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Guide for Certifying Pressure Vessels and Systems

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PREFACE

This guide is intended to provide methodology and describe the intent of the Pressure Vessels and Systems (PV/S) Certification Program. It is not meant to be a mandated document but is intended to transmit a basic understanding of the PV/S program and include examples. After the reader has familiarized himself with this publication, he should have a basic understanding of how to go about developing a PV/S Certification Program.

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SECTION 1. INTRODUCTION

1.1 Purpose

This document defines the general principles and methods involved in certification of pressure vessels and pressurized systems (PV/S), and is intended to serve as a guide for use at Kennedy Space Center (KSC), Florida, and other locations where KSC has design, operation and maintenance (O&M), or sustaining engineering responsibility. The overall goal is to implement a documentation, analysis, and inspection program which will provide a high degree of assurance in the continued safe operation of the PV/S under KSC cognizance. The major elements of this certification program are as follows:

- A comprehensive pressure vessel/system inventory, including the retrieval or development of relevant design and manufacturing data.
- Certification analysis of all pressure vessels and systems to determine degree of compliance with applicable codes and standards.
- Development and implementation of an inspection/testing program.
- Maintaining files of pressure vessels and systems documentation.
- Preparation of certification reports which include results of findings and analysis for all systems and vessels.
- Implementation of an on going Inservice Inspection (ISI) program.

This document provides a general overview of the PV/S Certification process and contains detail sections to supplement those areas where additional guidance is necessary. The information presented in this document is based on experience and "lessons learned" from several years of PV/S certification efforts at KSC and other NASA facilities.

1.2 Background

The National Aeronautics and Space Administration (NASA) has established a uniform policy regarding the design, inspection and certification of PV/S which are owned by NASA or used on NASA property. NASA Management Instruction NMI 1710.3, "Safety Program for Pressure Vessels and Pressurized Systems," requires pressure vessels and pressurized systems be certified and inspected in accordance with applicable codes, standards, and guides to the maximum practical extent, and when deviations are required, supplemental analyses, tests and examinations be performed to ensure safety of personnel, equipment, and facilities is not compromised.

NASA Handbook NHB 1700.6, "Guide for Inservice Inspection of Ground-Based Pressure Vessels and Systems," establishes an outline of Inservice Inspection and recertification procedures for ground-based unfired PV/S. This handbook provides the overall NASA requirements for PV/S and was written to be applied, as appropriate, to all NASA facilities.

KSC issued management instruction KMI 1710.5 entitled "Certification Program for Pressure Vessels and Pressurized Systems." KMI 1710.5 requires that PV/S be certified in accordance with the current nationally recognized codes. KHB 1710.15, "KSC Pressure Vessel/System Certification Handbook," explains responsibilities and provides instructions concerning the documentation and certification of ground-based PV/S at KSC.

This guide is intended to serve as a major reference document for the performance of PV/S certification at KSC. This document is controlled and subject to revision and updating as information becomes available. The guidance provided in this document is intended to supplement the information provided in applicable NASA and KSC management instructions and handbooks and therefore is not intended to replace these documents as the primary source of certification requirements.

1.3 Scope

In general, all PV/S at KSC must be certified as safe to operate, and must be periodically recertified to maintain personnel and equipment safety. Some PV/S, however, are not required to be certified due to their low potential for failure, low risk, and low stored energy. Guidelines for exclusion are contained in Chapter 3 of KHB 1710.15. The following three tables categorize fluids at KSC. Table 1-1 lists fluids considered to be nonhazardous and their standard abbreviations. Table 1-2 lists fluids considered to be hazardous and their standard abbreviations. Table 1-3 lists fluids considered to be lethal and their standard abbreviations.

TABLE 1-1 List of NON-HAZARDOUS FLUIDS

Fluids	Standard Abbreviation
Gaseous Argon	ARGON
Compressed Air	AIR
Breathing Air	BAIR
Gaseous Carbon Dioxide	CO2
Freon 114	F114
Gaseous Helium	GHE
Hydraulic Fluid	HYD
Gaseous Nitrogen	GN2
Gaseous Oxygen	GO2
Water	WATER

TABLE 1-2 List of HAZARDOUS FLUIDS

Fluids	Standard Abbreviation
Alcohol	ALCOH
Gaseous Hydrogen	GH2
Liquid Air	LAIR
Liquid Hydrogen	LH2
Liquid Nitrogen	LN2
Liquid Oxygen	L02
Liquified Petroleum Gas	LPG
Ammonia	NH3
Trichloroethylene	TRICH

TABLE 1-3 List of LETHAL FLUIDS

Fluid	Standard Abbreviation
Aerozine 50	A50
Hydrazine	N2H4
Monomethyl Hydrazine	MMH
Unsymmetrical Dimethyl Hydrazine	UDMH
Nitrogen Tetroxide	N2O4

Notes to Tables

- *Lethal and hazardous fluids are defined in KHB1710.15.*
- *Standard abbreviations are from NASA Reference Publication 1059.*

Excluded items include low energy, low risk vessels and systems. These systems include heating, ventilation, and cooling systems; potable water systems; and air systems. The following items are excluded from the certification program based on the performance of normal routine inspection and maintenance.

- PV/S as described in KHB 1710.15, Chapter 3, such as fire extinguishers, heating boilers, self-contained air breathing equipment, air conditioning systems, and instrumentation.
- Mobile equipment for gases and liquids covered by the Code of Federal Regulations, Title 49.
- Pressure gages used in systems which operate with pressure less than 150 psig are excluded (for water system gages, a 250 psig exclusion applies).
- Temporary flex hoses used for test or checkout purposes or to connect portable/mobile equipment.
- Utility compressed air systems with pressures less than 150 psi. This exclusion is for uncontaminated compressed air used for air-operated tools and other shop-type applications.
- Vessels excluded from American Society of Mechanical Engineered (ASME) Boiler and Pressure Vessel (B&PV) Code Section VIII, Division 1, paragraph U-1, and Division 2, paragraph AG-121.
- All potable water systems.
- All clean water systems that have no potential for operation above 250 psig. (Relief devices in these systems cannot be set above 250 psig.)
- Launch associated water systems when maintained at less than 250 psig.
- Hydraulic systems designed to consensus standards and considered as utility services.

Exclusions for other low-energy, low-risk systems will be considered by the Pressure Systems Manager (PSM). All proposed exclusions from the program will be presented as a request for exemption. Requests for exemption should include all information about the PV/S including fluid type, maximum operating pressures, pressure cycles, vessel and component types and sizes, types of material used, and location of the system. The request for exemption should be packaged with enough information to allow assessment of the potential hazards and for justifying exclusion from the program. A sample exemption form, KSC Form 20-168, Deviation/Waiver/Variance Request, is provided in Appendix C. Additional pages should be attached, if necessary.

An example of a system that could have an exemption is a gaseous nitrogen piping system of less than 150 psi design pressure that is outside, with no potential for a nitrogen leak to gather and form oxygen deficient areas. Systems which can be verified as low hazard can obtain an exemption.

1.4 Role of Pressure Systems Manager

The Pressure Systems Manager (PSM) is responsible for reviewing and evaluating all PV/S certification efforts at KSC. The role of the PSM is to continuously monitor and review all certification efforts, as required, to establish a technical assessment of certification program status. Monitoring will include periodic visits and interviews with cognizant NASA and certification contractor staff and witnessing of selected field certification efforts. In order to assure a smoothly functioning program by all certification personnel, the PSM or representative will be responsible for the following:

- Assuring necessary documentation to support the certification program is maintained on all systems owned or operated by KSC or its contractors.

- Reviewing/approving pressure vessel/system certification criteria for special cases not covered in this document, reviewing certification implementation schedules, defining required documentation, analysis, inspection, testing, nondestructive examination, and reporting requirements for pressure vessels and pressurized systems.

- Evaluating exclusion criteria and approving exclusions other than those listed in Chapter 3 of KHB 1710.15.

- Reviewing disposition (i.e., rerate, repair, scrap) of all pressure vessels or systems which do not pass inspection or testing requirements.

- Reviewing, as necessary, hazardous and nonhazardous inspection and test procedures utilized by the certification program to assure adequacy of safety considerations.

- Evaluating supplemental analyses, tests, procedures, and examinations.

- Evaluating proposed wavers/deviations/variances involving pressure vessels and systems covered by the certification program.

- Maintaining a baseline inventory/status of all pressure vessels/systems for which KSC has design/operational responsibility and preparing a yearly summary report for NASA Headquarters.

- Reviewing/evaluating KSC-wide implementation of KHB 1710.15.

- Evaluating modifications to certified/recertified pressure vessels/systems to assure compliance with KHB 1710.15.

- Reviewing, evaluating, and retaining all PV/S certification reports.

1.5 Interrelationship With Other Programs

The purpose of the certification program is to ensure the safety of personnel and equipment by maintaining reliable pressure vessel/systems. Certain pressure components or systems may be routinely tested to requirements which meet or exceed those of the certification program. Such components should not be retested as part of the certification program, but the documentation should be included in a certification package to verify the testing. Testing of components is done to ensure the safety of personnel and equipment, not merely to obtain certification documents.

For example, most safety relief valves are routinely tested under a recall program. The testing of these valves ensures their continued safe use, and should be documented in a certification package. Other types of programs include operation and maintenance instructions (OMI's) and routine service checks. All possible test data sources should be used to supplement the certification package and prevent redundant efforts.

SECTION 2. CERTIFICATION PROGRAM OVERVIEW

2.1 Introduction

The PV/S Certification Program at KSC is undertaken to improve the overall reliability, maintainability, safety, and efficiency of ground-based pressurized systems. The value of the certification program is found in the increased confidence gained in the integrity of important systems, the reduction in the potential for personnel injury, serious system failures, and long-term system operational assurance. PV/S Certification is achieved through the application of a program which combines the following major elements:

- Field surveys and engineering design reviews performed per ASME Code Section VIII, Divisions 1 and 2, ASME B31.3, and any other applicable facility design codes and standards.
- Inspection and testing plans are developed and implemented, and post inspection analyses performed to provide assurance of the structural integrity, pressure-retaining capability, and continued safe operation of key components.
- A configuration management program is implemented for the control of all documentation accumulated during the program to provide guidelines for program coordination, and to provide a permanent tool for tracking the status and configuration of each pressure vessel and system.

The following sections describe the steps involved in establishing a certification program, including the long-term Inservice Inspection (ISI) plan. The ISI program is designed to maintain a high level of confidence in vessels and systems certified under the baseline program. Typically, the certification program can be divided into three major phases:

- **Phase I:** Engineering Analysis, Configuration Baseline Development and Inspection Planning
- **Phase II:** Inspection, Repair, Replacement Program
- **Phase III:** Inservice Inspection Program

Each of these phases is divided into individual subtasks. Each phase is described in this section. Flow charts have been included to point out the relationship between program phases and associated subtasks.

2.2 Phase I: Engineering Analysis, Configuration Baseline Development and Inspection Planning

The certification of PV/S at KSC, many of which were designed and constructed over twenty years ago, involves a number of unique problems. These problems areas follows:

- A complete inventory of vessels and components is typically unavailable.
- Original documentation describing the initial design and subsequent modifications is often incomplete.
- Inspection and repair records are widely dispersed and are frequently unavailable for review.
- Responsibility for repair, replacement, or modification of a system has, typically, not been coordinated by a single group or individual.

This overall lack of an integrated program results in a loss of control over system configuration and increases the possibility of service failures. The coordinator of an integrated certification program must be prepared to begin with a careful inventory of system components, followed by an exhaustive search for documentation on each item inventoried. Once this database is established, an engineering design and operability evaluation using applicable codes and standards can be conducted. To manage this task, KSC has developed certification guidelines in the form of a hndbook (KHB 1710.15) to maintain consistency at KSC. The following sections outline each of the subtasks involved in the initial task of this program. Figure 2-l illustrates the major subtasks for Phase I of an Integrated Certification Program.

2.2.1 Field Surveys

A survey of all systems is the first step in developing an adequate database on all vessels, relief devices, and associated components. This survey is designed to uniquely identify each component, accumulate manufacturer nameplate data, and define system pressure boundaries. In addition, all available system documentation should be gathered from the facility staff, as well as any available data on operating history, including previous service fluids.

2.2.2 Preliminary Priority Grouping

To achieve an orderly review of documentation and perform engineering analysis on a timely basis for high hazards systems, a priority grouping should be established. Priority levels should reflect the PV/S current service and potential for injury to personnel and damage to one-of-a-kind facilities. Certification efforts can then concentrate on those vessels and systems involving the most hazard.

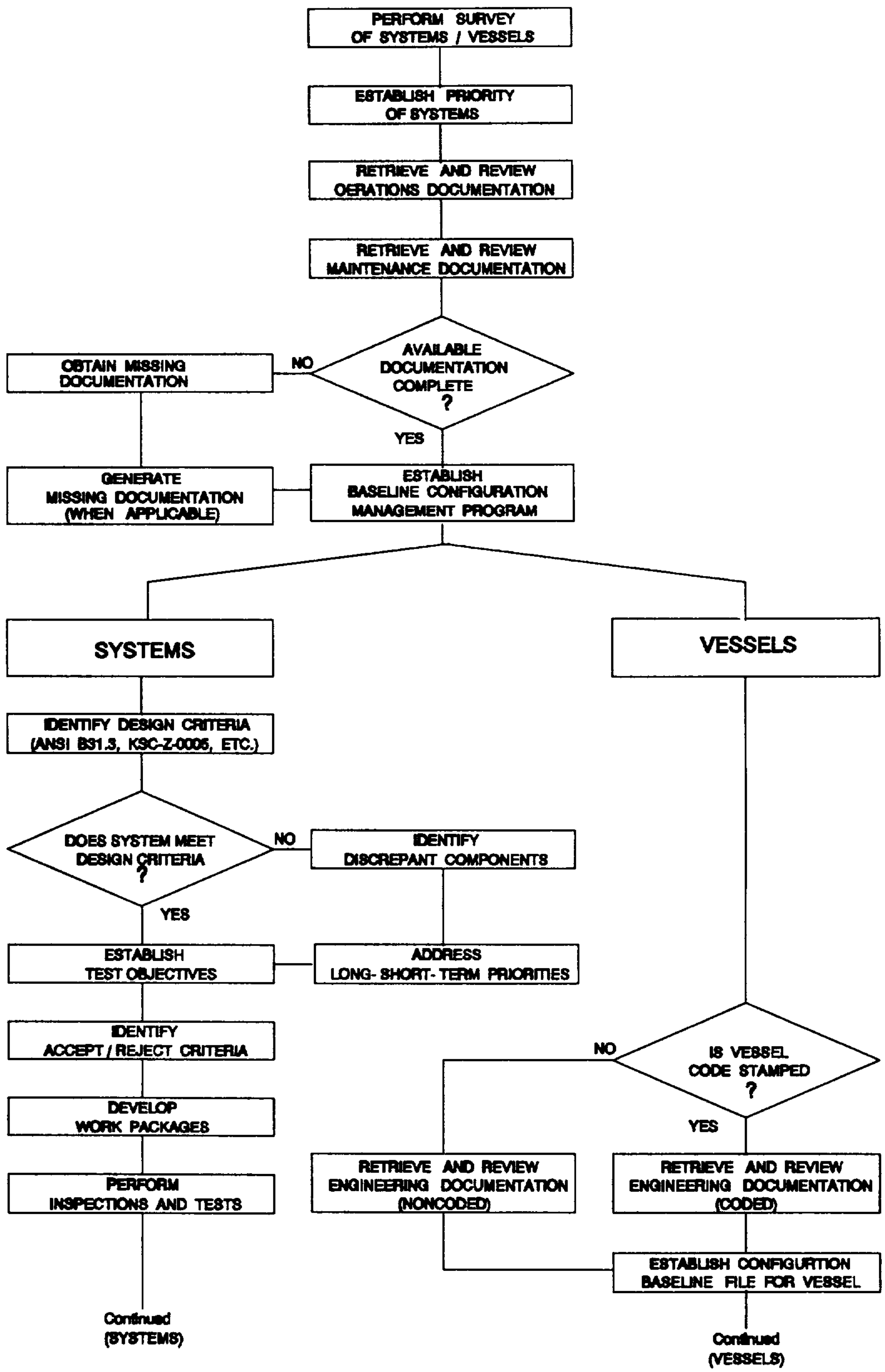

Figure 2-1 Phase I, Engineering Analysis, Configuration Baseline and Inspection Planning

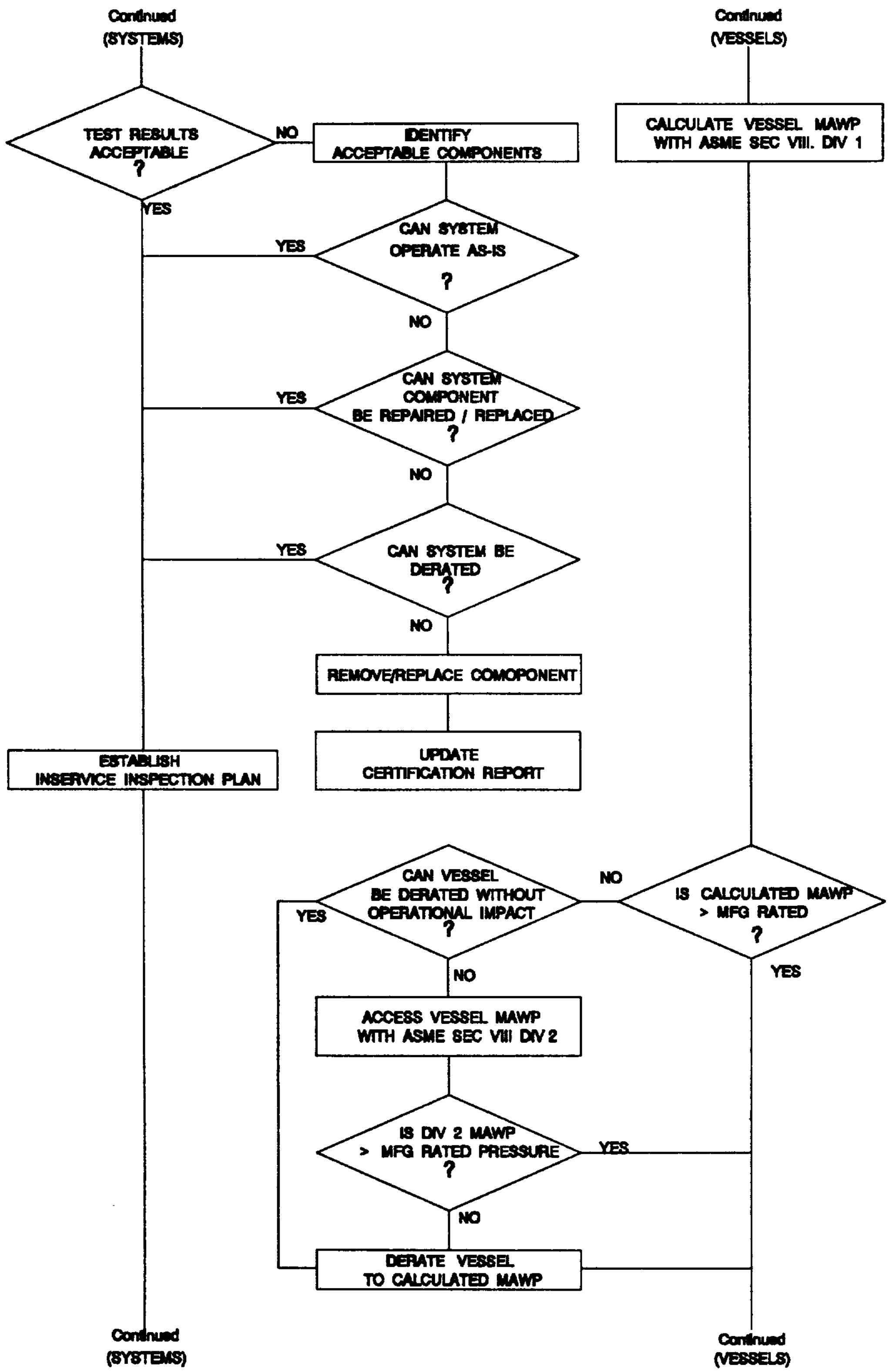

Figure 2-1 (Continued) Phase I, Engineering Analysis, Configuration Baseline and Inspection Planning

