout of all hoisting equipment with simulated actual weights prior to lifting flight systems. Provide protective covers and heaters to keep crane brake drums dry.
18.	During removal of a lug on the forward stage handling ring, the workman disengaged the last nut and the lug fell damaging the forward skirt of the stage.	A procedural error in that no action was taken to restrain the lug prior to removal of bolts and no protective covers were provided to catch falling objects.	Require all procedures to include a step for restraining of any parts being removed or installed over flight hardware.
19.	During transport of an aft skirt of a stage from storage to an air terminal, the skirt struck a telephone pole along the road, causing damage to the pole and the aft skirt.	The driver pulled too far to the right preparatory to making a left turn and struck the pole. Contributing cause was inadequate planning and supervision of the move to identify critical turn points.	Require outside observors ahead of and behind wide loads during movement of flight hardware. Require pre-identification and marking of critical clearance areas along the route.

SECTION X
TRANSPORT/HANDLING SYSTEMS (CONT.)

Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
20. During hoisting of a dummy aft interstage from the dock to a dolly, it was dropped 2 ft. when the crane failed, striking the dolly and breaking the handrail.	Malfunction of the Crane Control and braking system.	Require deadweight checkout of hoisting equipment prior to lifting end item hardware.
21. Booster stage and protective cover damaged during manufacturing when it was stored next to a sliding door and was struck by the door when it was closed.	No plan was developed for handling and placement of the stage, resulting in its being positioned too close to the sliding door. Contributing factors were personnel error on the part of supervisory personnel and inadequate inspection during movement and placement of the vehicle.	Ensure that handling plans are developed for all transport and handling operations of flight vehicles. Pre-mark exact positioning points for placement of the vehicle prior to movement. Require inspection checkoff after all handling or transport of flight vehicles.
22. While removing a handling sling from an engine, engine fixture rotated, damaging the heat exchanger and bellows.	The handling procedure had not been brought up to date even though this problem had been encountered previously. Contributing factors were use of an inexperienced crew without proper briefing and certification.	Positive methods should be established for ensuring that procedures are updated when problems are identified. All personnel handling flight systems should be certified for their duties and should be briefed upon hazards prior to each operation.
23. During transport of empty LOX tanks, barge struck bridge of Inland Waterway, damaging barge and bridge. Bridge was out of use for two weeks due to extensive damage.	The movement plan was inadequate and had not been updated when changes were made in the plan, resulting in failure to recognize hazards. Contributing causes were inadequate tug horsepower, use of marginal waterways for the size of the load, and performing the movement at night on a strange waterway.	Ensure that a detailed transport and handling plan has been prepared prior to movement of all propellants. Require safety review and approval of all propellant movement plans to ensure that all hazardous contingencies are considered. Ensure that equipment is compatible with loads, routes, and environment.

Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
24. During movement of spacecraft in manufacturing, the handling sling failed and the spacecraft was dropped six feet causing structural damage to the spacecraft.	Attaching studs in the sling were not properly assembled and it had not been proof tested. Handling and inspection procedures were inadequate and the sling was poorly designed. There were no safety snubbers on the vehicle.	Require all handling equipment used with flight systems to be proof loaded and qualified prior to use. Ensure that all handling operations are designated as safety critical and detailed procedures followed. Qualify and certify all personnel for handling duties. Require designation of a handling coordinator for each operation.
25. A main derrick at a facility failed to operate properly leaving a booster stage suspended in the air for four hours. High heat, humidity and dust in control room caused the motor generator regulator power amplifier to overheat and fail.	A deficiency in the design for operation under high heat, humidity and dust conditions and failure to provide a current overload warning device. Contributing cause was failure to qualify the derrick under the environmental conditions prior to handling flight systems.	Ensure that design requirements for Flight System Handling equipment include environmental specifications for temperature, humidity and dust. Require all handling equipment to be pre-operationally qualified under the environmental conditions of actual test operations.
26. During training for water recovery operation a boilerplate vehicle was lost when a hoist fitting broke while attempting to hoist the vehicle from the water. The vehicle was deliberately sunk when no practical way of hoisting it to the deck of the ship was available.	A design deficiency in that the pickup ring was unable to support the loads encountered in heavy seas. Contributing cause was lack of contingency planning to provide alternate methods for hoisting or towing.	Emergency and contingency plans should be prepared for all tests conducted under actual or simulated recovery conditions. All hoisting equipment and fittings should be proof-tested at 1.5 times anticipated loads, prior to operational use.