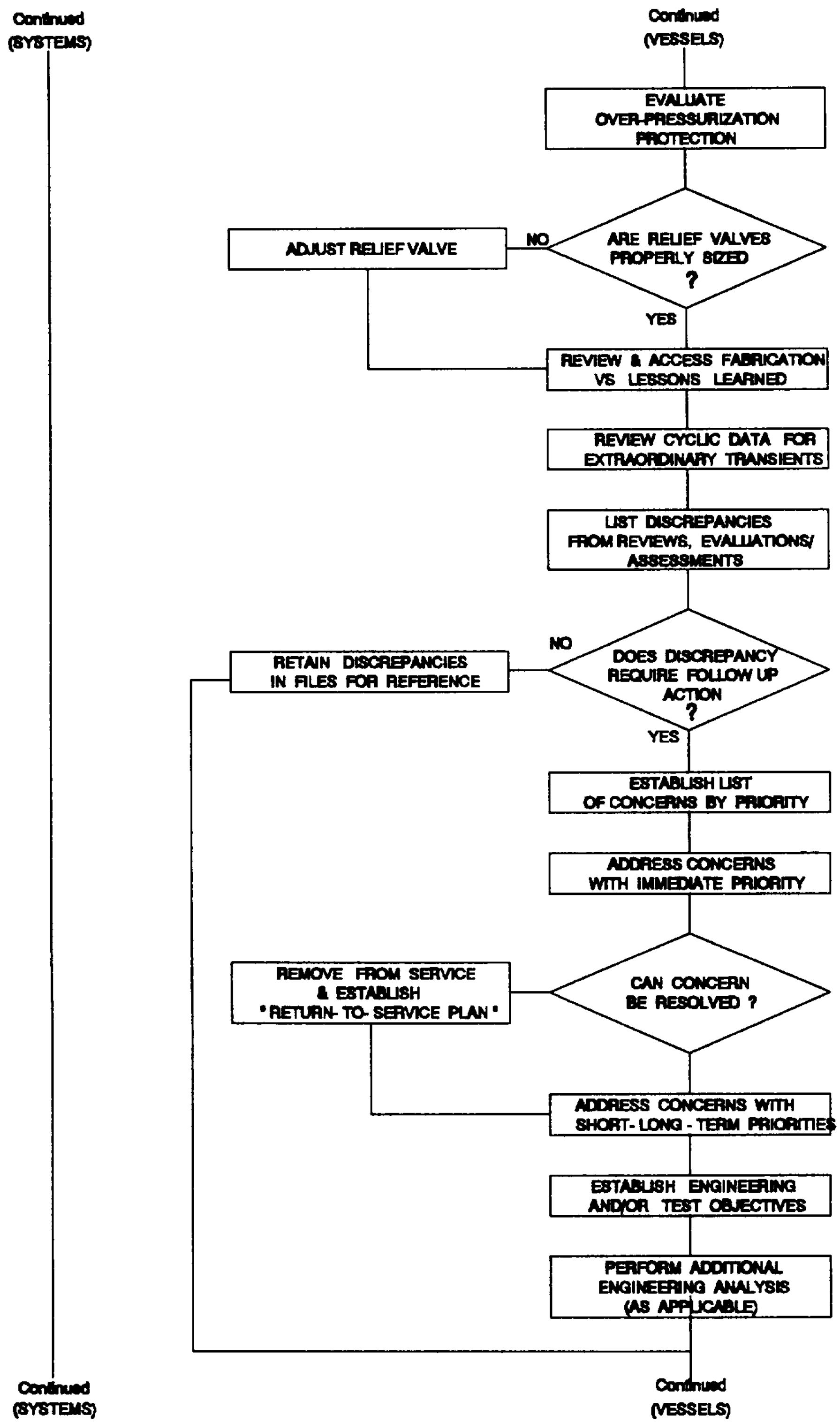

Figure 2-1 (Continued) Phase I, Engineering Analysis, Configuration Baseline and Inspection Planning

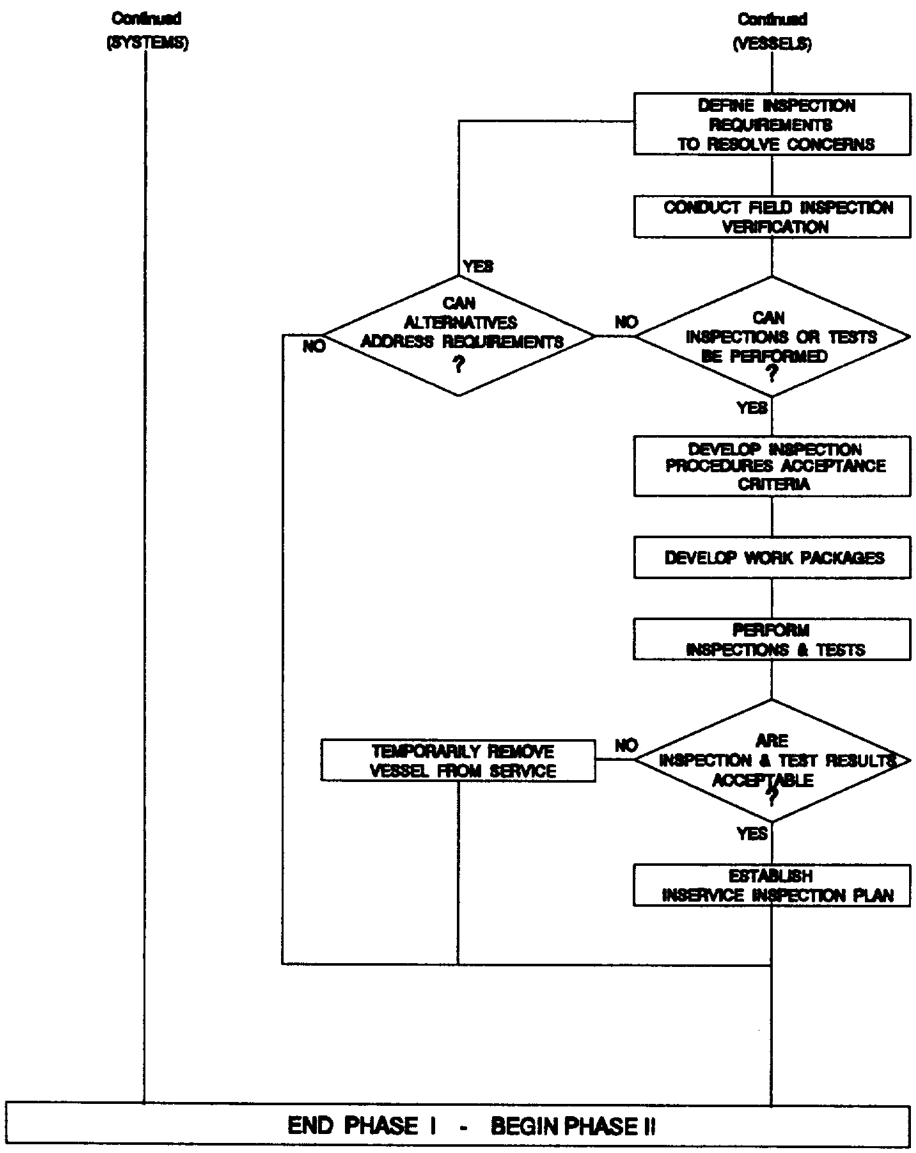

Figure 2-1 (Continued) Phase I, Engineering Analysis, Configuration Baseline and Inspection Planning

2.2.3 Documentation Review, Retrieval, and Generation

The establishment of a database for each vessel and system is the first task in the development of a complete configuration management program. The preliminary task in this process is the accumulation and review of documentation gathered from the facility archives and site personnel. Verbal histories from site personnel can be a valuable source of information and, thus, should be carefully documented. This verbal information is, typically, compiled as part of the initial system survey. Due to the age of many systems, written documentation is often incomplete or unavailable. However, its retrieval provides an important part of operational history. Documentation on pressure vessels can be obtained from a number of sources, depending on the status of the original design. General categories of surveyed vessels are:

- **Pressure Vessels Manufactured to ASME Code Specifications, with ASME Code Stamp and National Board Number**
  The Manufacturers' Data Report (ASME Form U-1 or equivalent) can be obtained from the National Board of Boiler and Pressure Vessel Inspectors, Columbus, Ohio, for a minimal charge. It should be noted that only those ASME coded vessels with National Board (NB) numbers are on file at the NB (and even then, not all NB stamped pressure vessels have records on file with the NB).

- **Pressure Vessels Manufactured to ASME Code Specifications with ASME Code Stamp but no National Board Number**
  The only source of Manufacturers' Data Reports for these vessels are the original manufacturer, or past or current owners of the vessel. Manufacturers will, typically, purge their files periodically and therefore retain records for a relatively short period of time. Additionally, many manufacturers may have gone out of business or may no longer produce vessels and associated components. The past or current owners of the vessels may have no requirements to retain records of certification on their pressure vessels and, typically, have no design documentation.

- **Pressure Vessels Manufactured to ASME Code Specifications but not ASME Code Stamped at Time of Manufacture**
  Manufacturers' Data Reports for these vessels may have never been completed. Although the pressure vessel may meet all ASME design requirements, the purchasing organization did not require ASME certification or inspection; therefore, no official data is available. Engineering drawings may be available from the manufacturer, including a majority of the information required for certification analysis. It should be noted the majority of these pressure vessels were not originally inspected per the requirements of the NB.

- **<u>Pressure Vessels not Manufactured to ASME Code Specifications</u>**
  The manufactures may have original drawings or reports on material specifications and inspection results. These pressure vessels may be constructed from non-ASME materials for specific operational requirements. Often pressure vessels built for military usage or to other government design specifications will fall in this category.

The task of documentation review and retrieval may be time consuming and complex, involving numerous phone contacts to trace down one drawing or Manufacturers' Data Report. If documentation cannot be retrieved through this process, it is necessary to develop equivalent information from the vessel or component itself. This generation of design information may involve nondestructive testing and the production of system and component drawings.

2.2.4 Configuration Management Program Development

All tasks previously described have been designed to establish a baseline configuration management program. That is, all information accumulated is compiled in a centralized area. This documentation file should be maintained with up-to-date PV/S certification documentation. This will include changes to the documentation resulting from repairs, replacement, modification, or inspection of the pressure vessels or components. The configuration management program sets guidelines for all documentation which will be generated as part of the future tasks, including engineering analysis, recertification and Inservice Inspection results, system and component drawings, and system and component data.

2.2.5 Engineering Analysis

The documentation describing the system, components and vessels design compiled as part of the baseline configuration management program, is reviewed using the ASME Boiler and Pressure Vessel Code Section VIII, Divisions 1 and 2, ASME B31.3, and additional appropriate codes and standards to determine whether a vessel or component is in compliance.

The Code Design Review consists of a certification of the original design against present code requirements. This may include recalculation of vessel wall thickness, design pressure, and re-evaluation of service conditions. The Code Design Review and Analysis can result in tentative certification to existing design pressure under current code requirements. Further engineering analysis using advanced techniques like Fracture Mechanics, Strain Energy Modeling, or Finite Element Modeling may be required for a complete vessel analysis. This additional analysis is acceptable if ASME Section VIII, Division 2, is used to certify a particular vessel. It has been found that a pressure vessel or system may require derating from the nameplate working pressure or require physical modification for a number of reasons: (1) the original design code specifications may have been incorrectly applied; (2) material specifications may have changed since the original design and manufacture; (3) the current code specifications may be different from the original specifications; (4) the existing pressure vessel application is not in conformance with its original design intent; and (5) relief devices, piping, or components may be inappropriate for current service.

2.2.6 Inspection Program Development

The development of a vessel and system-specific inspection program establishes baseline data for both the initial certification and for a long-term Inservice Inspection (ISI) plan. The documentation available from field surveys and through configuration management baseline programs is required to confirm the initial design, operation, maintenance, and existing inspection criteria for the vessels or systems. Additional inspection may be identified at this time to confirm the present design configuration. If minimal documentation is available, and the operating history is not confirmed, extensive examination may be required to establish baseline data on the condition of system components and their individual integrity. Phase I is designed to implement the acceptance criteria for inspections, develop system/component-specific inspections, and develop uniform site-specific inspection and test procedures.

2.2.7 Preliminary Certification and Inservice Inspection and Test Program

Nondestructive Evaluation (NDE) is the primary means for providing assurance of the structural integrity, pressure-retaining capability, and safe operation of the vessels and systems. Specific examination requirements can be developed for each system, including all system components such as vessels, piping, threaded fittings and welds, relief valves, pressure gages and switches, clamps and support structures, and flexible hoses. The examinations and tests are based on the results of the preliminary engineering analysis of this program and the programs currently in place at KSC.

These examinations and tests are selected on a case-by-case basis, as applicable to a given system or component.

2.2.8 Field Verification

Following the development of the initial system-specific certification and ISI plan, a field verification for system configuration and inspectability should be conducted. This field verification should note any inconsistencies between system operating characteristics and the documentation available. Included in the field verification are any operational and/or physical access constraints that preclude the use of any specific NDE techniques. The surveyor should be familiar with the NDE practices/techniques required, and the operational restraints placed on the system by the facility staff, prior to initiating the field verification.

Results from the field verification may indicate further testing, engineering analysis, component repair, or component replacement are required. Complete documentation of all findings is required for baseline documentation.

2.2.9 Summary of Phase I

The results of Phase I of the Certification Program are preliminary in nature, establishing operating conditions and setting the foundation for the inspection program. Initial Inservice Inspection (ISI) programs can be established at this time; however, the results of any test program may alter inspection schedules.

Phase I preliminary engineering analysis, configuration baseline development and inspection phase is summarized below:

- A preliminary field survey is completed to establish the inventory of pressure vessels, components, and system boundaries.
- A priority grouping is established based on location, contents, potential for failure, and impact of failure.
- Documentation review, retrieval, and generation is performed to establish the configuration management baseline.
- An engineering design review is undertaken using applicable codes and standards to provide preliminary certification of design pressure and service conditions.
- Preliminary certification inspections and tests are developed to generate system or vessel specification.
- A field verification is completed to assure that the system configuration, examinations, and tests are compatible and current with system operation.
- Certification and ISI plans are finalized to establish the program basis for Phase III, program implementation.

2.3. Phase II: Inspection, Repair, Replacement Program

Once a complete system baseline is established, it becomes necessary to implement an inspection program and a repair program to bring a system to current requirements. Typically, the field verification of a system, as discussed in Phase I, identifies the requirements for further inspections, replacement, or repair. Figure 2-2 illustrates the major subtasks for Phase II of a certification program. Care in coordinating the implementation of Phase II to minimize impact on facility operations is an important consideration.

2.3.1 Inspection

The NDE's performed on a vessel or system may detect unacceptable indications. Detailed acceptance/rejection criteria can be found in the applicable portions of consensus codes and standards. Unacceptable indications may result from these inspections. At times, all of the information on these unacceptable indications may not be available, due to the limits of the inspection technique, to make an accurate judgment. Hence, an additional inspection method may be prescribed to further characterize a faulted area. It is important to note that some techniques may show an area as acceptable, where another technique would show the same area as unacceptable. Therefore, it becomes extremely important to understand the geometry, fit-up, inspection limitations, and material properties for the area of interest.

If, upon completion of all inspections, the faulted area is unacceptable, then additional engineering analysis may be performed for the flaw as discussed in Phase I. The engineering analysis will conclude one of three results: (1) continue operation or modify operation with an ISI program suited to monitor the flaw, (2) recommendation for repair of the component with return to service or, (3) remove the component from service.

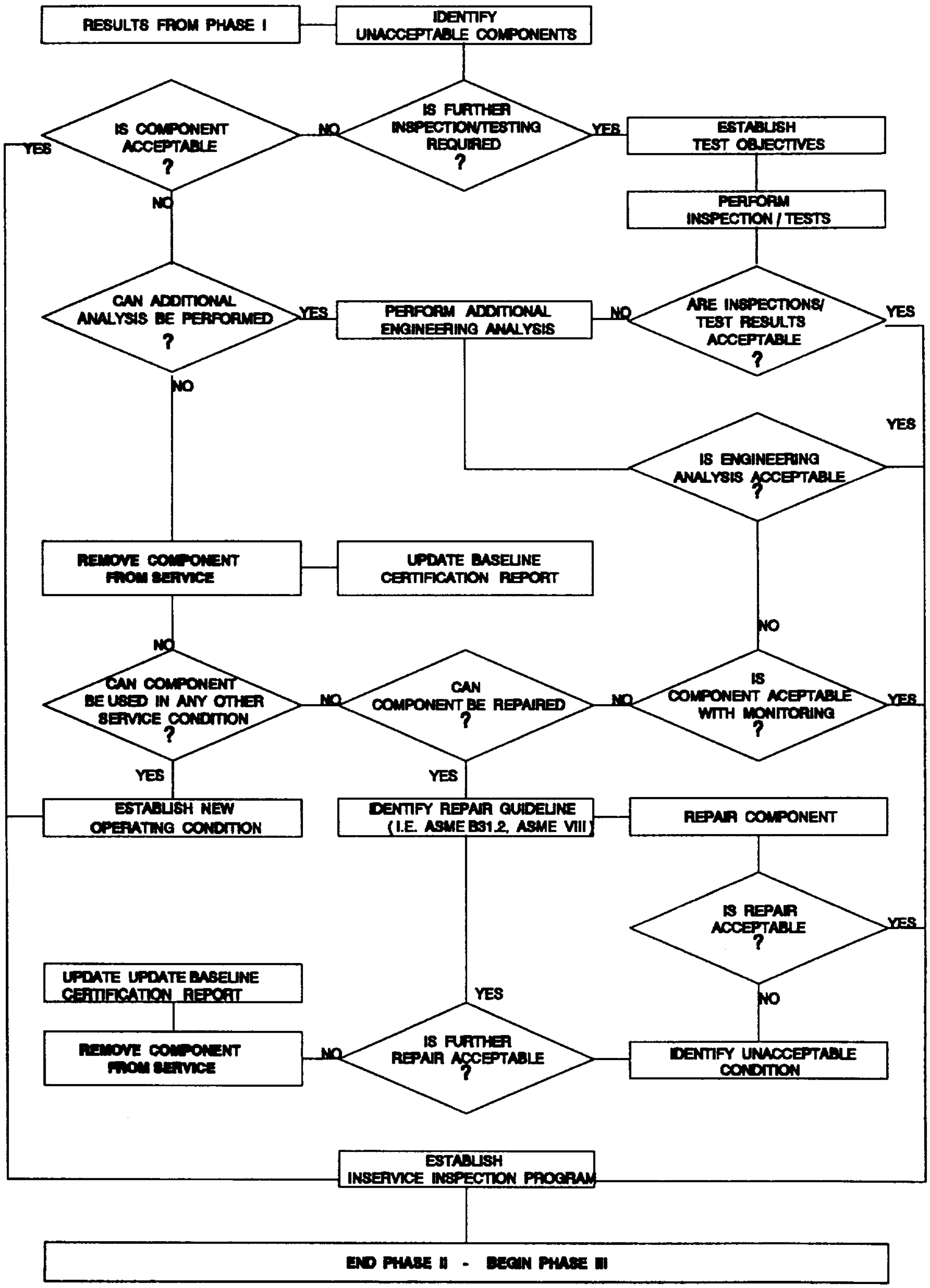

Figure 2-2 Phase II Inspection, Repair, Replacement

2.3.2 Repair

In-place repairs to system components are typically limited to the vessels or system piping/tubing. Other system components at KSC, such as valves, filters and regulators are typically inspected/repaired on an as-fail basis or, if the component is critical to launch operations, monitored in a preventive maintenance program. Pressure gages, relief valves, and flex hoses are monitored in a recall program.

All repairs to vessels and system must meet the requirements of the appropriate KSC design standards. It is prudent to provide KSC's Pressure Systems Manager visibility over the requirements for repair, the repair process, and results of the repair program. All vessel modifications must be reviewed by the O&M/design organization before work is initiated.

Repairs to the system pipe/tube network should be made by qualified personnel. System repairs should met the requirements of ASME B31.3 or the appropriate KSC design standard. Special attention should be given to those materials sensitive to heat input from weld processes. Additionally, operational service may dictate the level of quality associated with the repair.

Repairs to vessels should meet the requirements of the National Board of Pressure Vessels Inspectors Handbook, NB-23, and the appropriate KSC design standard. Additionally, repairs on vessels should meet the requirements of ASME Boiler and Pressure Vessel Code, with the exception that an R-stamp is only required for vessels that have an ASME Code stamping. An equivalent level of quality, integrity, and documentation must be maintained for non-coded vessels. For vessels that were not originally registered with the National Board, alternate "R-1" repair forms can be obtained through third party inspectors and registered in their files.

Upon final acceptance of the repair, a revision to the baseline certification should be provided to maintain a current configuration of the pressurized systems.

2.3.3 Replacement

Replacement of a component is an acceptable method to correct faulted conditions. It is beneficial to perform a cost study between alternatives prior to initiating a replacement program.

In specifying a replacement component, care is required to match the new component with the system service conditions (i.e., design pressure, service fluids, and operating parameters) and that the new component is acceptable to KSC's design requirements and consensus standards.

When a component is replaced, the certification report may require updating to reflect the new system configuration.

When replacing a component, the old item, if no longer useable, should be configured in such a manner that it becomes inoperable. For example, pressure vessels should be drilled or cut so that they no longer can hold pressure (Ref. KHB 1710.15, Chapter 9, paragraph 902).

2.4 Phase III: Inservice Inspections

An Inservice Inspection (ISI) and test plan is a list of inspections and tests, and the frequency, to be performed on the PV/S. The plan is designed to provide assurance that any concerns identified in the certification process are monitored and re-evaluated on a periodic basis. Figure 2-3 illustrates the major subtasks for Phase III of a certification program. Hence, the plan is developed based upon the results analyzed in the engineering evaluation of the certification process.

2.4.1 Development

Criteria for establishing an ISI Program is based on the system configuration and results of Phase I and II. Additionally, the hazard level associated with the systems operating conditions and proximity to populated facilities are considerations. Recertification of PV/S should not exceed a 20 year period for any system.

Guidelines for system ISI are found in NHB 1700.6. However, each certification contractor in evaluating each system in earlier program phases may alter these guidelines to meet the systems operational expectations.

2.4.2 Implementation

The configuration database and baseline certification report identify the specific system ISI Plans. The initial ISI Program established through the guidelines of NHB 1700.6 can be modified to reflect a different inspection interval as discussed in Phase II. Implementation of these plans is required over a lengthy service period.

To ensure each component is inspected at timely intervals, an active database which tracks the component and inspection data must be maintained.

Some methods available to monitor ISI at KSC include: operational recall; maintenance; scheduling database; the certification database requirements of KHB 1710.15; or the establishment of a separate, monitored database by the PV/S certification group. With proper input, systems configuration, maintainability, reliability and service conditions will be monitored and remain current for the certification period.

Upon completion of each ISI task or groups of tasks, the present system configuration should be reviewed against the baseline configuration. Hence, system degradation will be monitored, and the system baseline reports will be accurately maintained.

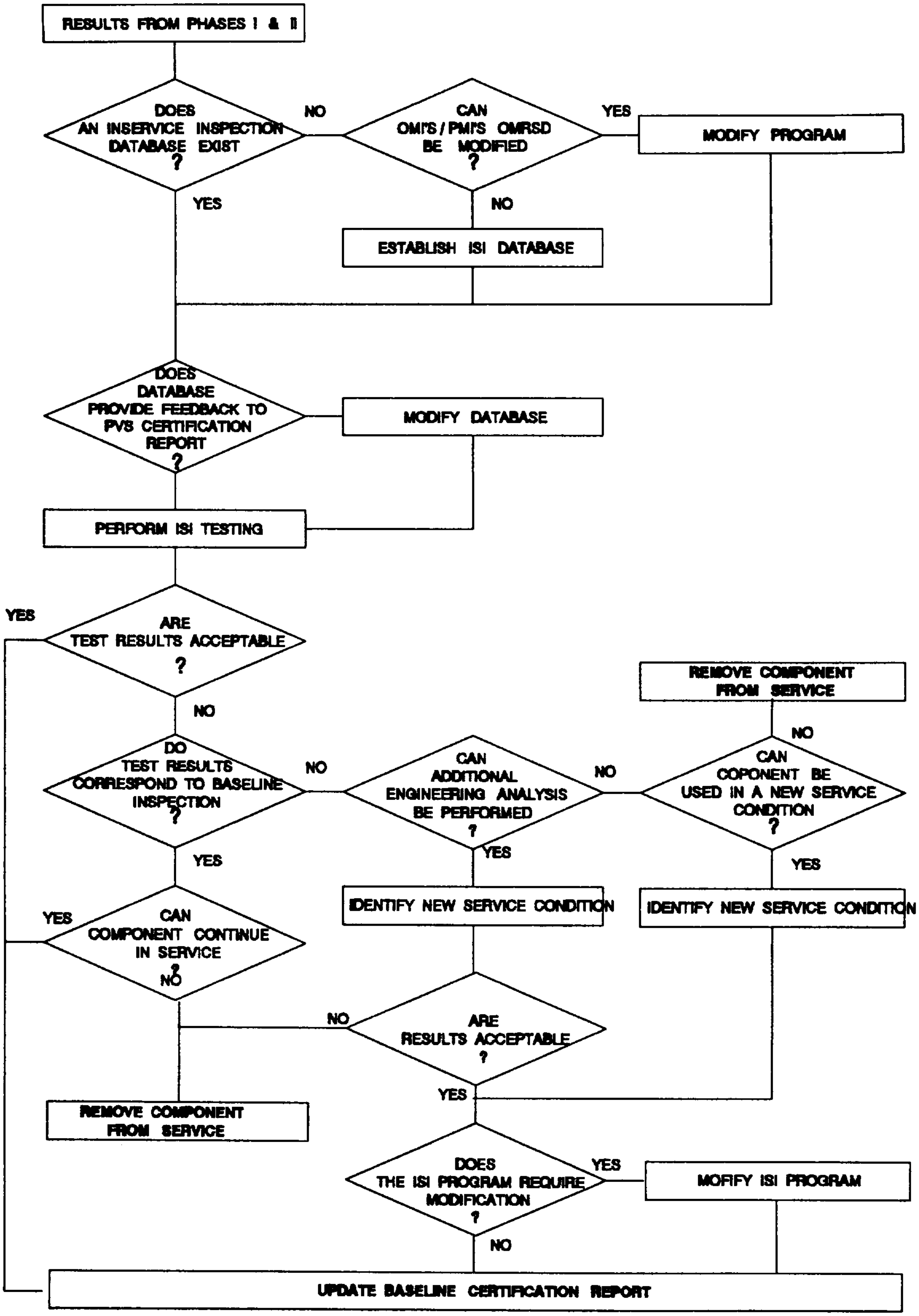

Figure 2-3 Phase III, Inservice Inspections

SECTION 3. PV/S INVENTORY AND CERTIFICATION DOCUMENTATION REQUIREMENTS

3.1 Overview

Establishment of an inventory of PV/S, followed by the collection of certification documentation, is the first step in the performance of a certification program and provides the basis for the certification program. Included in this effort are reviews of existing inventory lists, drawings, and documentation files, as well as actual field surveys of the PV/S.

3.2 Field Survey for PV/S Inventory

A survey of all PV/S is the first step in developing an adequate database on all systems, vessels, and components. The survey should result in a detailed inventory of all PV/S and pressure vessels to be included in the certification program. The exclusion criteria discussed in Section 1.3 can be used in screening systems, along with Chapter 3 of KHB 1710.15. The resultant inventory list of systems and vessels will then become the basis for scheduling and implementing the remaining certification tasks.

KHB 1710.15, Chapter 10, requires all PV/S included in the certification program be identified in an inventory and certification status database. The reporting requirements sheets of KHB 1710.15 provide the minimum database input requirements for PV/S, and their certification status. The database files are to be updated quarterly by each PV/S organization. All KSC organizations participating in the certification program are required to provide updates to the Pressure System Manager.

Verification of the initial inventory lists can be performed in conjunction with the initial field survey. A primary concern during the inventory verification is that all PV/S requiring certification are included. In addition, a review of the listing should eliminate PV/S that should not be included in the certification program. Any system that should be included in the program, but is not identified properly by the responsible contractor, should not be deleted from the program, but should be correctly identified to reflect the proper responsibility.

Pressure systems should be identified by location and fluid contents. System boundaries are generally associated with the charging or filling station and the ultimate usage points. System-to-system interfaces are generally designated at a valve which separates different commodities or users. Further, pneumatic systems are often defined by operating pressure; i.e., establishing boundaries at major pressure regulators.

3.3 PV/S Certification Documentation

Chapter 4 of KHB 1710.15 identifies the documentation required for PV/S certification and is presented here for continuity. Specific documentation required is as follows:

- Documentation Required for Vessels

  (A) Manufacturer's drawings. The drawings can be either certified shop fabrication drawings or as-built drawings. The drawings should contain the following:

  (1) Manufacturer's Name.
  (2) Date of Manufacture (may be stamped on vessel nameplate).
  (3) Dimensions and details of construction.
  (4) Design and operating conditions, including service fluid, operating temperature, and maximum allowable working pressure (MAWP).
  (5) Material Thicknesses (head, shell, etc.).
  (6) Corrosion Allowance.
  (7) Identification of materials, including type of alloy, tensile properties, impact properties, etc.
  (8) Efficiency of weld joints.
  (9) Nondestructive evaluations performed (radiographic, ultrasonic, magnetic particle, etc.).
  (10) Types of tests performed (hydrostatic, pneumatic).

  (B) Design calculations. Design calculations for pressure vessels, which include MAWP and/or design pressure, static head, temperature, wind, vibration, and any other applicable loadings. The applicable codes, standards, or other design basis should be indicated. If the manufacturer's calculations are unavailable, then an engineering evaluation/code compliance evaluation as described in KHB 1710.15, Chapter 5, should be performed.

  (C) Manufacturer's Data Report (ASME Forms U-1, U-1A, U-2, U-3, U-4 as applicable). Manufacturer's Data Reports are furnished with all components built to the rules of the ASME Boiler and Pressure Vessel Code. For Non-Code vessels, the original manufacturer, in most cases, maintains a file of the original design configuration, materials properties and inspections.

  (D) Inspection and test records such as hydrostatic test, ultrasonic, magnetic particle, etc.

(E) Facsimile of nameplate stamping. If not provided by the manufacturer, a pencil rubbing of the actual vessel nameplate as stamped, may be prepared. A photograph which legibly shows all the nameplate data is also acceptable.

- Documentation Required for Systems

(A) End-to-end system drawings/schematics which show, as a minimum, system operating pressure, safety device settings, line sizes, and wall thicknesses of piping/tubing. All components (valves, regulators, filters, pressure gages, etc.) should be identified by part number traceable to the manufacturer. Sufficient fabrication/installation documentation detail should be available to enable analyses to be performed to verify structural adequacy and compliance with design standards for supports, brackets, anchors, etc.

(B) KSC component specification drawing/component maintenance drawing or equivalent, and/or vendor data for each unique component in the system, suitable for verifying pressure rating, materials of construction, flow parameters, operating characteristics, and relief device capability to maintain system pressure within code-allowable limits.

(C) Approved operating or preventive maintenance procedures (OMI's, PMI's) or equivalent, which include requirements regarding periodic maintenance of system components (i.e. relief devices, gages, etc.).

3.4 Sources for Documentation

Much of the documentation identified in the previous section may be available through various sources at KSC/CCAFS, including engineering documentation centers, procurement office files, system operator files, system designer files, or from other cognizant facility personnel. Some documentation collection may require going to outside sources, including the National Board of Boiler and Pressure Vessels Inspectors, component manufacturers/vendors, and previous system operators/owners. Further discussion on the approach used in collecting documentation and other pertinent information is provided in the subsections that follow.

3.4.1 Record Nameplate Data

Recording of nameplate data from pressure vessels is important to the accumulation of documentation. A special form entitled "Pressure Vessel Nameplate Review" (Appendix C) has been developed, based on the ASME Code marking requirements, to assist in recording pertinent data from vessels.

During the initial field survey, the form can be filled out from information on the nameplate affixed to each pressure vessel by the manufacturer. The Serial Number, National Board Number, and Manufacturer's Name obtained from the nameplate are invaluable in obtaining required data for certification (keep in mind some vessels may not have a National Board Number). Nameplates may be painted over and will require the paint to be removed before the data can be recorded. On pressure vessels which do not have nameplates attached, look for data stamped into the head of the vessel, which may be traceable to the fabrication facility. Nameplates may also be found affixed to some part of the vessel support structure.

3.4.2 KSC Documentation Sources

Primary sources of drawings, vendor data, historic records, specifications, etc., which will assist in the preparation of certification packages, are contractor and government files located at KSC.

Contractors responsible for operation and maintenance (O&M) and engineering functions may have documentation files containing many of the required items needed for certification. The O&M files are generally on site where the systems and facilities are located. Historical records, such as equipment operating and maintenance data sheets and procedures, may be found at these facilities. Drawings and system schematics are generally kept current by site personnel. Therefore, an investigation of files kept by system operating personnel is helpful in locating pertinent documentation. Engineering and configuration management files within the contractor organizations will provide information on vendor data, drawings, specifications, and modifications. In many cases, if manufacturers' serial numbers for vessels differ by only one or two numbers, the drawings for one vessel may provide information about the other vessels.

Government documentation sources exist in libraries, archives, and various documentation centers located at KSC. The KSC Library, located in the Headquarters Building (M6-399), has specifications and standards on file. Also, the Engineering Documentation Center (EDC) is located in the Headquarters Building, Room 3430. Many government branch and section offices also have documentation files where specific systems data is maintained. These files are generally the property of individuals responsible for specific systems.

3.4.3 Outside Sources of Documentation

Documentation required for PV/S certification, which is not available from on-site sources, may often be obtained from sources within the industry and, perhaps, from other government facilities. Manufacturers' Data Reports for ASME Coded and Registered vessels can usually be obtained from the National Board of Boiler and Pressure Vessels Inspectors, 1055 Crupper Avenue, Columbus, Ohio 43299.

Generally, for all vessels, the original manufacturer should be contacted for vessel design drawings, data sheets, design calculations, fabrication data, test data, and other pertinent information which will assist vessel certification. Although manufacturers' data, typically, may be purchased (if available), a single drawing or calculation will be suitable for multiple vessels of identical design and construction. Several pressure vessel manufacturers are identified in Table 3-1, with geographical location and phone number, where available.

Pertinent pressure vessel certification data may also reside with the previous owner of the vessel (i.e., prior to KSC NASA procurement). A search of procurement documents may identify a previous owner of the pressure vessel and give a contact source, such as another NASA facility, military installation, or industrial facility. Contacting these previous sources may produce pertinent information for fatigue life analysis and service history. Vendor data for components such as valves, gages, filters, etc., which is not available on site, is best obtained directly from the vendor.

TABLE 3-1 Pressure Vessel Manufacturers

Manufacturer	Location	Telephone	Notes
A. O. Smith Corp.	Milwaukee, WI	414-447-4409	(1)
Advance Tank	Green Bay, WI	414-276-8348	
Air Products 12	Allentown, PA	215-481-4911	
American Bosch	Springfield, MA	413-781-2200	
American Standard	Detroit, MI	313-931-4000	
American Welding Mfg. Co.	Jessup, GA	*	(2)
Autoclave Engineers, Inc	Erie, PA	814-838-2071	
Buehler Tank & Welding Works	Orange, CA	714-538-8805	
Butane Tank Corp.	Los Angeles, CA	213-261-5118	
Capital Westward Mfg.	Paramount, CA	213-634-2013	(3)
Chicago Bridge and Iron (CF Braun Co.)	Chicago, IL	312-427-6708	
Cryenco	Denver, CO	303-287-3371	
Delta Tank Mfg. Co.	Macon, GA	*	
Douglas Aircraft LB	Long Beach, CA	*	
Downey Welding & Mfg. Co.	Downey, CA	213-923-9616	
Environment Inc.	Van Nuys, CA	*	
Foster Wheeler	Dansville, NY	716-335-3131	
Grave	Pasadena, TX	713-474-5121	
Greer-Hydraulics, Inc.	Los Angeles, CA	213-725-0110	
Harsco Corp.	Bloomfield, IA	*	(2)
Haskel Engrg & Supply Co.	Burbank, CA	213-843-4000	
Hoke, In.	Cresskill, NJ	201-568-9100	
Horton Tank/Chicago Bridge & Iron	Chicago, IL	312-427-6708	(4)

(continued)

TABLE 3-1 (Continued) Pressure Vessel Manufacturers

C. E. Howard Corp.	South Gate, CA	213-961-1502	
Hydrill Company	Houston, TX	713-449-2000	
Herrick L. Johnston, Inc.	Columbus, OH	*	
Kaiser Steel Corp.	Napa, CA	707-224-5421	
LA Boiler Works	Los Angeles, CA	213-221-1186	
Leader Iron Works	Decatur, IL	*	
Marison	South Elgin, IL	312-742-2500	
NASA/Teledyne	Huntsville, AL	205-453-2121	
Nash Machine Co.	*	*	
Nat'l Annealing Box Co.	Washington, PA	412-225-6000	
Nat'l Pittsburgh/US Steel	Mckeesport, PA	412-664-6613	
Nat'l Tank & Mfg. Co.	Los Angeles, CA	213-583-1841	
Nat'l Tube/US Steel	Mckeesport, PA	412-664-6613	
Nooter Corp.	St. Louis, MO	314-621-6000	(1)
Plant City Steel	Clearwater, FL	813-752-1133	(2)
Southwest Fab & Welding Co	Houston, TX	713-928-3451	(5)
Steel & Alloy Tank	Newark, NJ	*	
Struther Wells	Titusville, PA	814-726-1000	
Taylor Forge	Paola, KS	913-294-5331	
U. S. Steel Corp.	Mckeesport, PA	412-664-6636	
Water Treatment Co.	*	*	
Westward Engrg & Mfg Co.	Paramount, CA	213-634-2013	(2)

Notes

(1) All documentation stored by A.O. Smith was destroyed or discarded. Vessel drawings can be obtained from Nooter Corporation.

(2) American Welding and Mfg. Co. and Harsco Corporation are subsidiaries of Plant City Steel.

(3) Capital Welding merged with Westward Engineering and Manufacturing Company to form Capital Westward.

(4) Horton Tank is a subsidiary of Chicago Bridge and Iron.

(5) Vessel documentation is discarded after 3 years.

* ... No information about the company has been obtained.

3.5 Documentation Verification

All PV/S documentation collected as part of the certification process should be verified for accuracy in accordance with KHB 1710.15. Verification is generally accomplished through field investigations. This will include system walkdowns, nameplate reviews, component serial number (or other identifying number), and relief valve and flexible hose marking verification. The system drawings should be reviewed during the walkdown to verify component manufacturers nameplate data, as-built configuration, piping/tubing (size, schedule, and wall thickness), connection fittings (type, size, and schedule). The drawings should be redlined for engineering update to include the required system information.

3.6 Priority Categories

The sequence of system/vessel certification should be established according to the following priority categories:

- Category A - located near administrative office complexes, cafeteria, public and private roads, and land--where if a mishap occurred it would probably affect nonoperational personnel not associated with the facility--and non-related facilities (highest priority).
- Category B - so located that a mishap would probably only affect the immediate operating personnel or the immediate facility. Barricades, natural terrain, etc., may be used as methods of providing protection of nearby personnel and facilities.
- Category C - all vessels/systems not covered by Category A or B, e.g., inactive systems, derated systems retaining a small positive pressure to prevent seal damage or internal contamination, etc.
- When pressure vessels/systems (PV/S) meet the requirements for two categories, the highest priority category should be assigned.

The purpose of establishing priority categories is to provide certification efforts on PV/S of the greatest potential hazard to personnel before those of relatively low hazard. Priority Category "A" PV/S should, therefore, be investigated before Priority Category "B" PV/S. This philosophy may be incorporated into a more detailed system-by-system certification schedule. Within a given priority category, systems may be evaluated on a relative hazard basis. For example, hypergolic (lethal) and high pressure gas systems would be analyzed, inspected, tested, and repaired/replaced/modified before low pressure nonlethal/nonhazardous fluid systems.

To establish a sequence within a Category, a multi-level priority grouping can be used to rank each vessel/system with respect to relative potential hazard. Priority groups should be developed to reflect the PV/S current service and potential hazards to personnel. Certification should begin with the highest categories (ie. Category A) and then the highest priority group within that category. The following describes the recommended priority group by service and special considerations.

- Priority Group 1: Systems and vessels containing lethal substances (including hypergolics) and pneumatic systems and vessels with design pressures of 3000 psig or greater.
- Priority Group 2: Flammable/combustible fluid systems and pneumatic systems with design pressures less than 3000 psig.
- Priority Group 3: Cryogenic systems and vessels and other liquid systems (e.g., hydraulics).

3.7 Certification Database

To assist in the tracing and management of the PV/S Certification Program, KSC has developed and implemented a PV/S Certification Database. This database is accessible to all KSC PV/S contractors and is a requirement of KHB 1710.15. The database itself is a user friendly, menu driven, multi-tiered, program that is personal computer (PC) based.

The documentation generated during the three program phases becomes the input into the database. In general, the input parameters for pressure vessels includes the nameplate data, design and operating pressure, ISI tests and due dates, along with the system/vessel identifier. Input parameters for the system within the database are similar, except that the only components tracked are those within a periodic recall system (i.e., pressure gages and transducers, relief devices, and flex hoses). These will only be tracked to the extent necessary to ensure that the periodic inspection, testing, and calibration required in the ISI program is being performed.

SECTION 4. ENGINEERING EVALUATION

4.1 Overview

Certification of PV/S requires an engineering evaluation of all pertinent documentation, an evaluation of the system and components in the as-built condition, and an evaluation of inspection and test results. The objective of certification engineering evaluations are to (1) determine the extent of conformance of PV/S designs with applicable codes, standards, and guidelines, (2) assess the structural integrity of PV/S through review of inspection and test results, and (3) resolve deficiencies in design or integrity by developing and implementing suitable repair, replacement, or modification work packages.

4.2 Documentation Evaluation

PV/S documentation must be analyzed to determine suitability as a basis for certification, as required by KHB 1710.15, Chapter 5. Documentation is determined suitable if the detail provided establishes the design and integrity of PV/S to be in conformance with applicable codes and standards to the maximum practical extent. Documentation required and sources for documentation retrieval were described in section 3. Fluid system designs are to be in conformance with the following KSC standards, as applicable:

KSC-STD-Z-0005	*Design of Pneumatic Ground Support Equipment*
KSC-STD-Z-0006	*Design of Hypergolic Propellants Ground Support Equipment*
KSC-STD-Z-0007	*Design of Hydrocarbon Fuel Ground Support Equipment*
KSC-STD-Z-0008	*Design of Ground Life Support Systems and Equipment*
KSC-STD-Z-0009	*Design of Cryogenic Ground Support Equipment*
KSC-STD-Z-0010	*Design of Environmental Control Systems, Ground Coolant Systems, Coolant Servicing Systems, and Ground Support Equipment*

These standards, latest editions are considered baseline documents for the KSC PV/S certification program, and establish the engineering and technical limitations for materials, processes, methods, engineering practices, and design as applied to a given fluid system type. These KSC standards incorporate, by reference, other NASA/KSC and industry standards for fabrication, design, and installation of system components (e.g., vessels, types of valves, pressure gages, flex hoses, piping/tubing, fittings, etc.). The ASME Boiler and Pressure Vessel Code, Section VIII, Division 1 or 2 as applicable, is the referenced code for the design and fabrication of stationary, unfired, pressure vessels. For example, Divisions 1 and 2 are referenced in KSC-STD-Z-0005. Certification of PV/S at KSC was baselined with the 1983 edition, winter 1984 addenda, of ASME Code, Section VIII. In general, the latest edition and addenda of the referenced codes and standards will be considered the governing documents for future PV/S certification.