SECTION X
TRANSPORT/HANDLING SYSTEMS (CONT.)

Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
27. During annual inspection of a facility crane hoist, steel plates fell on a booster engine damaging engine accessories and a helium sphere. The hoist was operated from a remote station which permitted the hook limit switches to be bypassed.	Two procedures were in use, one of which permitted bypassing of the limit. switch. Also, inspection should not have been permitted over or adjacent to flight systems. Contributing causes were inadequate training of operators and a design deficiency which permitted by-passing of the limit switch from the remote operator position.	All transport and handling operators should be specifically certified for duties involving flight hardware. Maintenance or inspection of handling equipment should not be permitted in areas where the flight hardware may be damaged. Cranes should be designed so that limit switches cannot be by-passed from any operator's position.
28. Five crated heat shields were improperly loaded on a fork lift truck during manufacturing/handling. Two fell off during transport and were damaged to an extent that required scrapping.	Lack of procedures for identification and markings of lifting points. Contributing causes were inadequate training of fork lift operator, lack of storage and handling procedure for heat shield and inadequate supervision.	Require that lifting points and center of gravity be stenciled on all flight hardware crates. Ensure that special handling and storage procedures are prepared for all individual flight components or systems. Require all personnel handling flight hardware to be certified for such duty.
29. During movement of upper fuel tank bulkhead in manufacturing, the crane brake malfunctioned dropping the moving tool 6 to 12 inches onto the bulkhead. No damage was incurred.	Malfunctioning of the crane brake.	Ensure that handling equipment is checked by use of deadweights, prior to lifting major end items.
30. During a lifting operation of a 15-ton booster forward handling ring by a mobile crane, the crane tipped up on the outriggers and tires on the load side causing the ring to settle to the ground resulting in minor damage. No injury to personnel.	Use of under capacity equipment and the lack of an adequate and complete proof load test. Contributing causes were lack of proper crane load table, exceeding lifting wind limitations, and not properly pre-positioning dolly to receive ring.	Require Quality Control to ensure that equipment of proper capacity is used and verify that an adequate and complete proof load test with the proof load weight attached is demonstrated. Quality Control should verify that the wind speeds, as established by Standard Operating Instructions are not exceeded, during handling of end item hardware.

Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
31. During movement of a crane in the manufacturing assembly area, the crane struck an overhead sizing ring, damaging the ring.	The operator of the crane was not the regular operator and no outside "watchers" were required to warn of clearances. Contributing cause was an overhead warning light which was inoperable at the time, due to a bad plug-in.	Require at least two observers during all movements of heavy equipment in manufacturing areas. Require verification of operation of all warning lights prior to movement. Ensure that all operators are properly qualified and certified for duties.
32. During movement of an engine actuator on a flatbed truck, the actuator fell off when a sharp turn was made and was damaged.	The operator failed to secure the actuator on the flatbed as required. The operator was not well trained and disciplined and failed to operate the flatbed safely.	Require all end items to be secured during transport. Ensure that all personnel operating transport vehicles are properly trained and certified for their duties.
33. During preparations for installing a stage in a vertical checkout building; the stand derrick operator inadvertently damaged the aft hoisting frame while lifting with the arms of the frame disconnected.	A procedural caution note stated that there will be no load put on the center link of the aft hoisting frame with the arms disconnected. This warning note was violated at the direction of the derrick rigger talker. Contributing cause was confusion from too many people in the lfit-a-loft basket with the talker.	Ensure that derrick operators and riggers are thoroughly briefed in stage lifting procedures prior to start of any lifting operation. Quality Control to verify condition of rigging to satisfy stage lifting requirements, minimum number of personnel to be used, with strict communications at all times.
34. Loss of stage handling equipment narrowly avoided when a transporter barge was secured for the night and left with one ballast valve open. Test crew noticed the list and opened the opposite ballast valve until crew could be recalled.	Failure to use a formal checklist in securing the barge for the night.	Require use of checklists in all operations involving transport or handling of end item hardware.

SECTION X
TRANSPORT/HANDLING SYSTEMS (CONT.)

	Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
35.	During lifting of a handling ring with a crane, an electrical arc occurred when the ring was lowered to within one inch of the handling dolly. No damage and no injuries occurred but could have resulted in a fire or fatal injury.	A deficiency in the 220V power receptacle. The ground lug of the receptacle had been hooked to power and provided 220V to the structure of the dolly.	Require grounding continuity checks of all facility power receptacles at least once per year. Color code all wires to power equipment to prevent cross connections. Require Quality Control verification of all power outlets prior to use.
36.	During installation of a booster engine, the engine was damaged when a "borrowed" handling fixture rotated and allowed the engine to strike the tail unit structure.	A substitute fixture was used without a special analysis of potential hazards and without changing the handling procedure. The approved handling fixture was undergoing redesign modification.	Require all handling equipment to be formally approved and certified for use on end item hardware. Require prior engineering approval for use of substitute handling equipment and verification of the applicability of operating procedures for use with substitute equipment.
37.	During hoisting of a 100,000 lb. facility LOX tank, the tank was dropped about six feet onto concrete supports causing extensive damage to the tank.	The crane was not positioned correctly over the tank and lifting was attempted at an excessive horizontal distance of the boom, causing the rear outriggers to give way and dropping of the load.	Require all handling equipment operators to be certified for handling end item hardware. Require member of supervision to be present during all handling operations.
38.	An unattended gantry crane (rail) was put in motion during the night by high winds and collided with a personnel barrier, causing minor damage to the barrier.	The rail clamps had not been installed prior to leaving the crane unattended. Checklists for securing equipment were not prepared or used.	Require the preparation of checklists for use at shift change to ensure proper securing of mobile equipment. Ensure that positive braking devices are provided for all equipment on rails.

SECTION X
TRANSPORT/HANDLING SYSTEMS (CONT.)

	Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
39.	During proof check of a hoist near a vehicle, the proof load weight drifted when raised and struck a module engine, causing minor damage.	Employee carelessness and inadequate control over work operations in areas near end item hardware.	Require a member of supervision to be present whenever hoisting operations are conducted with or near end item hardware. Ensure that all personnel engaged in transport and handling operations are trained and certified for their duties and require a pre-briefing of all personnel prior to the operation.
40.	During removal of an O_2 shelf from a spacecraft, the shelf was damaged when a weld failure occurred on an installation adapter.	Proof loading requirements were past due, but equipment used was authorized by waiver while in a red tagged condition. A contributing cause was a design deficiency in that the handling equipment was designed for a shelf weight of approximately 90 pounds less than the actual shelf weight.	Quality Control should verify that proof load requirements are performed per schedule and ensure that equipment in "red tagged" condition is not used until design inadequacies have been corrected. Waivers should be prohibited for any proof loading discrepancies.
41.	During installation/assembly of a flight cover on a spacecraft display panel, the panel dropped approximately three feet to the floor when retaining bolts were removed from the work fixture, with subsequent rotation of the panel. Major damage resulted to instruments and hardware requiring complete panel replacement.	There was no evidence of installation procedures, safe work practices and hardware handling precautions. Contributing was the absence of a positive holding mechanism to prevent panel/jig movement following retaining bolts removal.	Ensure that all assembly/installation procedures specify detailed sequential steps and checkpoint precautions to protect against hardware damage and personnel injury. Manufacturing work fixtures should include provisions for safe handling of end item hardware during installation/assembly.

SECTION X
TRANSPORT/HANDLING SYSTEMS (CONT.)

	Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
42.	During off-loading of helium Dewars from a commercial truck, the fork lift was backed off a concrete slab, causing one Dewar to fall off and become damaged.	The operation was being performed over rough terrain, without adequate positioning of the transporter and the load had not been tied down.	Require certification of all fork lift operators for handling program material. Require approval by supervision of off-loading prior to initiation.
43.	The rear landing structure of an astronaut training vehicle failed during structural inspection, as the vehicle was being raised to remove a diagonal brace on the structure. Structure was overstressed, requiring replacement, and delay of training schedule by 3-4 weeks.	Failure to follow proper work sequence which required vehicles to be supported by jacks during removal of support bracing. Contributing was evidently the lack of procedural inspection checkpoints to verify the proper structural inspection sequence.	Require written procedures or plans for lifting, hoisting or handling of end item vehicles. Require supervisory control during such operations and require Quality Control verification and sign off at critical procedure points.
44.	During removal of mock-up vehicle from transporter at a test site, two of four attaching points to the vehicle did not engage properly and the load shifted. Although the vehicle was lowered without dropping, this incident could have resulted in complete loss of a flight vehicle under similar conditions.	The sling hooks were not properly engaged and verified, even though Q.C. visually inspected and bought-off the attachment. The procedure was deficient in that it did not require entering the vehicle to positively verify attaching points and did not include 3 successive steps in verification.	Require procedure for lifting or hoisting of flight vehicles to include positive verification at successive sequential steps that sling attaching points are properly engaged. Require Q.C. buy-off for each successive verification sequence.

	Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
45.	During final assembly of a flight vehicle, the lanyard attach ring and sling attach pin separated allowing the pin (approximately 1" in diameter) to fall to the vehicle deck floor. Subsequent damage was done to the deck floor necessitating replacement of mid-section deck assembly.	Design deficiency of the safety lanyard retaining ring which separated when pulled with the pin under tension. Contributing to this was inadequate communication to insure proper pin tension for removal and inadequate pre-operational briefing of crew members. The only communication available was voice relay.	Require pre-operational briefing of all crew members prior to hoisting operations over or near flight vehicles. Perform dry run simulation of lifting operations prior to actual lifting over flight articles. Require a safety analysis and proof testing of all hoisting equipment to at least 150% of working weight. Require headset and visual and aural signals for all hoisting operations.
46.	While preparing a piece of flight critical hardware for shipment, the equipment was placed on an unsecured, padded diving board after the technician removed it from its test installation. The stand was used because the technician had momentarily lost his balance under the make-shift arrangements that were made for this removal sequence. The stand tipped, and the equipment slipped to the floor suffering damage that subsequently rendered the unit unfit for flight operations.	Lack of adequate removal instructions, including proper stands, containers, and personnel support. Contributing factors include the lack of inspection actions prior to the removal of flight critical hardware.	Require post operation inspection of work areas to ensure loose equipment is removed. Require Q.C. or supervisory verification of required tools and support equipment prior to work on flight vehicles. When components are being removed from flight vehicles, require component containers to be provided and require a minimum of two workmen to perform the task.

SECTION X

TRANSPORT/HANDLING SYSTEMS (CONT.)

	Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
47.	During removal of the helium tank of the propulsion system of a flight vehicle, the tank outer shell was cracked and imploded. Subsequent damage was experienced over an area 12" x 4' deep requiring replacement of the tank.	Inadequate design considerations in that no provisions were included to hold down feeder tubes going into the tank through extremely thin outer skins. During removal, the feeder tubes were slightly bent, causing distortion of the outer & He tank shell which houses an evacuated chamber. The distortion and crack resulted in implosion of the outer chamber. Contributing factor to this incident was the inadequacy of the removal precedure.	Design consideration should incorporate adequate disassembly fixtures to preclude distortion of components being removed. Where fragile surface areas are interfaced, design should provide reinforced stress points to accept generated loads. An external holding fixture should be provided to act as a means of transmitting indirect stresses from the fragile structures area. Procedures and inspection of the removal sequence should reflect logical dis-assemble of the unit, and supporting connections.
48.	During assembly in manufacturing, a space vehicle landing gear strut assembly was inadvertently damaged when it was knocked off its cradle on a table by an adjacent workman bumping the table.	Inadequate work control procedures. The assembly was placed properly on a cradle but was not restrained even though it was placed on a table near other workers.	Require all components or assemblies be restrained on their cradles when temporarily stored in work areas during assembly.
49.	A large GSE end item was damaged extensively when it was dropped off a loading dock while movement was being attempted with a forklift.	The center of gravity of the item had not been determined and marked on the crate. Insertion points for the forklift were not marked and the CG of the item was off center causing it to tip off the dock when the forklift was raised.	Require CG and lifting points to be identified on all crated end items.