The following industry societies and associations can be contacted to obtain copies of referenced codes and standards:

- ANSI Standards prepared by the American National Standards Institute
  1430 Broadway
  New York, New York 10018
  (212) 868-1220

- API Standards, prepared by the American Petroleum Institute
  1801 K Street, N.W.
  Washington, DC 20006
  (202) 457-7000

- ASME Code, prepared by the American Society of Mechanical Engineers
  345 East 47th Street
  New York, New York 10017
  (212) 705-7722

- ASTM Standards, prepared by the American Society for Testing and Materials
  1916 Race Street
  Philadelphia, Pennsylvania 19103
  (215) 299-5400

- CGA Standards, prepared by the Compressed Gas Association
  500 Fifth Avenue
  New York, New York 10036
  (212) 524-4796

- NFPA Standards, prepared by the National Fire Protection Association
  470 Atlantic Avenue
  Boston, Massachusetts 02210
  (617) 482-8755

4.3 Engineering Analysis

Engineering analysis is generally required during the PV/S certification process leading up to the development of engineering work packages, and following the implementation of these packages. Typically, analysis performed prior to the preparation of engineering work packages includes the development of design calculations for pressure vessels and components to support an otherwise incomplete documentation package, and/or the performance of alternate calculations, as necessary, to assure that the system/components design, design documentation and component integrity meet current specified criteria. The extent of the engineering analysis performed depends on the completeness and accuracy of design documentation, the importance of the system, safety, design complexity, degree of standardization, and similarity to previously proven designs.

4.3.1 Vessel Design Verification

Calculations are required for every pressure vessel. In some cases, calculations are part of the documentation obtained from the manufacturer, while in some cases, calculations are unavailable. In these cases, calculations must be performed and documented.

> For example, if design calculations for pressure vessels are not obtained through other sources, they must be generated and should include head, shell, and nozzle calculations including pressure, static head, dead weight, wind, and vibration loads, where applicable, as required by ASME Code, Section VIII.

The ultimate responsibility for the vessel analysis lies with the engineer performing the calculations. According to the ASME Code, the basic concerns which must be addressed as follows:

- Shells with Internal Pressure
- Heads with Internal Pressure
- Nozzle Neck Thickness
- Opening Reinforcement
- Flanges and Pipe Fittings
- Material
- Quality of Workmanship

Typically, the shell is the limiting factor in the design pressure calculations for pressure vessels. In fact, the circumferential stress calculation usually determines the design pressure. Care should be taken to ensure that the proper joint efficiencies and material allowable stresses are used for each calculation. The intent of the code calculations is to ensure the vessels have adequate safety margins at design pressures. Whenever there are discrepancies between the code and the manufacturer's design, the more conservative method is recommended, unless sufficient analysis and documentation are provided to justify the deviation.

Head calculations are required and should use the appropriate equations for each specific head geometry. Just as in the shell, proper joint efficiency and material allowable stresses must be used with each calculation. The six basic types of heads- ellipsoidal, torispherical, hemispherical, conical, toriconical, and flat--all use different equations for determining design pressure.

ASME also provides guidance in performing calculations for nozzle neck thickness, opening reinforcement, and flange design for attachments to a vessel. Additionally, all pressure retaining boundaries must be adequate to meet design loads. Stresses in the vessel must be analyzed, as well as the effects on the vessel at the saddle/vessel interface. Stresses in the support structure must be analyzed where the condition of the support is suspect. The adequacy of the support structures to withstand operating loads may, generally, be determined through visual examination. Calculations for the support structures are required when unacceptable conditions are found during the visual examination. Good engineering practices and interpretations of the ASME Code, along with KSC design standards, should be applied as appropriate.

Additional calculations may be required for external mechanical loads such as wind, seismic, dead weight, vibration, piping, impact, or temperature-induced loads. The effect of these loads must be assessed for each vessel with explanation provided, if the loads are deemed negligible. For the case of vacuum jacketed vessels, the stated MAWP of the vessel should include the vacuum pressure of the vessel annular space.

4.3.2 Additional Vessel/System Analysis

A more detailed stress analysis may be required if a vessel is to be certified in compliance with ASME Code, Section VIII, Division 2. Division 2 provides design calculations for those geometries found in Division 1. However, unlike Division 1, Division 2 allows lower safety margins (i.e., higher allowable stresses) in most instances for identical materials, hence allowing for higher design pressures. Fatigue now becomes a primary design concern, and a cyclic history review is required to determine the materials adequacy to continue in safe operation. Additional analysis performed prior to implementing engineering work packages for a complete system may include-

- Determination of adequate pipe/tube wall thickness
- Piping and component material compatibility
- Safety relief valve set point and flow capability calculations
- Pipe whip calculations
- Piping support analysis
- Fatigue analysis
- Adequacy of component pressure ratings

Following the documentation evaluation, the performance of supporting engineering analysis, and a review of visual examination results, engineering work packages may have to be developed. These packages define, for implementation, the special inspections and tests, repairs, replacement, or modifications necessary to establish the PV/S as certifiable.

Visual examination, followed by more involved nondestructive testing, may identify defects or discontinuities in the system and components which require analysis to assure that the system integrity is not compromised.

The types of analyses which may be required for faulted component integrity include fracture mechanics and detailed stress analysis, and could lead to a destructive analysis involving mechanical property testing, chemical analysis, fractography, and metallography, depending on the type and cause of the discontinuities identified. Loss of wall thickness in pressure retaining components from corrosion, erosion, or wear will require analysis to assure adequacy of the component to sustain the load conditions and to assure allowable stress intensities are not exceeded. Repair or refurbishment may become a necessity at this point. The extent of analysis and testing performed will depend on the importance of the system, its location with respect to populated facilities, and the overall required level of safety. A cost-benefit study may be required prior to additional repair, refurbishment, or replacement.

4.3.3 Design Verification Checklists

KHB 1710.15 requires that all systems be reviewed against the requirements in the KSC design standards. In KSC-STD-Z-0005, the piping for pneumatic systems is required to be designed to meet the guidelines in ASME B31.3, Chemical Plant and Petroleum Refinery Piping Code. ASME B31.3 provides detailed guidelines for the design and installation of piping, components, and supports.

Design verification checklists provide a systematic method of reviewing a system for compliance with design requirements. See Appendix B for a sample checklist which can be used to verify compliance with KSC-STD-Z-0005. Similar checklists should be prepared and used to verify compliance with other KSC design standards (KSC-STD-Z-0006, -0007, -0008, -0009, -0010). Checklists should remain current and incorporate the latest changes to these standards. Systems whose baseline review was to checklists developed for earlier revisions are suitable for continued operation. However, new systems and modifications to systems are to be designed and reviewed to the most current document.

4.4 Additional Engineering Analysis

As the certification of PV/S at KSC continues, specific discrepancies arise that warrant additional engineering analyses. This section contains a brief description of several concerns and the resulting engineering analyses which are generally applicable to all KSC vessels and systems.

4.4.1 Flanges Designed to ASME/ANSI B16.5

Standard flange designs currently used have been around for many years, with operating experience in a wide variety of services. The original designs of ASME/ASNI B16.5, Pipe Flanges, and Flanged Fittings were based on the operating history of the flanges, with little correlation to material properties. In the early 1970's, a revision to B16.5 was made that directly correlated material properties to rated pressures. The standard was not accepted nor used by the industry. However, in 1979 a revised B16.5 was issued. The revision used operating history to establish rated pressures for flanges made out of ASTM A105 material, which is the representative steel for material group 1.1, as identified in B16.5. All other pressure ratings were based on a comparison of material properties with those of ASTM A105. This comparison for establishing rated pressures for various material groups and for various temperature ranges up to 800°F was based on the methods found in Annex D of B16.5.

A question presented early in the certification program at KSC was how to rate flanges that meet ASME/ANSI dimensional standards fabricated of material specifically addressed in B16.5. The particular case involved flanges on the nozzles of vessels manufactured by A.O. Smith with a design pressure of 6600 psig. The flange dimensions are the same as a standard Class 2500, 1-1/2-inch flange, including the number of bolt holes, flange thicknesses, and diameters. However, the flanges are made of A.O. Smith specification 5002 Modified; a non-ASME specified material.

After discussing the question with several flange manufacturers and the Chairman of ASME/ANSI B16.5, the consensus was that there should be no concern. To determine the rated pressure for the flange, simply apply the rules in Annex D of B16.5. The A.O. Smith flange has a higher yield strength than A105 material. Thus, according to D2.2 (4), the selected stress, S1, is based on one of several options, but can be no higher than the minimum value for any material listed in a given material group. However, for temperatures less than 500°F, Group 1.2 is to be used. Thus, from Table 1D of B16.5, the rated pressure for the flange is 6250 psig for ambient temperatures. The vessel, therefore, must be derated to 6250 psig MAWP. Furthermore, the highest allowable pressure for any Class 2500 ASME/ANSI flange is 6250 psig, which may limit the operating pressure of systems originally designed for at 6600 psig.

4.4.2 Bolting for ASME/ANSI Flanges

ASME/ANSI B16.5, Section 5.3, provides specific guidelines for bolting in standard ASME/ANSI flanges. During system walkdowns, a comparison to Table 1B of ASME/ANSI B16.5 identified bolting not acceptable for use in high pressure flanges. Low strength bolting (such as A193-B8, Class 1) may only be used in Class 150 or 300 flanges. Table 4-1 lists flange bolting materials found in use at KSC. Some of the bolting found in Class 2500 and 1500 flanges at KSC should only have been used in Class 150 or 300 flanges. The low strength bolting identified is unacceptable and should be replaced with A193-B8 Class 2 bolting, an intermediate strength stainless steel bolting, rather than high strength carbon steel bolting such as A193 B7, due to the severe corrosion problems at KSC. However, adequate assembly requirements should be established to minimize corrosion of the bolting materials. Stress corrosion is a common failure mode of stainless steel bolts; therefore, type 303 stainless steel bolting should be avoided because of its susceptibility to stress corrosion in the KSC environment. During system design walkdowns, all low strength bolting as well as all type 303 stainless steel bolting should be identified and replaced before the system is certified. All bolting should be reviewed per the criteria of ASME B31.3, paragraph 309, and appendix A, Table A-2. For example, this review reveals that A193-B7 bolting may not be used below -20 degrees F unless it has been quenched and tempered, in which case, it may be used as low as -50 degrees F without impact testing.

TABLE 4-1 Sample Bolting Materials Found at KSC

SPEC. GRADE	MARKING	MATL	YS	TS	STRENGTH	USES
A193-B7	B7	4140	105K	125K	HIGH	ANY FLANGE
A193-B6	B6	410	85K	110K	MEDIUM	ANY FLANGE
A193-B8 Cl.2	B8	304	65K	105K	MEDIUM	ANY FLANGE
A320-B8C Cl.2	B8C	347	65K	105K	MEDIUM	ANY FLANGE
A320-B8M Cl.2	B8M2	316	65K	95K	MEDIUM	ANY FLANGE
A320-B8T Cl.2	B8T	321	65K	105K	MEDIUM	ANY FLANGE
A320-B8F Cl.2	B8F	303	65K	105K	MEDIUM	ANY FLANGE
A193-B8 Cl.1	B8	304	30K	75K	LOW	CLASS 150/300
A320-B8C Cl.1	B8C	347	30K	75K	LOW	CLASS 150/300
A320-B8M Cl.1	B8M	316	30K	75K	LOW	CLASS 150/300
A320-B8T Cl.1	B8T	321	30K	75K	LOW	CLASS 150/300
A320-B8F Cl.1	B8F	303	30K	75K	LOW	CLASS 150/300

4.4.3 Fracture Mechanics

Linear Elastic Fracture Mechanics (LEFM) is a method for predicting vessel failure mode and estimating the remaining cyclic life in components with known defects. Application of LEFM depends on knowing material property data for the service environment of concern and is, typically, not supplied by vessel manufacturers. Material data can be found in ASTM standards for common steel in common environments, but involved literature research is often required for vessels, due to frequent use of more exotic materials. LEFM can be a useful tool only if the proper material properties can be determined.

LEFM analysis assumes that any structure has flaws created during fabrication or through service conditions. The level of stress applied to a given flaw, which would cause it to become an unstable crack, is sought. Flaw growth through the elastic stress field present at a crack tip is dependent on both the flaw shape and specific material properties, such as the critical stress intensity factor (K_c).

For this analysis, crack size assumptions and calculations are to be based on NDE acceptance criteria set by industry codes, actual flaw sizes from NDE, or the maximum stable crack size under operating stresses at given design temperatures and pressures. Steps for each portion of an LEFM analysis tend to yield conservative projections for cyclic life. Methodology is typically based on mono-block vessels of standard construction, but may also be used for multi-layer type pressure vessels. Cyclic life projections for multi-layer vessels also tend to be conservative, since normal crack propagation is interrupted at any layer interface in such vessels.

An LEFM analysis was performed, in conjunction with other engineering analysis and NDE, on a bank of vessels manufactured by U.S. Steel and located at Launch Complex 36. During inspection of these integrally forged vessels, cracks were found using magnetic particle inspection. One bank of 10 vessels was completely refurbished with all identified cracks measured and ground out. LEFM was used to estimate the remaining cycles for the other banks of vessels. The conservative analysis indicated a large number of cycles would be required before these identified cracks would fail. Based on the LEFM analysis, it was determined refurbishment and NDE on the remaining vessel banks could be performed over a 3-year period. LEFM was not used to allow indefinite operation, but as a mechanism for justifying the extension of the refurbishment period.

4.4.4 Vent Line Sizing

The design of vent lines to handle worst case flow rates without significant back pressure should have been considered in the original, system design. For many systems, verification can be accomplished at the time of the system field review. Many systems have large diameter, short vent lines fed only by small lines with low flow rates. Initially then, calculations are not required for these lines. If a field verification cannot establish the adequacy of the vent lines, then calculations should be performed. Back pressure and choked flow can be a concern in long vent lines, and this should be analyzed where appropriate.

Maintaining the rated flow capacity of relief valves is always a prime consideration in the design of a venting system. ASME Code, Section VIII, requires relief valves be set no higher than the vessel MAWP or design pressure and reach maximum flow by 110% of the set pressure. Tolerance on relief valve set pressure is established at plus or minus 3 psi up to 70 psig and plus or minus 2 percent over 70 psig. Special considerations should be given when two or more relief valves are connected to the same port.

SECTION 5. CONFIGURATION MANAGEMENT DOCUMENTATION ORGANIZATION

5.1 Overview

The certification program configuration management system includes numerous means of maintaining documentation on PV/S. Each PV/S must be uniquely identified so documentation can be easily retrieved. Chapter 4 of KHB 1710.15 identifies the requirements and the level of detail for PV/S certification. A documentation package should be prepared for each PV/S, which documents the system capability and verifies each PV/S is safe for continued operation.

5.2 Marking and Labeling

All PV/S must be labeled in accordance with applicable design, fabrication, and installation drawings and specifications.

KHB 1710.15, Chapter 4, provides detailed marking/labeling instructions, and requires each pressure vessel be identified with a brass or stainless steel tag which is permanently affixed as near as possible to the original manufacturer's nameplate. This tag must bear, as a minimum: "KSC PV/S CERTIFICATION PROGRAM," "CERTIFIED MAWP xxxx PSI," and "EFFECTIVE DATE (month/year)," as shown in Figure 5-1. The reason for this tag is that most vessels will have been rerated to reflect changes in the applicable codes or standards. Many times this rating will be lower than the original pressure rating. Marking should be done in a way that will allow easy identification of the information mentioned above.

Each safety-relief valve must be tagged with the relief setting in psi, date calibrated or set, and due date of next test in accordance with KHB 1710.15. Most relief valves, flex hoses, and pressure gages at KSC are currently tagged as part of an active recall program, and all components in the recall program must indicate the next due date. Additional marking/labeling to enhance identification and operation of the system is not precluded, provided the nomenclature is consistent with the applicable codes and standards, and allows for component traceability.

KSC PV/S CERTIFICATION PROGRAM

Certified MAWP ____________ psi

Effective Date ________________

FIGURE 5-1 Sample Vessel Identification Tag

Set Pressure ________________ psi

Calibration Date ________________

Due Date ____________________

FIGURE 5-2 Sample Relief Valve Tag

5.3 Unique Identification Numbers

All components in pressurized systems must be identified by a unique identifier (Find Number) traceable to the system mechanical schematic.

5.3.1 Vessel/System Identification

A four part numbering system utilizing the facility numbers from the GP-14-2 utilization charts was developed and used on some PV/S early in the certification program. This numbering system proved to be unworkable for systems already certified at KSC and is no longer recommended.

5.4 Drawing Control

Typically, system schematics are controlled documents and are maintained up-to-date. These drawings should be referenced in a certification package, but are not required to be maintained in certification files, since they can easily be retrieved from KSC documentation centers.

5.5 Certification Package

A certification package is a collection of documentation in various formats that verifies the capability for continued safe operation of a pressure vessel or system. Each package must contain sufficient information to verify the safety of the system and components at the certified pressures. KHB 1710.15, Chapter 4, specifies the documentation required for certifying PV/S. Additional guidelines on documentation requirements can be found in Section 3 of this guide.

Certification packages are, typically, prepared on a system basis. They should contain all available information obtained through documentation retrieval, field surveys and engineering analyses required for certification, and should be maintained on file by the certification contractor. The package can be divided into seven sections. The recommended minimum outline for a certification package is as follows:

<u>FILE SECTION</u> <u>CONTENTS</u>

1 .... File Content Summary
2 .... Field Audit Data
3 .... Documentation Review (e.g., manufacturer data report, drawings)
4 .... Documentation and Engineering Analysis Results (e.g., calculations)
5 .... Engineering Work Packages
6 .... Inspection and Test Results and Analysis
7 .... Inservice Inspection Plan

The following sections describe each file section of the certification package and the Certification Report. A certification package should be prepared for each system, where a system is defined as all piping, vessels, and components operating with the same fluid.

A system may contain any number of vessels and components and should be simplified where required. For example, this may require a gaseous nitrogen system be divided into several systems, each at a different operating pressure. Each separate system or division of a system would then require a separate certification package. To simplify a system, the certification contractor should use established interface points to eliminate confusion between the operations and certification identification.

Each certification package should remain current, reflecting the system's configuration, operation, and certification. As each phase of PV/S certification is completed, each file section should be reviewed and updated. Hence, it is maintained and becomes a current certification file.

5.5.1 File Content Summary

The File Content Summary should identify the vessel(s) or system involved, the system fluid, the location, the responsible certification contractor, and O&M contractor, if different. Additionally, the File Content Summary should identify the location of the system documentation required for certification, if different from the certification files.

5.5.2 Field Audit Data

The Field Audit Data section identifies the details of the field survey on a particular system. This section should list all vessels, relief valves, components, and piping in a fashion thoroughly identifying the capacity, pressure ratings, and manufacturer of each item. Each certification package is required to contain an accurate inventory list of all system vessels, piping, and components.

5.5.3 Documentation Review

Documentation is the foundation of the PV/S certification program. Documentation collection precludes more costly methods of establishing PV/S configuration, specifications, and certifications. Collection and review of documentation should be initiated at the onset of certification work and should be presented in as thorough a fashion as possible in the certification package.

The documentation analysis section of a certification package describes the findings of PV/S documentation analysis. Report findings should include a detailed inventory of all documentation readily available, the documentation obtained from other sources, and documentation requiring development. Each certification package is required to identify all documentation available for each vessel and system as required by KHB 1710.15, Chapter 4.

Copies of documentation obtained on vessels including drawings and manufacturer's data reports should be included. KSC controlled drawings, such as system schematics, should be referenced, but are not required as part of the certification package.

Included in the documentation analysis section should be an indication that a field verification of the system supporting documentation has been performed. All PV/S documentation is required to be verified through field investigations. All system and component specific data should be verified to the extent possible through visual surveys.

An optional section in the documentation analysis section is a system description summary. System descriptions identify the system location; function; pertinent operating parameters including pressure, contents, relief protection; major components; and materials. Descriptions can be enhanced by photographs and line drawings, as required.

5.5.4 Documentation and Engineering Analysis Results

Depending on the documentation available for each PV/S, various levels of engineering analyses may be required. As a minimum, a verification of system design documentation is required. This verification will assure system and vessel designs are in conformance with the applicable codes, standards, and industry practice. The design verification process will, typically, include a special review of documents and the performance of alternate calculations, as necessary, to assure the design meets the specified criteria.

Visual inspections performed by qualified examiners are required to assure the structural integrity of all pressure system components. Visual inspection should include all accessible components and welds for indications of potential failure or degradation such as cracks, flaws, corrosion, deteriorating pipe supports, pipe flange bolting, brackets, or other physical deterioration. The results of all visual inspections from the initial inspection and ISI review must be documented and summarized in the documentation and engineering analysis results section of each certification package.

Engineering analysis should be performed as necessary for system and vessel design verification, documentation verification, continued operation and visual inspection results analysis.

Engineering analysis tasks conducted prior to issuance of engineering work packages include, as needed, the following:

- Verification of adequate design per ASME Vessel Code, Section VIII, Division 1, including Head, Shell, and Nozzle Calculations.

- Detailed stress analysis to demonstrate compliance with ASME Code Section VIII, Division 2, if a Division 1 analysis does not establish the required certification.

- Verification of adequate system design per KSC design standards, ASME/ANSI, and other codes and standards, including pipe stress and safety relief valve set point and flow capacity calculations.

5.5.5 Engineering Work Packages

Documentation required for engineering work packages (EWP's) should be included in the certification package. Based on the documentation review and engineering analysis report, the EWP's should clearly and specifically define all required NDE, special tests, and repairs to ensure the PV/S are in compliance with applicable codes. An EWP is, typically, the set of documents required to obtain services. A Support Request (SR) is, typically, used for obtaining NDE support services, while an Engineering Support Request (ESR) is used for other support services. A sample of an ESR is contained in Appendix C.

Any required actions regarding PV/S monitoring, repair, replacement or modifications to ensure personnel safety/vessel integrity/and to correct code violations/ must be documented. These actions may include re-analysis of the vessel, vessel repairs, piping systems support changes, and system operational modifications.

5.5.6 Inspections and Tests Results and Analysis

The implementation of EWP's will generate documentation on inspections and tests. The results of these examinations, tests, and repairs must be analyzed to ensure they meet all requirements for PV/S certification. Analysis of the results of the EWPs must be sufficiently documented to allow verification by independent reviewers. All inspections and tests must meet the acceptance criteria in accordance with industry standards.

5.5.7 Inservice Inspection Plan

Chapter 7 of KHB 1710.5 discusses the requirements of an Inservice Inspection (ISI) Plan. Typically, PV/S recertification occurs at a twenty year interval. However, depending on the results of initial certification program or system hazards, the intervals for continued inspection may vary. Each system's ISI Plan is unique and is documented in the certification file. The ISI Plan is developed based on the results of the certification process.

5.6 Certification Report

For each vessel and system, a certification report is required by KHB 1710.15, Chapter 4. Each report must describe the steps involved in the certification along with the rationale for certification. Reports are to be based on all of the results of the inspection, analysis, NDE, etc., performed. The length of the certification report will vary, depending upon the results contained in the other sections. For each system, a certification report must be provided to the KSC Pressure Systems Manager (PSM) for review and retention.

Since the Certification Report is the only document submitted, it must contain sufficient detail to justify certification. A sample outline for a Certification Report is shown in Table 5-1.

Included in the Certification Report should be a certification certificate for each PV/S. As required by KHB 1710.15, Chapter 4, each certificate indicates that the system, its vessels, and components comply with KHB 1710.15. Each certificate should also indicate those non-safety related discrepancies that have not been adequately addressed prior to the release of the certification report. It should be noted that a PV/S is not considered certified until all safety-related hardware discrepancies are corrected.

TABLE 5-1 Sample Outline for a Certification Report

SECTION 1	SYSTEM DESCRIPTION: Identifying the major components and briefly describing the operation and configuration of the system. Photographs and drawings are used as required. System end-points should be clearly defined.
SECTION 2	DOCUMENTATION SUMMARY: Describing the documentation available, identifying nomenclature such as title, drawing number, etc., its location, and identifying significant discrepancies.
SECTION 3	DESIGN VERIFICATION RESULTS: Describing the system and vessel design verification effort, identifying applicable codes and standards, input data, and significant findings.
SECTION 4	ENGINEERING WORK PACKAGES: Describing documentation issued for inspection and tests, and repairs and modifications required for PV/S certification.
SECTION 5	INSPECTION AND TEST RESULTS: Providing a summary of the tests and nondestructive examinations performed, including visual inspections. Unacceptable results should be described in detail.

(continued)

TABLE 5-1 (continued) Sample Outline for a Certification Report

SECTION 6	ENGINEERING ANALYSIS: Summarizing all significant engineering analysis performed including results of calculations, analysis of inspection results, and special engineering analysis performed.
SECTION 7	CERTIFICATION SUMMARY: Providing a complete summary of the PV/S certification effort and the final disposition of the system and components (e.g., certify, rerate, replace, remove from service, etc.)
SECTION 8	INSERVICE INSPECTION REQUIREMENTS: Identifying the 20 year Inservice Inspection (ISI) Plan, including inspection/tests to be performed, and the frequency, for the system and individual components. ISI guidelines are established in NHB 1700.6. A discussion of the purpose and extent of inspections identified should also be provided.
SECTION 9	RECOMMENDATIONS: Providing recommendations on future system operation, inservice inspection, preventive maintenance, and recertification based on the performance of the certification program.
SECTION 10	CERTIFICATION CERTIFICATE: Indicating that system and vessel(s) comply with KHB 1710.15 except for non-safety-related discrepancies identified in the certification report. PV/S are not considered certified until all safety-related hardware discrepancies are corrected. The most common safety-related discrepancy is improperly set and/or under-sized relief devices. See KHB 1710.15, Chapter 5, paragraph 500.5 for how to address safety-related discrepancies which are identified after the PV/S have been certified.

SECTION 6. CERTIFICATION INSPECTION

6.1 Overview

Certification Inspection defines the nondestructive evaluation (NDE), inspection, and tests necessary for certification of PV/S. The results of the NDE, inspection, and tests completed, combined with documentation and engineering analysis, provide the basis for future Inservice Inspections (ISI). Inspection is based on the results of an engineering evaluation of documentation, engineering analysis of the system and component design and, most importantly, an understanding of the failure modes which are specific to each respective system and component. Inspections and tests can then be selected which will best identify indications of the predicted failure mode. Further, all NDE techniques cannot be universally applied and, in fact, may be limited by specific material types, vessel designs, etc. As a result, certification inspection requires an understanding of the various NDE techniques and their limitations, on a system-by-system and component-by-component basis. Inspections should be planned and coordinated with facility O&M personnel to minimize outages and user impacts.

6.2 Inspections and Tests

6.2.1 Visual Examination

In accordance with KHB 1710.15, the minimum inspection/test to be performed is a visual external examination of all PV/S piping and components. This requires an examination of the exterior surfaces of all pressure retaining vessels/components and supports for evidence of deterioration, including physical damage, excessive corrosion, and cracks. Visual examination should be performed by qualified and certified visual examiners.

ASME B&PV Code, Section V, identifies visual examination requirements and is used as the basis for visual examination procedures. Signed visual examination records are to become a part of the PV/S documentation package.

A distinction is made between visual inspections performed to detect evidence of component failure (e.g., cracks, flaws, corrosion) and the visual inspection required to verify a system/component's design, documentation, configuration, nameplate, and tag or label data. Visual inspections required to perform the latter are herein referred to as field surveys, visual surveys, or visual verifications, and are described elsewhere. In several cases, the performance of a visual external examination may be impeded by paint, insulation, or limited visual access. In general, paint need not be removed for an examination of parent metal. Paint may be removed, however, if the general condition of weld areas cannot be established due to excessive paint, and in areas where a deteriorated condition is suspected.

In cases where insulation covers surfaces to be inspected, it should be removed, if of the removable type. If the insulation cannot be readily removed, then a spot- check of the surface is recommended and should be performed by removing portions of insulation from low areas (under vessels, etc.), crevices, and other areas with the greatest potential for surface corrosion or stress corrosion cracking. The spot-check external examination should be supported with a visual internal examination.

In case of limited visual access, as with tightly packed vessel banks or arrays, a visual examination is to be performed to the maximum practical extent, without disassembly. If generic failure characteristics are suspected, a representative vessel bank can be disassembled and thoroughly inspected. Further, limited visual examinations may be supported with a pressure test and acoustic emissions monitoring.

6.2.2 Ultrasonic Thickness Measurements

Ultrasonic thickness measurements are recommended on vessels and piping walls to verify certification documentation and to support the analysis for pressure retaining capacity. In general, spot-checks should be performed on at least three locations on each pressure vessel head, three on the vessel wall, and at two locations for each discrete piping/tubing assembly (i.e., each piping/tubing section between welded or fitted joints).

Additional measurements or a complete thickness mapping may be required if internal corrosion is suspected. Thickness measurements can be readily obtained using ultrasonic equipment with digital display employing pulse-echo capabilities and a calibration block of appropriate thickness and material grouping.

6.2.3 Other Nondestructive Evaluations (NDE's)

Other NDE techniques are to be used to supplement existing documentation, engineering analysis results, and visual examination results, as required, to establish an adequate database for certification and assure the integrity of the PV/S. Additionally, these NDE techniques are, typically, relied upon for the long-term ISI planning and implementation. NDE's available include acoustic emission (AET), liquid penetrant (PT), magnetic particle (MT), radiographic (RT), ultrasonic (UT) and replication. A pressure test may be required to assess stress corrosion cracking following other NDE examination which identifies severe surface or crevice corrosion. Typical examinations and tests performed in accordance with ASTM or ASME B&PV Code Section V are summarized below:

- <u>Acoustic Emission Testing (AET)</u>
  Evaluates a pressure vessel's structural integrity by detecting, locating, and classifying emission sources (i.e., active vessel defects while the vessel is in a stressed condition). Pressure vessels are stressed by the application of internal pressure during AET. While currently not being used at KSC, other NASA centers have had success in using AET when supplemented with follow-up NDE to completely characterize an emission source.

- Liquid Dye Penetrant Examination (PT)
  Detects discontinuity and defects open to the surface in solid, nonporous materials. The solvent-removable PT method using visible dye is, typically, used for field testing.

- Magnetic Particle Examination (MT)
  Detects surface and near-surface discontinuities or defects in ferromagnetic materials. The yoke method of MT examination with dry-type magnetic particles is, typically, used for field testing.

- Radiographic Volumetric Examination (RT)
  Detects internal defects and variations including porosity, inclusions, cracks, lack of fusion, geometric variations, and corrosion thinning within a metal volume.

- Ultrasonic Volumetric Examination (UT)
  Detects lack of weld fusion, cracks, porosity, and other vessel defects, typically in the weld volume. Geometry and the physical properties of material may affect the technique prescribed and results.

- Replication
  A field metallography technique which involves the polishing of a metal and the use of softened acetate film to reproduce grain structures. Replication can show the effects of welding at the heat effected zone, Alpha-Beta compositions of the material, hydrogen embrittlement, and creep damage.

In general, NDE's, including visual examinations, should only be performed by those persons holding a valid certificate in their respective fields of expertise.

6.3 Inspection Planning

Inspection planning requires (1) the selection of inspections and tests necessary to establish the PV/S integrity and certification, (2) a field review of PV/S inspectability, (3) development of an inspection and test schedule compatible with PV/S operation, and (4) development of engineering work packages for implementing the inspection and tests.

As discussed, the selection of inspections and tests is based on an evaluation of documentation, engineering analysis, and visual examination results. Following this initial evaluation, additional NDE's may be necessary and scheduled with an ISI review of the pressure systems and vessels. This review will establish the inspectability of each system/component for the additional inspection requirements. This is an important step in inspection planning, since it will identify inspections and tests which may be impractical due to system requirements, cost, or incompatibilities, and may result in the establishment of alternate testing techniques. The review will account for such concerns as PV/S contents, service, cost, and age. Further, the review should identify specific requirements to be incorporated into the engineering work package, including accessibility, special equipment, cleaning requirements, special test concerns (e.g., system isolation/depressurization, valve and piping alignment), and safety concerns. An inspection planning memorandum, as shown in Appendix C, can be used to record the results of a field review and serve as the basis for the development of engineering work packages.

6.4 Other NDE Concerns

As the certification of PV/S at KSC continues, specific discrepancies may arise which warrant further documentation. This section contains a brief description of the problems and the additional NDE's required to certify vessels and systems.

6.4.1 Flaw Detection of Full Penetration Welds

Many of the pressure vessels at KSC were designed and built with full penetration welds, either at the head-to-nozzle junction, head-to-shell junction, or between two shell sections. These welded joints are, historically, the areas in the vessel most likely to fail. In addition, many of these vessels can only be certified to their original design pressure by using the requirements of Section VIII, Division 2. A lengthy and involved re-rate program may be initiated if more pressure is required; however, a re-rate should be performed as established by the National Board of Boiler and Pressure Vessel Inspectors (NBBI). Section VIII, Division 2 requires that all butt-welds in monoblock vessels be volumetrically inspected. Some girth-welds for layered vessels may be excluded.

As a result of these constraints, many vessels require NDE to determine the integrity of all full-penetration welds. The required NDE can either be ultrasonic flaw detection or radiography, depending on the weld and vessel geometry. Either method is acceptable as long as assurance of the quality of the entire weld is provided.

6.4.2 Corrosion Control

Due to the marine environment at KSC, all systems exposed to the weather are susceptible to corrosion. As a result, many systems have some degree of degradation due to corrosion. When corrosion is found, an assessment is required to determine the severity and the required corrective action. As a minimum, the corrosion needs to be controlled by cleaning the areas and repainting the affected area in accordance with KSC-STD-C-0001. Additional NDE and engineering analysis may be required to ensure the corrosion does not jeopardize the integrity of the system or vessel.

SECTION 7. INSERVICE INSPECTION PLANNING

7.1 Overview

This section discusses a successful Inservice Inspection (ISI) plan applicable to ground-based pressure vessels and systems (PV/S) at Kennedy Space Center. The goal of this ISI plan is to provide a reasonable level of certainty that pressure vessels, piping, and components that have been certified for their intended service do not degrade with use to the point of becoming unsafe to personnel and surrounding property. A comprehensive ISI program is an integral part of the overall certification effort and, typically, involves minimal capital commitment to obtain the assurance that critical components serve a long life. Development of the ISI plan should be based on the guidelines established in NHB 1700.6, "*Guide for Inservice Inspection of Ground-Based Pressure Vessels and Systems*," which describes, along with KHB 1710.15, systems which do not fall under the guidelines discussed herein.

7.2 Inspection Requirements

The specific examinations performed during periodic ISI should be determined from the information available from several sources. The existing certification package should be reviewed to determine if any specific concerns were raised during the certification analysis of the PV/S. Nozzles of some pressure vessels may have particularly high stresses (although less than the allowable stress) or the operating conditions the vessel or piping undergoes may give rise to concern over a potential fatigue problem. A particular run of piping may have inherent dynamic instability or areas of high stress concentration. Pressure vessel welds may have been found faulted at the time of volumetric inspection but, by analysis, rapid flaw growth is not anticipated. All of these items should be given due consideration by the engineer preparing the ISI requirements for a given vessel or system.

In addition to consideration being given to potential causes or sites of failure, the consequence of a given failure should also be taken into account and used in establishing the required inspections. The fact that a vessel contains a particularly hazardous or lethal commodity or is located such that its failure would endanger personnel or critical facilities or equipment should influence the engineer in selecting the frequency and type of examination. Conversely, if a vessel contains a rather harmless commodity and is not located in an area frequented by personnel, the engineer may decide on a less comprehensive inspection than if the vessel posed a risk to personnel (i.e., high pressure water located at a remote site).

Therefore, some of the factors that should influence the engineer's selection of periodic inspection techniques include: (1) concerns raised during the Phase I certification analysis, (2) the effects on personnel of failure of PV/S, and (3) the effects on facilities or equipment of a failure of PV/S. These factors and others determine the appropriate level of NDE to be employed. For example, a vessel considered to be of critical importance as discussed above could receive extensive volumetric examination (radiography, UT shear wave), while an identical vessel in a less critical application might require only routine surface examination (visual inspection, etc.).

Although the implication here is that ISI is unique to each system, many systems at KSC fall into very similar categories. For example, two gaseous nitrogen systems at LC-39 having the same or similar service histories could have identical ISI programs. Care is required in applying these generic guidelines to ISI, so that system-specific concerns identified for individual components are not overlooked.

7.3 Establishing Intervals of Inspections

Chapter 6 of NHB 1700.6 provides very structured guidelines for determining the frequency of ISI on PV/S. A quantitative method of assessing the destructive potential of the pressure system is employed, with consideration being given to the commodity being stored, as discussed above. This quantitative method uses "value units" to assess the destructive potential of the system. The more dangerous commodities are allowed fewer "value units" for a given inspection interval.

The Tables given in Chapter 6 of NHB 1700.6 are organized by the commodity contained in the pressure system. In the course of reviewing a system to establish the proper ISI intervals, individual parts of the system such as pressure vessels, piping and components, expansion joints and flex hoses, and relief valves are considered as if they were separate entities. Each system component category uses a different method of computing "value units."

The Tables given in Chapter 6 of NHB 1700.6 imply ideal, static conditions for the systems under consideration. However, NHB 1700.6 does recommend the pressure system engineer preparing the ISI guidelines be cognizant of the fact conditions may exist which make it prudent to modify these Tables. Such conditions include fatigue, corrosion and erosion, proximity of personnel, and issues raised during the certification analysis of the PV/S as discussed in Section 7.2. All of these considerations can potentially modify the baseline intervals established in the Tables.

7.4 Implementation Into Maintenance Documents

Performance of periodic maintenance on PV/S is an integral part of facility operation activities at KSC. Certain Operating and Maintenance Instructions (OMI's) Preventive Maintenance Instructions (PMI's) or Operating and Maintenance Requirements Specification Documents (OMRSD's) can be considered part of the ISI program. For example, changing a relief valve as a maintenance procedure can also be considered one of the items of an ISI program, and should be documented as such. A coordinated approach to both routine maintenance and ISI is the most cost-effective method of ensuring component integrity and safety. However, unique components or system concerns not identified by existing OMI's/PMI's should have separate documentation written and incorporated into the specified ISI programs to ensure complete system integrity.

7.5 Continuous NDE Monitoring of Flaws

Certain types of flaws, which are typically caused during the initial fabrication of a vessel, may require periodic monitoring throughout the life of the vessel to ensure integrity. Weld flaws, which include lack of fusion, slag inclusions, and porosity, would have been rejectable at the time of original fabrication but may not have been detected due to the level of examination employed. If repair is not immediately mandated, then periodic monitoring of the flaw is prudent to ensure it does not propagate and cause a failure of the vessel. The interval and level of examination applied to a flaw should be such that the flaw geometry can be characterized accurately and monitored to assure it is not growing.

The inspection interval required for a given flaw depends on the location of the flaw, flaw geometry, type of flaw, and material properties. Flaws with geometries conducive to stress concentration that are located in high stress areas are of greater concern than small flaws having no stress risers in low stress areas.

7.6 Evaluate ISI Results With Baseline Inspections

The results of periodic ISI must be compared to the baseline inspection for a given vessel to determine if any changes in vessel integrity have occurred. The baseline for any vessel is determined during the original certification analysis and establishes a datum for documentation, modification, and cyclic history of the vessel. Comparing the results of periodic inspections with the vessel baseline is particularly important when evaluating known flaws, as discussed in Section 7.5.

If an existing flaw is discovered to be propagating, it must be repaired. The criticality of the repair is determined by several factors. A conservative fracture mechanics analysis (see Section 4.3.2) can be used to determine the number of operating cycles remaining. It must be emphasized that this technique is to be employed very conservatively. If the fracture mechanics analysis indicates the vessel has few remaining cycles, the flaw should be repaired immediately or the vessel should be taken out of service. If the analysis indicates many remaining cycles, the repair could be delayed; however, inspections should be made more frequently to ensure the actual propagation of the flaw is, in fact, within reason of what was calculated. There may be other considerations, such as economic, in determining whether to repair a flaw.

7.7 Update of Certification Reports

Based on the evaluation of ISI results, as discussed in Sections 7.5 and 7.6, each certification report should be re-examined and updated as necessary so that future inspections can be properly evaluated. The vessel baseline, as established in Section 2.2, must be kept up to date so future inspections can be accurately interpreted.

SECTION 8. CERTIFICATION OPTIONS

8.1 Overview

Where the pressure vessel MAWP or system design pressure does not meet the ASME/ANSI code requirements, it may be necessary to derate or lower the vessel/system operating pressure. When this option is considered, the user minimum requirements will dictate the feasibility of this approach. An analysis of required flow rates, pressure levels, and storage capacity must be performed and evaluated, while keeping in mind certification is intended to reduce the possibility of unsafe conditions. During system and design reviews many discrepancies may be identified. Some of these items will have a direct impact on system safety while other items are required to conform to KSC design standards. Safety-related items, such as incorrect relief valve settings/flow capacity, must be corrected before certification can be complete. Non-safety-related items, such as labeling, tagging, and drawing changes may not necessarily have to be completed in order to certify a system; however, these items must be tracked until they are properly dispositioned.

A request for waiver/deviation/variance, with associated justification, can be submitted when it is necessary to continue to operate an existing system after it has been determined that it cannot be certified. An approved waiver/deviation/variance will become a part of the system/vessel data package. A request for waiver/deviation/variance should be prepared using the Deviation/Waiver/Variance Request, KSC Form 20-168. A sample form is included in Appendix C.

8.2 Typical Certification Scenarios

As the certification of PV/S at KSC continues, specific scenarios are emerging for certifying PV/S. This section contains a brief description of the problems encountered while certifying various systems at KSC. These approaches to certification can be applied to other similar systems.