	Accident/Incident Description	Causes	Recommended Preventive/Corrective Action
50.	A spacecraft propellant tank suffered major damage when an unmanned rail mounted crane rolled down the track and struck another crane which was lifting the tank.	The two cranes were mounted on the same track and the unused crane was not properly blocked to prevent rolling. Control procedures were inadequate for ensuring safety of operation.	Require that work control procedures are established for all work areas. Require manning of all vehicles on common tracks during lifting operations. Require detailed procedures for securing mobile equipment when not in use.
51.	During loading of a stage on a transport aircraft the stage was damaged by workmen walking on it.	The cover used on the stage was not marked to identify "walk" and "no walk" areas. When workmen climbed on top the stage to attach the crane hook, they stepped in a "no walk" area.	Ensure that all covers for major end items are marked to identify approved walkway areas.
52.	During changeout of instrumented mounting studs on a stage, a crane hook was inadvertently left attached to the stage upon work completion. Subsequent failure by workmen on the following shift to note crane hook attachment, rotated the stage and resulted in damage to the forward "C" ring on a LOX tank.	Failure to properly secure equipment after completion of an installation and failure to transfer essential information from one shift to the next. The stage rotation procedure did not require a check of equipment or stage before rotation.	Require procedures to specify requirements for transfer of information at shift changes. Require area supervisor to conduct a "secure" check following each operation involving end item hardware handling or movement. Require all handling equipment to be placarded "Do Not Operate" when unfinished work is endangered.

APPENDIX

GLOSSARY OF ABBREVIATIONS, ACRONYMS AND TERMS

ACE	-	Automatic Checkout Equipment
ASI	-	Apollo Standard Initiator
ASME	-	American Society of Mechanical Engineers
CG	-	Center of Gravity
CO_2	-	Carbon Dioxide
CRS	-	Cold Rolled Steel
DB	-	Design Burst
ECS	-	Environmental Control System
EO	-	Engineering Order
GH_2	-	Gaseous Hydrogen
GN_2	-	Gaseous Nitrogen
GSE	-	Ground Support Equipment
He	-	Helium
Hz	-	Hertz (cps)
KOH	-	Potassium Hydroxide
LH_2	-	Liquid Hydrogen
LN_2	-	Liquid Nitrogen
LOX	-	Liquid Oxygen
N_2O_4	-	Nitrogen Tetroxide
LUT	-	Launcher Umbilical Tower
O_2	-	Oxygen
OCP	-	Operational Checkout Procedure
PSI	-	Pounds Per Square Inch
PSIA	-	Pounds Per Square Inch Absolute
PSIG	-	Pounds Per Square Inch Gauge
QC	-	Quality Control
QD	-	Quick Disconnect
Q&RA	-	Quality and Reliability Assurance
RCS	-	Reaction Control System
R&D	-	Research and Development
RF	-	Radio Frequency
RPM	-	Revolutions Per Minute
SCAPE	-	Self Contained Atmospheric Protective Ensemble
SCFM	-	Standard Cubic Feet Per Minute
TC	-	Test Control/Test Conductor
TCD	-	Test Checkout Directive
TCP	-	Test Checkout Procedure
TPS	-	Test Preparation Sheet
TPI	-	Threads Per Inch
TV	-	Television
TVD	-	Toxic Vapor Disposal
UDMH	-	Unsymmetrical Dimethylhydrazine
VDC	-	Volts, Direct Current

Accident	-	A type A or B mishap as defined in the NASA Safety Manual, NHB 1700.1 (VI)
Incident	-	A mishap of less than accident severity as defined in the NASA Safety Manual, NHB 1700.1 (VI)
Cryogenics	-	The science of producing and the application of low temperature processes below minus 150° F and the techniques involving handling, storage and usage of liquified gases. Examples are hydrogen, oxygen and helium.
"D" Water	-	Distilled water.
Dewar	-	A double walled metal vessel or tank, with an evacuated space between walls, used for storing fuels and propellants in a liquid state.
Hardware -	-	Any program component, subsystem, system, module, stage or vehicle, plus any facility equipment and property, ground support equipment (GSE) and other used in direct support of program hardware.
Software	-	Any formalized written policy, directive, procedure, plan, specification, requirement or analysis prepared as an essential tool in the conduct of program activities.
"Hoke" Bottle	-	A small pressure vessel or container used in obtaining, handling and transporting gases and liquids for sampling.
"K" Bottle	-	A portable pressure cylinder or tank commonly used as a pressure source.
"Kluge"	-	A frequently used slang term for a temporary or unauthorized installation.
Program Phase	-	The four phases of a major research and development/ operations program as defined in the NASA Phased Project Planning Guidelines, NHB 7121.2, August 1968 Edition.
Program Activities-		Tasks, work, functions and responsibilities associated with program hardware development/operations as defined in NASA Phased Project Planning Guidelines, NHB 7121.2, August 1968 Edition.