8.2.1 U.S. Steel Vessels at Launch Complex 36

Eighty-four vessels at Launch Complex 36 were manufactured by U.S. Steel (now CP Industries) using an integrally forged fabrication method. The vessels were built in 1964 for gaseous service. They carry ASME "U" Stamps on their heads and were designed for a MAWP of 6000 psig at -20 to 200°F, per Code Case 1205. The vessels are mounted horizontally and have a combined water volume of 1680 cubic feet. The visual examination of these vessels indicated excessive corrosion near the vessel supports. These vessels support key launch operations for the Atlas Centaur vehicle and cannot be removed from service for lengthy intervals. In order to assess the structural integrity and extent of the corrosion, one bank of ten vessels was removed, disassembled, sandblasted, and inspected. The corrosion was determined to be mostly on the saddles with minimal degradation of the vessels. Magnetic particle examination was performed on 100% of the vessels to determine if cracking was occurring due to the corrosion. The corrosion was determined not detrimental to operation but did necessitate refurbishment to prevent further degradation. Furthermore, numerous linear indications were found on the vessel's surfaces.

The magnetic particle linear indications were determined to be unacceptable; thus, each indication was removed by mechanical grinding. Only one indication required grinding below the minimum wall thickness. U.S. Steel Specification CP-E-1218 was followed during the removal of this indication. This method of crack removal, used by U.S. Steel for all forged vessels when they are manufactured, allows grinding below minimum wall thickness, providing the wall thickness surrounding the grind area is sufficiently thicker than minimum wall to provide adequate reinforcement. Figure 8-1 illustrates the methodology used. Complete thickness measurements of each indication were obtained. Each vessel was then painted and reassembled.

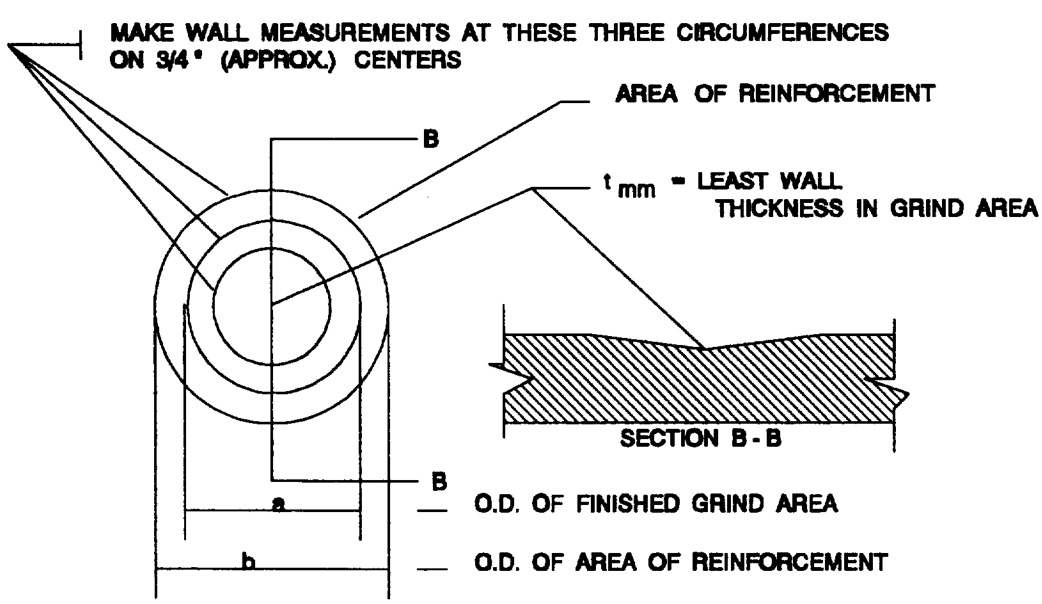

FIGURE 8-1 Removal of Cracks by Grinding (FROM U.S. STEEL SPEC.: CP-E-1218)

The inspection of this representative bottle bank revealed two problems that had to be corrected. The corrosion had to be stopped, which required all of the bottle banks to be disassembled, sandblasted, and repainted. Magnetic particle examination needed to be performed on all vessels and all linear indications needed to be ground out. Based on a conservative fracture mechanics analysis, these vessels can undergo several thousand full pressure cycles before the worst case crack will grow large enough to cause vessel failure. Based on this analysis, the systems were certified for three years, during which time the remaining 74 vessels were to be refurbished or removed from service.

In 1989, the remaining vessel clusters were removed from service, disassembled, sandblasted, tested, painted and reassembled. Test results were similar to those of the test group, where localized corrosion was found with linear indications at random locations on the vessels. This program resulted in 83 vessels being recertified for a twenty-year ISI cycle. One vessel was removed from service due to an unacceptable crack in the vessel wall.

8.2.2 U.S. Steel Vessels at Launch Complex 17

Two gaseous storage systems consisting of 64 pressure vessels were in service at Launch Complex 17. The vessels were mounted horizontally in clusters of eight. The vessels were originally designed and built in 1960 for 2800 psig gaseous oxygen storage at a Titan missile site. However, they were being used in gaseous nitrogen and helium storage at LC-17 operating at 2250 psig. The total sixty-four vessel battery water volume was approximately 2390 cubic feet. The vessel construction and material type were similar to ASME code stamped vessels built per ASME Code Case 1205, with the exceptions of the support bands welded to the vessels and an allowable stress value of 1/2 of the material yield strength, rather than 1/3 of the material ultimate strength as specified in Code Case 1205. Obviously, the vessels were not ASME Code stamped. The vessels were 24 inches outside diameter, had a minimum design wall thickness of 0.817 inches, and an overall length of 21 feet 5-1/2 inches (nozzle-end to nozzle-end).

Numerous concerns were identified during the inspection and test portion of Phase I. The primary concerns were (1) the condition of the vessel wall where the support rings were welded to the shell and (2) the corrosion evident on the majority of vessels. A representative bank of vessels was removed and two vessels were removed from the bank for further testing. The testing performed consisted of--

- 100% visual examination of the entire outer surface of two vessels after sandblasting
- 100% magnetic particle examination (MT) of the entire outer surface of two vessels
- Ultrasonic volumetric examination (UT) of the support ring weld areas on two vessels
- Ultrasonic depth measurement of sample MT findings on two vessels
- Acoustic emission testing (AET) of one vessel
- Hydrostatic testing of one vessel to failure
- Metallurgical evaluation of one vessel

The integrity of the welded support ring was thoroughly tested for the one vessel analyzed. The results indicated very favorable material properties in the base metal and heat affected zone.

The surface corrosion was uniform pitting with negligible loss of vessel wall material. The corrosion areas did not show signs of intergranular or accelerated attack.

Over 200 unacceptable linear indications were found on each vessel using MT, and numerous unacceptable indications were found using ultrasonic shear wave on the weld support rings. Samples of the 200 indications from MT were polished and inspected. The indications were determined to be surface deformities not detrimental to the vessel. Hence, the majority of the MT indications were considered non-relevant. The indications in the weld region were determined to be reflections from the support attachment design, thus were acceptable.

The two vessels were then shipped to White Sands Test Facility, New Mexico, for destructive testing. One vessel was supported vertically, filled with water and pressurized (the other vessel was not pressure tested).

An AET did not indicate any active flaws in the vessel during testing to 2800 psig. The vessel was then pressurized to 9680 psig where failure occurred. No significant AET activity was noted. The flaw in the vessel shell where failure occurred was 2-1/2" long by 0.4" deep. This flaw showed no measurable cyclic growth.

Failure from the destructive test was at a flaw that was "most likely formed during the manufacturing process." Thus, the remaining vessels were assumed to have similar flaws of unknown size. Estimates of the flaw sizes were made using fracture mechanics, cyclic data, and the manufacturer's hydrostatic test pressure data. The fracture toughness values estimated from the burst test were used to estimate a conservative fracture toughness value. Using this data indicated the flaws in the vessel could have been as large as through-wall before they reached critical flaw size. The material fracture toughness value was calculated based on the loads at the time of failure. This approach indicated a leak-before-burst failure mode, but could not accurately predict flaw sizes in the remaining vessels; hence, the probability of failure could not be accurately estimated.

Certification of these vessels based on the analysis and data available was not possible. Each vessel could have been inspected to assure the user of the integrity of each vessel until a complete volumetric inspection of each vessel was conducted, but adequate safety margins to facilities and personnel could not be guaranteed. Therefore, these vessels were removed from service.

8.2.3 Taylor Forge Banded Vessels

In the late 1950's and early 1960's, Taylor Forge developed and produced a particular type of vessel known as an "autofrettage" vessel or "banded" vessel. This type of construction is not currently used by Taylor Forge. Vessels of this design are found at KSC in the Industrial Area, Propellant Systems Cleaning Laborabory (PSCL), and Fuel Farm 1. It is important to note these vessels are not ASME Code stamped but built in accordance with Taylor Forge proprietary manufacturing procedures and some aspects of the ASME Boiler and Pressure Vessel Code.

The autofrettaged vessel, as produced by Taylor Forge, consisted of a pressure-containing inner cylindrical vessel with hemispherical end closures and with abutting cylindrical reinforcing bands and end rings on the outside of the inner vessel. These vessels were designed so the inner vessel carried the complete axial or longitudinal pressure load and the outer bands reinforced the vessel circumferentially. In order for the bands and end rings to serve as effective reinforcement, they had to be of higher strength material than the inner vessel, and had to be in effective contact with the inner vessel.

After fabricating the inner cylindrical vessel, Taylor Forge placed the higher strength cylindrical outer bands and end rings over the inner vessel. The outer bands had an inside diameter approximately 1% to 1-1/2% greater than the outside diameter of the inner vessel, while the end rings were tapered to match the inside diameter of the outer bands and the outside diameter of the inner vessel at the head-to-shell joint. This permitted the outer bands to be freely installed over the inner cylinder without interference before the end rings were installed.

Once the outer bands and end rings were installed, the inner vessel was subjected to hydrostatic pressure sufficient to plastically flow or yield the inner vessel in a circumferential direction until contact with the outer bands had been achieved. The hydrostatic pressure was then increased further until the outer bands and end rings were elastically stressed. The hydrostatic pressure was, typically, limited to a level which would not allow the stress in the vessel heads, or the axial stress in the inner shell, to exceed 90% of the yield strength. Having reached this stress condition, the hydrostatic pressure was released and both the inner and outer layers sprang back elastically, remaining in contact, with a residual tensile stress in the outer bands and residual compressive stress in the inner shell.

Generally, the inner vessel was fabricated complete with heads, nozzles, manways, etc., with complete radiography of the full penetration welds. After the inner vessel was complete and all NDE tests had been performed, it was stress relieved in an enclosed furnace prior to installation of the outer bands and end rings.

Typically, the outer bands and two narrower end rings were manufactured using rolled plate and weld fabrication techniques. Each band/end ring was heat treated after welding and also NDE tested. Each of the bands was slid into place over the inner vessel, then the two end rings were installed on the inner vessel near the head/shell girth weld. The outer bands were made tight by hydraulic expansion of the inner shell (autofrettage expansion process). Tightness between the two shell layers was demonstrated by the increase of circumference of the outer bands measured with strain gages. Upon release of pressure, the two layers sprang back elastically into a prestressed condition, the outer layer being in tension, and the inner layer in compression (in the circumferential direction). When pressure is reapplied, the two layers function as an elastic unit up to the previously applied autofrettage pressure.

For many of the vessels of this design, Taylor Forge used nickel-modified SA-302B material. Recorded ultimate tensile strength values, after the chemical modification and heat treatment listed by Taylor Forge are, typically, 95 ksi for the inner shell and 115 ksi for the outer bands and end rings. Charpy impact data after strain provided by Taylor Forge shows a slight decrease in ductility; however, in all cases, the Nil-Ductility zone is to the left of the zero degree Fahrenheit mark. Therefore, ductile material properties are expected for these vessels over the operating temperature range at KSC.

8.3 Cryogenic Systems

All components used in cryogenic systems should be designed to operate at the normal boiling point temperature of the cryogenic system in which they are installed. The components should be fabricated from type 304/304L, 316/316L stainless steel or other compatible materials. Components installed in VJ transfer piping should be vacuum jacketed and mate with the transfer piping inner and outer pipe sizes. Where the vacuum annulus of the component is separate from that of the piping to which it is attached, there should be a separate pump-out and relief port.

8.3.1 Cryogenic Storage Vessels

Three major factors should be considered regarding the inspection/testing methodology for ensuring the integrity of cryogenic storage vessels. First, since the space between the inner and outer vessels is either evacuated or maintained at a slight positive pressure with a dry inert gas, and the inner vessel is constructed of corrosion resistant material, corrosion and stress corrosion are not significant mechanisms for failure of the inner vessel. Second, for the materials used to fabricate cryogenic inner vessels and their supports, studies have shown that crack propagation characteristics are such that detectable leakage will occur prior to vessel failure. Finally, periodic pneumatic or hydrostatic pressure testing is not an effective means of detecting leaks for cryogenic vessels in continuous service, and could even be detrimental for stainless steel inner vessels. Hydrostatic retests are impractical due to the large cycle time needed to drain, warm, test, dry, and re-cool the vessel to cryogenic temperature. Additionally, the weight of water could impose adverse loadings on the support systems for certain vessel (i.e., LH2 vessels).

Periodic annulus pressure monitoring provides an excellent check for leaks. Those cryogenic storage vessels that are in continuous service should be checked for leaks by ensuring a stable condition exists in the annular space between the vessels. If vacuum cannot be maintained without continuous pumping, or if venting occurs from the annular space of non-vacuum jacketed vessels, the source of leakage should be located and corrected. Leakage from the inner vessel must be corrected and may entail a repair program.

The outer vessel should be periodically inspected and have all corrosion removed and affected areas repainted.

Although not necessarily a safety concern, excessive heat gain through the vessel is undesirable in that increased evaporation can overload the normal venting system, resulting in higher than normal ullage pressures. Also, high heat leak rates can be costly in terms of lost commodity. Increased heat leak can be caused by loss of annulus vacuum, as well as settling of the powdered perlite insulation material. Settling of the perlite insulation material is accelerated by repeated chill-down/warm-up cycles. For this reason, the number of these cycles should be kept to a minimum. Once the integrity of the annulus is established, a continued high heat-leak rate is an indication that the Perlite has settled. A visual inspection for external surface condensation or cold spots, and a measurement of boil-off should be performed for all cryogenic vessels.

Those pressure relief devices which protect the cryogenic storage vessel should be periodically pressure checked and, if necessary, reset to not exceed the vessel MAWP.

8.3.2 Cryogenic Piping

Piping systems for transferring cryogens can be either insulated or uninsulated for liquid nitrogen (LN2) and liquid oxygen (LO2), depending on operational requirements and the desired temperature at the use point. Other types of insulation for these cryogens are (1) natural frost build-up as a result of the cold pipe and moisture in the atmosphere and (2) pre-formed foam insulation materials installed on the outer surface of the pipe. Although vacuum jacketed (VJ) pipe may sometimes be used for LN2 and LO2, VJ transfer piping is always used for liquid hydrogen (LH2) and liquid helium (LHE).

The primary safety concern for cryogenic piping is in identifying those sections of the piping system which can be isolated with residual cryogens entrapped, thereby causing overpressurization by vaporization of the trapped liquid cryogen. As part of the initial system certification inspection, a walkdown of transfer piping must be conducted to identify any isolatible sections of cryogenic piping which do not incorporate relief device protection. The intent of this inspection is to ensure an unprotected piping section does not exist. Pressure relief devices should be periodically tested, and gages should be periodically recalibrated. In addition, the vacuum jacket annular space should be periodically checked for loss of vacuum or leakage.

As in cryogenic vessels, the vacuum integrity is also important to VJ piping. A relief device should be installed on the jacket to protect the vacuum annulus from overpressurization should a leak or rupture occur in the inner pipe. This relief device need not be functionally checked periodically and should be of simple design, such as a rupture disc or a vacuum retained plug. The relief device and pumpout port should be protected from physical damage.

8.3.3 Cryogenic Valves and Flexible Hoses

Cryogenic shutoff valves should be designed with an extended bonnet and stem seal to preclude possible stem leakage. Valves having extended bonnets should be installed approximately vertical to prevent the cryogen from coming in contact with the stem packing.

Both gate and ball-type valves should have body cavities vented through a hole in the downstream gate plate and/or the ball flow cavity.

Flexible hoses for cryogenic service should be fabricated from convoluted stainless steel materials. Teflon or other non-metallic hose materials are not acceptable for this service.

8.4 Hypergolic Fuel/Oxidizer Systems

Hypergolic fuels and oxidizers are used in launch vehicle and spacecraft propulsion systems. The GSE storage and transfer systems for these fluids have unique design considerations. Some of the critical design considerations are toxicity, vapor migration, materials compatibility, and safe disposal of venting vapor. Both pressure vessels and systems must be designed for lethal service. (See ASME Code Section VIII, Division 1, Paragraphs UW-2 and UCI-2; Division 2, Paragraph AG-301.1(c) and ANSI B31.3, Appendix M).

Hypergolic fluid transfer systems should be designed to preclude unnecessary liquid traps in transfer lines and components. Evaluation of the fluid flow path and passageways in components assists the designer in selecting suitable components.

Mechanical connections used in transfer system piping should be selected for their proven performance of no leakage. For example, raised face flanges conforming to ANSI B16.5 should have concentric serrations in accordance with ANSI MSS-SP-6, as opposed to spiral serrations. Other mechanical type connections and fittings should be similarly considered to include features eliminating possible fluid leakage.

Due to the high hazards associated with hypergolic fluids, the system design should prevent vapor migration of hypergolic fluids into pneumatic supply lines interfacing with fuel or oxidizer transfer systems. These interfaces should incorporate a hand-operated shutoff valve upstream of a poppet or cone-type, spring-actuated check valve to permit positive shutoff of the pneumatic branch and unidirectional pneumatic flow. Pneumatic supply branches should be designed to interface with only one type of hypergolic fluid (i.e., fuel or oxidizer). See KSC-STD-Z-0005 for recommended design of pneumatic/hypergol interfaces.

APPENDIX A REFERENCES

1)	NHB 1700.6	*Guide for Inservice Inspection of Ground-Based Pressure Vessels and Systems*
2)	NMI 1710.3	*Safety Program for Pressure Vessels and Pressurized Systems*
3)	NSS/HP 1740.4	*NASA Medium Weight Pressure Vessel Safety Standard*
4)	KMI 1710.15	*Certification Program for Pressure Vessels and Pressurized Systems*
5)	KMI 2410.2	*Data Processing Support*
6)	KMI 5310.11	*Nonconformance Reporting and Corrective Action System*
7)	KHB 1710.2	*Kennedy Space Center Safety Practices Handbook*
8)	KHB 1710.15	*KSC Pressure Vessel/System Certification Handbook*
9)	Federal Register	*Volume 37, No. 202, Title 29 - Labor, Chapter VIII - OSHA Part 1910*
10)	49 CFR	*Hazardous Materials Regulation Board, Shipping Container Specifications, Subpart C, Specifications for Cylinders, Section 178.36 through 178.68*
11)	ANSI/ASME B40.1	*Gages, Pressure Indication, Dial Type - Elastic Element.*
12)	ANSI/NB-23	*National Board Inspection Code*
13)	ASME B&PV Code	*Sections I, III, IV, VI, VII, VIII and XI*
14)	ANSI/ASME B31.3	*Chemical Plant and Petroleum Refinery Piping*
15)	KSC-STD-SF-0004	*Safety Standard for Ground Piping Systems Color Coding and Identification*
16)	KSC-STD-Z-0005	*Standard for Design of Pneumatic Ground Support Equipment*
17)	KSC-STD-Z-0006	*Standard for Design of Hypergolic Ground Support Equipment*

APPENDIX A REFERENCES (Continued)

18) KSC-STD-Z-0007 *Standard for Design of Hydrocarbon Fuel Ground Support Equipment*

19) KSC-STD-Z-0008 *Standard for Design of Life Support Ground Support Equipment*

20) KSC-STD-Z-0009 *Standard for Design of Cryogenic Ground Support Equipment*

21) KSC-STD-Z-0010 *Standard for Design of Environmental Control Systems*

22) KSC-GP-14-2 *Utilization Charts, NASA Facilities at KSC, CCAFS and PAFB*

APPENDIX B SAMPLE SYSTEM CHECKLIST

Requirements Checklist for KSC-STD-Z-0005

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Requirements Checklist for KSC-STD-Z-0005

PNEUMATIC GROUND SUPPORT EQUIPMENT

GENERAL NOTES

1) This document was developed by General Physics Corporation to assist in the evaluation of pressure systems against the requirements of Standard KSC-STD-Z-0005, *Standard for Design of Pneumatic Ground Support Equipment*, as part of the KSC Pressure Vessel and System Certification Program. This checklist is not intended to be a substitute for current requirements documents for the design and fabrication of pressure systems. Where discrepancies occur in the interpretation, the KSC standard takes precedence.

2) Several specifications and standards documents are referenced by this checklist in addition to KSC Standard KSC-STD-Z-0005. Use the latest issue (revision) of referenced documents when completing this checklist.

3) Each question identified on the checklist should be addressed with a YES, NO, N/A to be applied as follows:

   YES: System/Component(s) meets the requirement.

   NO: System/Component(s) do not meet the requirement.

   For questions answered "NO" an additional comment sheet should be attached that specifically identifies the areas of nonconformance. A recommended resolution should also be provided.

   N/A: The requirement does not apply to the system/component(s) design, type, or configuration.

4) The system identification number, date, and the checklist reviewers' signature should be identified on each checklist.

5) Requirements identified by a (*) require a response when reviewing new (to-be-fabricated) system designs.

Requirements Checklist for KSC-STD-Z-0005

PNEUMATIC GROUND SUPPORT EQUIPMENT

GENERAL SYSTEM REQUIREMENTS

Identification Number(s) ______________________

Service ______________________

Spec Section	Requirements	Yes, No or N/A
ALL SYSTEMS		
1.3	Is the pneumatic ground support equipment (GSE) designed in accordance with the provisions and requirements of KSC-DE-512-SM?	____
	NOTE: In case a conflict between KSC DE-512-SM and KSC-STD-Z-0005, the requirements of the latter shall take precedence.	
3.9	Are all castings subjected to pressure made of ASTM A 351, grade CF8M or grade CF8 material* ____	
3.16.2	Is the distribution system grounded and bonded in accordance with KSC-STD-E-0012?	____
3.17.1 3.17.2	Are distribution plumbing, associated components and mechanical equipment designed to withstand exposure to KSC environment, or else is it equipped with a special enclosure which is provided with a flow-through, positive-internal pressure purge in accordance with KSC-STD-E-0002?	____
3.17.3	Is special enclosure provided for system components designed to perform in the launch environment?	____
3.17.4	Are the distribution plumbing and components protected from corrosion deterioration according to KSC-STD-C-0001?	____
3.20.1 3.20.2.2	Is the distribution system and components that contact GSE fluid media cleaned to the requirements of KSC-STD-C-0123?	*____
3.22.1	Is the maximum allowable working stress for all components in accordance with ASME Boiler & Pressure Vessel Code Section VIII (for pressure vessels) and ANSI B31.3 (for piping/tubing, valves, etc.)?	____
3.22.2	Have all components been hydrostatic/pneumatic tested per these codes?	*____
3.23	Have the distribution system connections been proven to be leaktight as determined by application of MIL-L-25567 type I or MSFC-SPEC-384 leak test solution?	*____
3.24.1	Are all components and interface connection ports assigned a unique identification number on engineering drawings and a tag attached to the component? (Ref. KSC-GP-435 Vol I.)	____
3.24.2	Does the face of all operating or control panels have black stripe interconnecting lines to each component representing the flow path of fluid media?	____

NOTE: Comments should be made on separate sheets for all questions answered no.

Reviewer's Name: ______________________
Date: ______________________
Extension: ______________________

Requirements Checklist for KSC-STD-Z-0005

PNEUMATIC GROUND SUPPORT EQUIPMENT

GENERAL SYSTEM REQUIREMENTS

Identification Number(s) ____________________

Service ____________________

Spec Section	Requirements	Yes, No or N/A
3.25.3	Does each fluid supply to a multiple fluid system terminate with an isolation valve followed by a check valve with a vent valve installed between the isolation valve and check valve?	____
3.26.2	Does the distribution plumbing system function properly at the extremes of the ambient conditions as defined in KSC-DE-512-SM?	*____
	Is temperature conditioning provided where required?	*____
	Are the required temperatures and their tolerances shown on the mechanical schematic at appropriate locations in all systems for which temperature conditioning is required?	*____
3.27.1	Are hazard analysis and failure mode and effects analysis for the distribution system and components in compliance with KSC-DE-P-360?	____
3.28	Is the maintainability criteria for the distribution system in compliance with KSC SR73-1020 and has the maintainability analysis been performed in accordance with KSC-DE-512-SM?	*____
OXYGEN SYSTEMS ONLY		
3.12.2	Does the oxygen system and components conform to the requirements of NFPA No. 50?	____
3.12.3	Does the plumbing and component material in contact with oxygen, including breathing gas mixtures, satisfy the requirements of NHB 8060.1?	____
3.12.5	Were fast opening valves avoided and were non-throttling shutoff valves provided with bypass metering valves?	____
HYDROGEN SYSTEMS ONLY		
3.13.1	Does the system conform to NFPA No. 50A?	____
3.13.4	Was pressure containing plumbing and component material selected for minimum hydrogen embrittlement susceptibility?	____

NOTE: Comments should be made on separate sheets for all questions answered no.

Reviewer's Name: ____________________
Date: ____________________
Extension: ____________________

Requirements Checklist for KSC-STD-Z-0005

PNEUMATIC GROUND SUPPORT EQUIPMENT

GENERAL SYSTEM REQUIREMENTS

Identification Number(s) ____________________

Service ____________________

Spec Section	Requirements	Yes, No or N/A
	NOTE: Austenitic stainless steel grades TP 304, TP 316 for piping and ASTM A 351 grades, CF8, CF8M for castings are preferred. Materials that should be avoided include, but are not limited to, titanium, maraging steels, 400-series stainless steels, MIL-S-16216, ASTM A514, ASTM A517, and the steels listed in Section 2.3 of MIL-HDBK-5, and precipitation hardening stainless steels.	
HYPERGOLIC SYSTEM INTERFACES ONLY		
3.14.2	Does the interface between the pneumatic distribution plumbing and the hypergolic propellant system meet the minimum requirement set forth in Section 3.14.2 (parts a-f)?	____
3.14.3	Does the interface between the pneumatic distribution system and the hypergolic propellant system meet the optimum requirements set forth in Section 3.14.3 (parts a-c)?	____
	If either answer is NO go to Section 3.14.4.	
3.14.4	If only the minimum requirement set forth in Section 3.14.2 (parts a-f) is met, but not the requirements set forth in Section 3.14.3 (parts a-c), is the pneumatic system interface with hypergol propellant system manually operated?	____
VENT SYSTEMS		
3.11.1	Is the discharging of oxidizers and fuels into the same vent avoided?	____
	Are vent systems handling fuels or oxidizers fluids equipped with a means of diluting the vented fluid and inerting the vent system with a gas such as nitrogen?	____
	Are oxidizer and fuel vent outlets to the atmosphere separated sufficiently to prevent mixing of vented fluids?	____
3.11.2	Are all vent system outlets located such that they are normally inaccessible to personnel and are they conspicuously identified?	____
	Are vent system outlets protected against rain intrusion and entry of nest building birds, insects, and animals?	____
	Are all vent outlets designed so as to prevent accumulation of vented fluid in dangerous concentrations in areas frequented by unprotected personnel or motor vehicles?	____

NOTE: Comments should be made on separate sheets for all questions answered no.

Reviewer's Name:____________________
Date:____________________
Extension:____________________

Requirements Checklist for KSC-STD-Z-0005

PNEUMATIC GROUND SUPPORT EQUIPMENT

GENERAL SYSTEM REQUIREMENTS

Identification Number(s) ____________________

Service ____________________

Spec Section	Requirements	Yes, No or N/A
3.11.3	Were all systems sized to provide minimum back-pressure consistent with required venting flow rates?	* ____
	Are all vent systems designed such that in no case can the back-pressure interfere with the proper operation of relief devices?	____
	Has a design analysis been performed to ensure excessive back-pressure will not occur in multiple-use vent systems?	* ____
3.11.4	Is each line venting into a multiple-use vent system protected against back pressurization by means of a check valve if the upstream system cannot withstand the back pressure or where contamination of the upstream system cannot be tolerated?	____
TUBING INSTALLATIONS		
3.1.1 3.1.1.1	Are all pressure tubing runs made of seamless, stainless steel tubing that meets the requirements of KSC-SPEC-Z-0007 and are they fabricated and installed per KSC-SPEC-Z-0008?	____
	Are all alternate fittings installed per KSC-STD-Z-0005 Section 3.1.2?	* ____
	Do the tube assemblies meet the minimum straight tube lengths and tube bend dimensions per Tables 1 through 4 of specification KSC-SPEC-Z-0008?	____
	Are tubing bends free of wrinkles, scratches and flat spots?	____
	Are all bulkhead fittings installed with the fixed hex outside of panels?	____
3.1.1.2	Do all flared tube ends have either a 37-degree formed flare or a buttwelded spud containing a machined 37-degree flare for joining tube to threaded fittings?	____
	Are all tube sizes with wall thickness greater than 0.109 inch fabricated with the buttwelded (spud) flare?	____
3.1.1.3	Are all threaded and buttwelded fittings limited to tube size from 1/4- to 2-inch outside diameter?	____
3.1.1.3.1	Do all KC threaded fittings using standard 37-degree flare ends meet the requirements of KC GP-425 and were they procured per KC-F-124?	____

NOTE: Comments should be made on separate sheets for all questions answered no.

Reviewer's Name: ____________________
Date: ____________________
Extension: ____________________

Requirements Checklist for KSC-STD-Z-0005

PNEUMATIC GROUND SUPPORT EQUIPMENT

GENERAL SYSTEM REQUIREMENTS

Identification Number(s) ____________________

Service ____________________

Spec Section	Requirements	Yes, No or N/A
3.1.1.3.1.1	In all cases where the original design drawings do not specify KC fittings, but specify plain-nose 37-degree flared tube fittings, are the fittings functionally equivalent per Table 1 of KSC-STD-Z-0005?	___
	Are all KC fittings limited to a minimum temperature of minus 320 degrees F, and a maximum operating temperature of 425 degrees F?	___
3.1.1.3.1.2	Is the standard port design for use with threaded fittings per MS33649 for rated pressures specified in KSC-SPEC-Z-0008?	___
	Is the super pressure port design with straight internal treads used when operating at pressures above the ratings specified in KSC-SPEC-Z-0008?	___
	NOTE: Existing equipment components that have MC240, AND10049, or AND10050 ports are considered acceptable for continued use in the GSE in which they are installed.	
3.1.1.3.2	Do all buttwelded tube joints utilize only those weld fittings as listed in the table in Section 3.1.1.3.2 of standard KSC-STD-Z-0005?	*___
	For buttwelded spuds (machined flares), are the ends subsequently joined to threaded fittings by using KC142 coupling nuts?	___
3.1.1.4	Are tube and buttwelded fittings joined by the tungsten-inert gas (TIG) welding method according to the requirements of KSC-SPEC-Z-0016?	*___
3.1.1.5	Are the limitations and procedures for tubing installation of KSC-SPEC-Z-0007 and KSC-SPEC-Z-0008 followed?	___
	NOTE: Flareless fittings are prohibited in pneumatic GSE. The use of crush washers in flared-fitting connections is also prohibited. Self flared fittings and brazed fittings shall not be specified without specific approval from KSC Directorate of Design Engineering. Threaded fittings listed in GP-425 are limited for use between minus 320 degrees F and plus 425 degrees F; however, use above 300 degrees F must be with the approval of Design Engineering.	
3.1.2	Have superpressure tubing and fittings been installed per manufacturer's instructions?	___

NOTE: Comments should be made on separate sheets for all questions answered no.

Reviewer's Name:________________
Date:________________
Extension:________________

Requirements Checklist for KSC-STD-Z-0005

PNEUMATIC GROUND SUPPORT EQUIPMENT

GENERAL SYSTEM REQUIREMENTS

Identification Number(s) ____________________

Service ____________________

Spec Section	Requirements	Yes, No or N/A
PIPING INSTALLATIONS		
3.1.3	NOTE: Buttwelded pipe may be used as an alternative for tubing.	
3.1.3.1	Were all piping installations designed in accordance with ANSI B31.3?	___
3.1.3.2	Does pipe material meet either of the following criteria:	
	a. Stainless steel pipe: seamless, cold-drawn type-316L or type-304L stainless steel per ASTM A 312 and ANSI B36.10M?	___
	b. Other material approved by DE?	___
3.1.3.3	Are all pipe weld fittings per ANSI B16.9 with ASTM A 403, grade WP-316L or WP-304L material?	___
3.1.3.4	Are KC type mechanical joints in stainless steel piping made by means of ASTM A 182 F316 buttwelded hubs (KC 155), and type 17-4PH teflon-coated seal rings (KC 162)?	___
	Do bimetallic-pipe mechanical joints utilize an ASTM A266, Class III, clamp assembly (KC155), and a Type 17-4PH teflon-coated sealing (KC162)?	___
	Were all KC-type mechanical joints assembled in accordance with KC163 with adequate space allowance for disengagement?	___
	Where industrial flange type mechanical joints used, are they in accordance with ANSI B16.5?	___
3.1.4	Are stainless steel piping runs fabricated by buttwelding per KSC-SPEC-Z-0003 or KSC-SPEC-Z-0016, or ANSI B31.3, and were all buttwelds 100-percent radiographically inspected?	* ___
	NOTE: Some exceptions to these requirements are detailed in KSC-STD-Z-0005, Paragraph 3.1.4.	
PIPING AND TUBING INSTALLATIONS		
3.1.5	Are tubing and piping runs external to pneumatic regulation/control panels identified in accordance with KSC-STD-SF-0004 and KSC-SPEC-Z-0008?	___
3.20.2.1	Is distribution plumbing provided with high and low point drains? (Applicable only if in-place cleaning is required.)	___

NOTE: Comments should be made on separate sheets for all questions answered <u>no</u>.

Reviewer's Name: ____________________

Date: ____________________

Extension: ____________________

Requirements Checklist for KSC-STD-Z-0005

PNEUMATIC GROUND SUPPORT EQUIPMENT

GENERAL SYSTEM REQUIREMENTS

Identification Number(s) ____________________

Service ____________________

Spec Section	Requirements	Yes, No or N/A
3.20.2.4	Do fluid sampling ports conform to Figure 7 of KSC-STD-Z-0005?	____
3.21.1	Do all pipe supports, anchors, hangers, etc. conform to the requirements of ANSI B31.3?	____
3.21.2	Are all flared-tubing supports per KSC-SPEC-Z-0008 and are all supports and mounting hardware of the Unistrut type or equivalent?	____
3.21.3	Are all pipe and tube support welds in accordance with KSC-SPEC-Z-0004?	*____
3.22.1	Is the maximum allowable working stress of distribution plumbing in accordance with ANSI B31.3?	____
3.22.2	Has the distribution plumbing been hydrostatic or pneumatic tested in accordance with ANSI B31.3?	____
	Are piping and tubing sections (individual lengths or fabricated assemblies) identified by an attached metal band (75MO4185), marked per KSC-STD-E-0015, with the pipe/tubing size, schedule/wall thickness, test pressure, date of test, and part number or other identifying nomenclature?	____
FLEXIBLE HOSES		
3.2.1	Are all flexible hoses used only for hook up of portable equipment or to provide for movement between interconnecting fluid lines when no other feasible means are available?	____
3.2.2	Do all flexible hoses consist of a seamless polytetrafluouroethylene or compounded polytetrafluouroethylene inner tube reinforced with a 300-series stainless steel wire construction of braid or spiral wrap or a combination thereof, or do they consist of a flexible 300-series stainless steel pressure carrier reinforced with 300-series stainless steel braid?	*____
3.2.3	Are all flexible hoses provided with 300-series or 17-4PH stainless steel (condition H1025 or greater) end fittings of the coupling-nut, 37-degree flared type or with mechanical joint fittings to mate with the appropriately sized pipe hub (KC 159)?	____

NOTE: Type 17-4PH and Type 303 stainless steel are particularly sensitive to stress corrosion in the KSC environment and shall be protected per paragraph 3.17.4 of KSC-STD-Z-0005. Also, for hoses used in hydrogen service, 17-4PH stainless steel shall not come in contact with pressurized hydrogen.

NOTE: Comments should be made on separate sheets for all questions answered no.

Reviewer's Name: ____________________
Date: ____________________
Extension: ____________________

Requirements Checklist for KSC-STD-Z-0005

PNEUMATIC GROUND SUPPORT EQUIPMENT

GENERAL SYSTEM REQUIREMENTS

Identification Number(s) ____________________

Service ____________________

Spec Section	Requirements	Yes, No or N/A
3.2.4	Are all flexible hoses provided with an identification tag per 75MO4185 which is permanently and legibly marked per KSC-STD-E-0015 with the following information:	
	a. Date (month and year) of hydrostatic test?	____
	b. Maximum rated working pressure?	____
	c. KSC part number if applicable?	____
	d. Vendor name and part number?	____
	e. Service media (only for dedicated system fluid hoses in support of any hydrocarbon or hypergolic fluid system)?	____
3.2.5	Is the inservice time period between inspections for each flexible hose specified in the appropriate engineering documentation for each system and is the date of the last inspection, the inspection procedure, and inspection organization documented by a tag on the hose?	____
3.2.6.1	Do all flexible hoses pressurized to 150 psig or greater comply with the restraint requirements specified in KSC-STD-Z-0005, Section 3.2.6.1 (KHB 1710.2 SOP41)?	____
3.2.6.2	If any flexible metal hoses or unlined bellows are used, has a flow-induced vibration analysis per JSC08123 been performed?	____
3.2.6.3	Are any polytetrafluouroethylene or compounded polytetrafluouroethylene inner tube hoses used where permeation of gases through the inner tube would be unacceptable?	____
3.22.1	Is the maximum allowable working pressure less or equal to one-fourth of the specified burst pressure of the flexible hoses (see 3.2.1)?	____
3.22.2	Have all flexible hoses been hydrostatically tested to a minimum of 1-1/2 times the maximum rated working pressure?	____
PRESSURE GAGES		
3.3.1	Do all pressure gages conform to the requirements of ANSI B40.1 except as specified by KSC-STD-Z-0005, paragraph 3.3.1?	____
3.3.2	Have all pressure gages been selected so that the normal working pressure falls within the middle half of the scale range, except those gages used in applications that require a very wide range of operating pressures, in which case the maximum pressure does not exceed the scale range of the gage?	____

NOTE: Comments should be made on separate sheets for all questions answered no.

Reviewer's Name: ____________________
Date: ____________________
Extension: ____________________

Requirements Checklist for KSC-STD-Z-0005

PNEUMATIC GROUND SUPPORT EQUIPMENT

GENERAL SYSTEM REQUIREMENTS

Identification Number(s) ______________________

Service ______________________

Spec Section	Requirements	Yes, No or N/A
3.3.3	Are all pressure gages made of one-piece, solid front case construction utilizing a window made of high-impact non-cracking plastic, heat treated glass or laminated glass, and a full-diameter pressure relief back case construction, and are all gages designed for flush front-panel mounting?	____
	Are all pressure gage materials normally in contact with the service fluid type 316 stainless steel?	____
	Are all pressure gages provided with a bourbon-tube bleeder or equivalent?	____
3.3.4	Do all pressure gages operating up to 10,000 lb/in^2 have a low-back type pressure connection with a MS 33649-4 port and do pressure gages operating above 10,000 lb/in^2 have a 1/4-inch superpressure port with a 9/16-18 internal thread?	____
3.18.1	Are all pressure gages designed for in-place calibration checkout and trouble-shooting utilizing portable test equipment, if required?	____
	Have all pressure gages been calibrated per manufacturer's specifications and limitations of acceptable performance stated in the maintenance/calibration instructions?	____
3.18.2	Is each pressure gage, pressure switch, or pressure transducer provided with an isolation valve and test port between the isolation valve and the pressure-actuated device?	____
	Is each test port either a bulk-head fitting (KC150C4 and KC124C4) or a plugged 1/4-inch superpressure bulkhead coupling assembly (KC169), depending on the pressure requirements?	____
	Is the volume communicating with test port between the isolation valve and the pressure gage less than or equal to 1.50 cubic inches, except when a vent valve is provided between the isolation valve and the pressure-actuated device?	____
RELIEF VALVES		
3.4.2	Is overpressure protection provided by means of a single conventional safety-relief valve or pilot-operated safety relief valve except as described in KSC-STD-Z-0005, paragraph 3.4.2?	____
3.4.3	For pressure vessels, does the relief valve installation conform to ASME Code, Section VIII, Division 1, paragraph UG-135? For systems, is a relief valve provided as close as practical downstream of each pressure reducing device (regulator) or downstream of any pressure source (compressors, gas rechargers, etc.) whenever any portion of the downstream system cannot withstand the full upstream pressure?	____

NOTE: Comments should be made on separate sheets for all questions answered no.

Reviewer's Name: ______________________
Date: ______________________
Extension: ______________________

Requirements Checklist for KSC-STD-Z-0005

PNEUMATIC GROUND SUPPORT EQUIPMENT

GENERAL SYSTEM REQUIREMENTS

Identification Number(s) ____________________

Service ____________________

Spec Section	Requirements	Yes, No or N/A
3.4.4	For pressure vessels, does the total required relieving capacity conform to requirements of ASME Code, Section VIII, Division 1, paragraph UG-133 or Division 2, paragraph AR150?	___
	For systems, does the relieving capacity prevent the pressure from rising more than 10% above the system design pressure in accordance with ANSI/ASME B31.3, paragraphs 301.2 and 322.6.3?	___
3.4.5	For pressure vessels, are the relief valves set to operate no higher than the MAWP?	___
	For systems, are the relief valves set to operate no higher than the system design pressure?	___
	Are all relief valve set limits specified in OMRSD's or other operating and maintenance documents?	___
3.4.6	Are all relief valves constructed of 300-series stainless steel per ASTM A 276, ASTM A 314, ASTM A 582, or QQ-S-763, or if relief valves are cast, are they constructed of ASTM A 351, grade CF8M or grade CF8 material?	___
3.4.7	Do all relief valve pressure connections for flared tube applications have internal threads per KSC-STD-Z-0005, paragraph 3.1.1.3.1.2 and do all relief valve pressure connections for piping applications mate with appropriately sized hub (KC 159)?	___
	Is inlet/outlet line size equal to or greater than port size of relief valves?	___
3.4.8	Have the effects of discharge from relief valves been assessed to ensure operation of relief valves will not be hazardous to personnel or equipment?	___
	NOTE: Items to be considered are thrust loads, noise, impingement of high-velocity gas or entrained particles, toxicity, oxygen enrichment and flammability.	
3.4.9	Are all pressure relief valves marked with manufacturer's name, serial number, part number, KSC part number (if applicable), and set pressure?	___
3.4.10	Do all relief valves require periodic retest and is the retest interval specified in the OMRSD or other maintenance documents?	___

NOTE: Comments should be made on separate sheets for all questions answered <u>no</u>.

Reviewer's Name: ____________________
Date: ____________________
Extension: ____________________

Requirements Checklist for KSC-STD-Z-0005

PNEUMATIC GROUND SUPPORT EQUIPMENT

GENERAL SYSTEM REQUIREMENTS

Identification Number(s) ____________________

Service ____________________

Spec Section	Requirements	Yes, No or N/A
PRESSURE REGULATORS		
3.5.1	Were pressure regulators selected to maintain set outlet pressures within required system tolerance over the entire range of expected flow rates and were balanced-valve pressure regulators used where widely varying inlet pressures would cause the set outlet pressure to exceed required tolerances?	*___
	NOTE: For each stage of regulation, it is desirable the ratio of upstream pressure to downstream pressure should not exceed 4 for optimum control of pressure and flow and to minimize problems in sizing relief valves. Standard commercially available cylinder regulators (including gages) are acceptable for applications utilizing k-bottles as the pressure source.	
3.5.2	Are all pressure regulator bodies constructed of 300-series stainless steel and do all materials that normally contact the service fluid conform to the manufacturer's recommendations and the compatibility requirements of 79KO9561 and, or 79K11948?	*___
3.5.3	Are all dome-loaded pressure regulators of the externally loaded type and is the dome capable of operating at the maximum rated inlet pressure of the regulator?	___
	Is the regulator diaphragm/piston able to withstand a differential pressure equal to the maximum system rated inlet/outlet pressure with no damage?	*___
3.5.4	Do all mechanically adjusted regulating devices reach a positive stop at both ends of the adjustment range, without disassembly of the pressure-containing parts upon application of a force?	*___
3.5.5	For flared-tubing applications, are pressure regulators provided with internally threaded ports per KSC-STD-Z-0005, paragraph 3.1.1.3.1.2?	___
	For piping applications, are pressure regulators provided with inlet and outlet connections that will mate with the appropriately sized pipe hub (KC 159)?	___
3.10.1	Were all pressure-regulating circuits designed according to system requirements including the required accuracy of regulation, minimum and maximum flow rates, required reliability and operational requirements?	*___
	Are pressure-regulating circuits configured as per Figures 1 through 4 of KSC-STD-Z-0005?	___

NOTE: Comments should be made on separate sheets for all questions answered no.

Reviewer's Name: ____________________
Date: ____________________
Extension: ____________________

Requirements Checklist for KSC-STD-Z-0005

PNEUMATIC GROUND SUPPORT EQUIPMENT

GENERAL SYSTEM REQUIREMENTS

Identification Number(s) ____________________

Service ____________________

Spec Section	Requirements	Yes, No or N/A
3.10.3	Were redundant regulating circuits designed for automatic switchover and in such a manner that components in either flow circuit can be repaired in place or be removed and replaced without interrupting the flow int he parallel circuit?	___
3.10.4	Are inlet and outlet isolation valves and appropriate intermediate vent valves provided for shutdown and maintenance?	___
	Are inlet/outlet isolation valves designed for bi-directional service? NOTE: Normal venting shall not backflow filters.	___
3.10.5	Are relief valves located as close as practical to pressure-regulator outlets and do they meet the requirements of KSC-STD-Z-0005, Section 3.4?	___
3.10.6	Are all pressure regulating circuits designed so that all components can easily by removed and replaced with space allowance made for disengagement of mechanical joints?	___
	Is the use of check valves as the sole pressure-isolation device for maintenance and repair operations involving opening of the pressure system avoided?	___
3.10.7	Are pressure-regulating circuits designed with the capability of maintaining outlet pressure within required tolerances at a flow rate not less than 20 percent above the normal system requirements?	*___
3.10.8	Are the limits of variation allowed on the inlet and outlet pressures of each pressure regulator in a circuit stated in the operating instructions and on the mechanical schematic?	*___
3.10.9	Is a test connection and a vent valve provided in the dome-loading circuit downstream of the loading regulator in accordance with KSC-STD-Z-0005, Section 3.18?	*___
	NOTE: It is desirable that dome-loading pressure regulators be loaded by means of a separate spring-loaded, hand-operated regulator having an automatic downstream pressure-relief capability. A separate relief valve is not normally required in regulator dome-loading circuits.	
3.18.1	Are pressure regulating circuit components such as pressure gages, pressure switches, temperature gages, transducers, regulator dome-loading circuits, and relief valves designed for in-place calibration/checkout, and troubleshooting utilizing portable test equipment, if required?	___
3.18.2	Is each pressure gage, pressure switch, and pressure transducer in a pressure regulating circuit provided with an isolation valve and a test port between the isolation valve and the pressure-actuated device?	___

NOTE: Comments should be made on separate sheets for all questions answered <u>no</u>.

Reviewer's Name: ____________________
Date: ____________________
Extension: ____________________

Requirements Checklist for KSC-STD-Z-0005

PNEUMATIC GROUND SUPPORT EQUIPMENT

GENERAL SYSTEM REQUIREMENTS

Identification Number(s) ____________________

Service ____________________

Spec Section	Requirements	Yes, No or N/A
	Is each dome-loading regulator in a pressure regulating circuit provided with a test port and a vent valve downstream of the loading regulator?	____
	Is each test port either a capped bulk-head fitting (KC 150 C4 and KC 124 C4) or a plugged 1/4-inch superpressure bulkhead coupling assembly (KC 169), depending on the pressure requirements?	____
	Is the volume communicating with test port between the isolation valve and the pressure-actuated device less or equal to 1.50 cubic inches, except when a vent valve is provided between he isolation valve and the pressure-actuated device?	*____
	Whenever pressure gages, pressure switches, and pressure transducers sensing the same are manifolded together, are they provided with a common isolation valve, test port and vent valve between the isolation valve and the pressure actuated devices?	____
PRESSURE VESSELS		
3.6.1	Are all pressure vessels designed, constructed, tested and certified and code stamped in accordance with the ASME Code Section VIII, Division 1 or 2, or DOT 49 CFR?	____
	Are all pressure vessels documented for recertification per KHB 1710.15?	____
3.6.2	Were T-1 steel or other alloys with substantially the same properties such as SA514 and SA517 avoided for pressure vessels?	____
3.6.3	Were all of the ASME Code pressure vessels provided with at least one opening for connection so system piping and another opening for inspection?	____
3.6.4	Were all pressure vessel openings provided with connection that will mate with the appropriately sized pipe hub (KC 159)?	____
3.6.5	Are the maximum working pressure at which the vessel will be normally operated and the name of the working fluid clearly painted on the pressure vessel and legible at 50 feet? (Where multiple vessels are used to store the same working fluid, only the most visible vessel in the group need be labeled.)	____
3.16.2	Are all pressure vessels bonded and grounded in accordance with KSC-STD-E-0012?	*____
3.22.1	Is the maximum allowable working stress in accordance with ASME Code Section VIII, Division 1 or Division 2, as applicable?	____

NOTE: Comments should be made on separate sheets for all questions answered no.

Reviewer's Name: ____________________
Date: ____________________
Extension: ____________________

Requirements Checklist for KSC-STD-Z-0005

PNEUMATIC GROUND SUPPORT EQUIPMENT

GENERAL SYSTEM REQUIREMENTS

Identification Number(s) ____________________

Service ____________________

Spec Section	Requirements	Yes, No or N/A
3.22.2	Have all pressure vessels been hydrostatically or pneumatically tested in accordance with KSC-STD-Z-0005, paragraph 3.6.1?	___
3.24.1	Are all pressure vessels assigned a unique identification on engineering drawings and a tag attached to the vessel? (Ref: KSC-GP-435, Vol.1)	___
SHUTOFF/METERING VALVES		
3.7.1	Are all shutoff/metering valves constructed of 300-series stainless steel per ASTM A 276, ASTM A 314, ASTM A 182, QQ-S-763, or if valves are cast, are they constructed of ASTM A 351, grade CF8M or grade CF8 material?	* ___
	Are all materials that normally contact the service fluid compatible per 79K09561 and, or 79K11948?	___
3.7.2	Has the use of manual valves that utilize external balancing ports or vents open to the atmosphere been avoided?	* ___
3.7.3	Do all shutoff/metering valves with pressure connections for flared tube applications have internal threads per KSC-STC-Z-0005, paragraph 3.1.1.3.1.2?	___
	Do valves used in piping systems have connections to mate with appropriately sized pipe hub (KC 159)?	___
3.7.4	Is valve-stem travel on all valves limited by a positive stop at each extreme position and will the application of force to the stem-positioning device <u>not</u> cause disassembly of the pressure-containing structure of the valve?	* ___
	Do all stem-position indicators sense position of the stem directly, and not the position of the actuating device?	___
	Are all shutoff valves capable of isolating full-rated pressure from either side, and are they installed in accordance with the manufacturer's recommended flow direction for normal operation in each particular application?	___
	Are all split-body valves utilizing flat nonmetallic body gaskets designed to restrain the gasket radially, and are they provided with concentric serrations on the body halves mating with the gasket faces?	* ___
	Are all shutoff/metering valves used in flared-tubing system applications designed for panel mounting?	* ___

NOTE: Comments should be made on separate sheets for all questions answered <u>no</u>.

Reviewer's Name: ____________________
Date: ____________________
Extension: ____________________

Requirements Checklist for KSC-STD-Z-0005

PNEUMATIC GROUND SUPPORT EQUIPMENT

GENERAL SYSTEM REQUIREMENTS

Identification Number(s) ____________________

Service ____________________

Spec Section	Requirements	Yes, No or N/A
FILTERS		
3.8.1	Have filters been installed immediately upstream of all interfaces where control of particulate matter is critical and at all appropriate points where control of particulate migration is desired, and was selection of filters done based on overall system performance in order to maximize protection of critical components with the least amount of pressure drop?	*____
	Do filters have replaceable elements?	____
3.8.2	Are all filter housings and elements constructed of 300-series stainless steel?	*____
	Are all materials that normally contact the service fluid compatible per 79K09561 and, or 79K11948?	____
3.8.3	Do all filter elements maintain filtering quality without being damaged in any way when subjected to maximum system design flow rate and clogged to maximum design capability?	*____
3.8.4	Are largest pore or hole sizes of all filters determined in accordance with ARP 901?	*____
3.8.5	Do filters, found in flared-tubing systems, have inlet and outlet ports per KSC-STD-Z-0005, paragraph 3.1.1.3.1.2, and are differential pressure ports when present per MS33649-4?	____
	For piping systems applications, are filters provided with connections that will mate with appropriate pipe hub (KC 159)?	____
3.8.6	Are definite maintenance requirements and instructions for filters included in the operating and maintenance instructions?	*____
	Does the design provide adequate clearance for filter element replacement, and do designs involving straight-line filters provide for replacement of the complete filter assembly with a spare?	____
3.8.7	Are filters permanently marked with manufacturer's name, the KSC and, or manufacturer's part number, flow direction, rated operating pressure, and serial number (if applicable)?	____

NOTE: Comments should be made on separate sheets for all questions answered no.

Reviewer's Name:____________________
Date:____________________
Extension:____________________

APPENDIX C SAMPLE FORMS

DEVIATION/WAIVER/VARIANCE REQUEST

1. ☐ DEVIATION	☐ WAIVER	☐ SAFETY VARIANCE	☐ DEVIATION ☐ WAIVER ☐ EXEMPTION	
2. REQUESTOR	ORGN.	PHONE	DATE	REQUEST NO.
3. CONTRACTOR	4. CONTRACT NO.	5. VEHICLE/GSE/EFFECTIVITY FACILITY	6. TIME PERIOD/DURATION	

7. DOCUMENT	8. TITLE	9. ITEM NO.

10. REQUIREMENT

11. DESCRIPTION

SAMPLE

12. DETAILED RATIONALE

13. REMARKS

14. REQUIRED APPROVAL

CONTRACTOR
☐ DESIGN ☐ R&QA
☐ OPERATIONS ☐ SAFETY

NASA
☐ DESIGN ☐ R/QA
☐ OPERATIONS ☐ SAFETY

15. TYPE OR PRINT NAME	SIGNATURE	ORGN.	DATE

KSC FORM 20–168 (7/87)

GENERAL PHYSICS CORPORATION

PRESSURE VESSEL NAME PLATE DATA REVIEW

VESSEL LOCATION ______________________________

FLUID CONTENTS ______________________________

VESSEL DESIGNATION ______________________________ V ___ ___ ___

MANUFACTURED BY: ______________________________

MANUFACTURER'S LOCATION: ______________________________

MANUFACTURER'S SERIAL NUMBER: ______________________________

MAXIMUM ALLOW. WORK PRESSURE ______ psi AT ____ °F

DESIGN PRESSURE _______ psi DESIGN TEMPERATURE ____ °F

HYDROSTATIC TEST PRESSURE ____________ psi

CORROSION ALLOW ______________________ IN

DIAMETER _______________ IN LENGTH ___________ IN

SHELL THICKNESS ______________________________

HEAD THICKNESS ______________________________

YEAR BUILT ______ NATIONAL BOARD NO. ______________________________

ADDITIONAL INFORMATION:

TYPE OF TANK: HORIZONTAL OR VERTICAL (Circle)

DESCRIBE FASTENINGS:

SAFETY VALVE OUTLETS: NUMBER: __________________ TYPE(S) __________________

SIZE: __________________ LOCATION: ______________________________

SUPPORTS: SKIRT: YES NO LUGS (No.) ______________ LEGS (No.) ______________

OTHER: (Describe) ______________________________ ATTACHED: ______________

REMARKS:

NAME: ______________________________ DATE: ______________________________

(Continued)

FOR USE WITH CRYOGENIC VESSELS

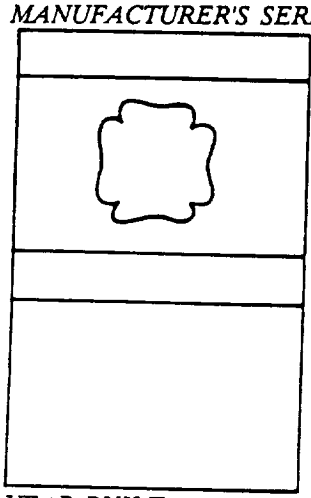
USE THE FRONT OF THIS SHEET FOR THE EXTERNAL VESSEL AND SIDE 2 FOR THE INTERNAL VESSEL

INTERNAL VESSEL CONTENTS: ______________________________

MANUFACTURED BY: ______________________________

MANUFACTURER'S LOCATION: ______________________________

MANUFACTURER'S SERIAL NUMBER: ______________________________



MAXIMUM ALLOW. WORK PRESSURE ______ psi AT ____ °F

DESIGN PRESSURE _______ psi DESIGN TEMPERATURE ____ °F

HYDROSTATIC TEST PRESSURE ____________ psi

CORROSION ALLOW ________________________ IN

DIAMETER _______________ IN LENGTH ___________ IN

SHELL THICKNESS ______________________________

HEAD THICKNESS ______________________________

YEAR BUILT ______ NATIONAL BOARD NO. ______________________________

ADDITIONAL INFORMATION:

SAFETY VALVE OUTLETS: NUMBER: ____________________ TYPE(S) ____________________

SIZE: ___________________ LOCATION: ______________________________

REMARKS:

NGINEERING SUPPORT REQUEST	1. DATE	2. PROGRAM NO.	3. ESR NO. REV.	4. SHEET ____ ____
5. LOCATION	6. EFFECTIVITY	7. EVENT REQ'D BY	8. USER NEED DATE	9. CATEGORY
10. FACILITY/SYSTEM/EQUIPMENT	11. PART	12. PART NO.	13. REF. DES/FIND	14. LEVEL INTERFACE AFFECTED
15. TITLE				17. MANUFACTURER
16. DESCRIPTION OF REQUIREMENT/CONDITION/EVENT				18. TYPE OF ACTION
				19. SCHEDULE IMPACT

20. ACTION REQUESTED

SAMPLE

21. JUSTIFICATION

22. COMMENTS AND ACTION ITEMS

23. TECHNICAL CONTACT			24. APPROVAL			25. DE APPROVAL		
NAME	ORG.	PHONE	SIGNATURE	ORG.	DATE	SIGNATURE	ORG.	DATE

KSC FORM 21-319 (REV. 3/87)

GENERAL PHYSICS CORPORATION

INSPECTION PLANNING MEMORANDUM

DATE ________ SHEET _1_ OF ___
PREPARED BY ________________

SYSTEM NUMBER ____________________

PRIORITY GROUP ____________________

VESSEL IDENTIFICATION ____________________

VESSEL MAWP ____________________

SYSTEM OPERATING PRESSURE ____________________

INSPECTION REQUIREMENTS:

REFERENCE TABLE	VE	VI	UT THK	UT VOL	PT	MT	AET
PRESSURE VESSELS							
VESSEL CLAMPS & SUPPORT STRUCTURES							
SYSTEM PIPING							
THREADED FITTINGS & WELDS							
RELIEF VALVES							
PRESSURE GAGES & SWITCHES							
FLEXIBLE HOSES							

SYSTEM VESSEL REQUIREMENTS

VESSEL/SYSTEM ACCESSIBILITY
VESSEL INTERNAL ACCESSIBILITY
VESSEL ISOLATION/REMOVAL
COMPONENT ISOLATION/REMOVAL

EQUIPMENT REQUIREMENTS

WATER
GN_2/COMPRESSED AIR
ELECTRICITY

GENERAL PHYSICS CORPORATION

INSPECTION PLANNING MEMORANDUM

DATE ________ SHEET _2_ OF __
PREPARED BY ________________

TEST REQUIREMENTS

SCHEDULING/APPROVAL ________________
SYSTEM ISOLATION/DEPRESSURIZATION ________________
SPECIAL VALVE ALIGNMENT ________________
JPL PERSONNEL REQUIRED ________________
SYSTEM REINSTALLATION ________________

CLEANING REQUIREMENTS

PRE INSPECTION ________________
PAINT/INSULATION REMOVAL ________________
SURFACE PREPARATION ________________
INTERNAL PREPARATION ________________
AREA PREPARATION ________________
POST INSPECTION ________________
REPAINT/REINSULATE
DEW POINT/HYDROCARBON TESTS
DRYING/PURGING
DRAINING

SPECIAL TOOLS/EQUIPMENT

FITTINGS ________________
FLEX HOSES ________________
VALVES/REGULATORS ________________
LIGHTING ________________
HAND TOOLS ________________
POWER EQUIPMENT ________________

SAFETY REQUIREMENTS

____
____
PROPER VENTILATION ________________
HAZARDS TO PERSONNEL/EQUIPMENT ________________
SPECIAL CLOTHING ________________
SECURING TEST PIECES/EQUIPMENT ________________

GENERAL PHYSICS CORPORATION

SAMPLE TABLE FOR THE FREQUENCY OF INSPECTION & TESTING

	TEST METHOD REQUIRED AT TIME INTERVALS (YEARS)					
DESCRIPTION	INITIAL RECERTIFICATION	1	2	5	10	20
Vessel						
Vessel Clamps & Support Structures						
System Piping						
All Threaded Fittings & Welds						
Relief Valves						
Pressure Gages & Switches						
Flexible Hose						

INSPECTION AND TEST METHODS

- AET = Acoustic Emission Testing
- UT-THK = Ultrasonic Thickness Measurement
- VE = External Visual Examination
- VI = Internal Visual Examination
- UT-VOL = Ultrasonic Volumetric Test
- BR = Bolt Re-Torque
- OD = Outside Diameter Measurement by Caliper
- CRVT = Relief Valve Certification Test
- C = Calibration
- PT = Liquid Dye Penetrant Examination
- MT = Magnetic Particle Examination
- H150 = Hydrostatic Pressure Test
- R = Recertification Required

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (*Leave blank*)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
		Initial Release

4. TITLE AND SUBTITLE

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5. FUNDING NUMBERS

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10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT

12b. DISTRIBUTION CODE

13. ABSTRACT (*Maximum 200 words*)

This guide is intended to provide methodology and describe the intent of the Pressure Vessel and System (PV/S) Certification program. It is not meant to be a mandated document, but is intended to transmit a basic understanding of the PV/S program, and include examples. After the reader has familiarized himself with this publication, he should have a basic understanding of how to go about developing a PV/S Certification Program.

14. SUBJECT TERMS

Pressure Vessel Certification, Recertification, Pressure Vessel Systems Certification

15. NUMBER OF PAGES

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	