U.S. DEPARTMENT OF ENERGY/NNSA

SAFETY GUIDE

OFFICE OF WEAPONS SURETY
PACKAGING AND TRANSPORTATION PROGRAM

Design Guide for Testing Type B Packaging

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US DOE SAFETY GUIDES

Safety Guides are issued to describe and make available to DOE contractors and the public methods acceptable to the DOE of implementing specific parts of the Department's regulations, to delineate techniques used by DOE in evaluating specific problems or postulating accidents, or to provide guidance.

Safety Guides are not substitutes for regulations, and compliance with them is not required. Methods and solutions different from those set out in the guides will be acceptable if they provide a basis for finding that the regulation has been met.

Design Guide for Testing
Type B Packaging

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FOREWORD

In a joint effort between U. S. Department of Energy (DOE)/National Nuclear Security Administration (NNSA) Albuquerque (AL) Office of Weapons Surety (OWS) Packaging and Transportation Program (PTP) and BWXT Y-12 L.L.C. of Oak Ridge, Tennessee, this guide has been developed for testing Type B Packaging for transport of Defense Programs materials. This guide is a follow-on document to the *Design Guide for Shipping Package Design* (November 1994). This Design Guide is the responsibility of OWS PTP. The primary goal of the Design Guide series is to standardize and document the design and test process that leads to a certifiable Type B container that can be used to package and transport of nuclear components that contain a Type B quantity of radioactive material (RAM) and other RAM of national security interest. The standardization of a packaging design and test process has the ultimate goal of promoting the application of standard codes, evaluations, computational techniques, and testing to increase the likelihood of regulatory acceptance.

The Design Guides are a comprehensive set of documents which apply a systems engineering approach to the design and testing of Type B fissile packages for radioactive material handling and shipping. The specific design aspects addressed in the guide are geared toward special nuclear materials. However, the design guides can be used to design and test any radioactive material package (fissile or nonfissile) for unirradiated material. This Design Guide covers all elements of a successful test plan development and its subsequent testing activities for normal conditions and hypothetical accident conditions.

The Design Guide series are living documents that will continue to be updated as new processes and/or technologies are developed and implemented, and as management systems change.

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U.S. Department of Energy

SAFETY GUIDE

DESIGN GUIDE FOR TESTING OF TYPE B PACKAGING

EXECUTIVE SUMMARY

The U.S. Department of Energy/NNSA, AL OWS PTP is responsible for evaluating and certifying Type B radioactive material packaging of nuclear components in support of the National Defense Programs (DPs). Evaluation and certification are conducted according to the Code of Federal Regulations - Transportation, Title 49, Part 173, Section 416, (49 CFR Part 173.416). This section of the CFR states that each Type B packaging must be designed and constructed to meet the requirements in 10 CFR Part 71.

OWS PTP maintains a series of safety guides to describe methods to implement specific parts of the Department's regulations, to delineate DOE's techniques for evaluating specific problems or postulating accidents, and to provide guidance. DOE Order O 251.1, *Directive System*, states in section 4g that "Orders, Notices, and Manuals may be accompanied by Guides when appropriate." This *Design Guide for Testing of Type B Packaging* is required to complete the series for packaging design. The design guide includes methods and techniques that provide a basis for determining whether regulations have been met.

Packaging used for transporting nuclear components of radioactive materials off DOE sites in U.S. Government owned conveyance must meet criteria specified by the U.S. Government to ensure that the risk to the public is minimized. These requirements are specified in 49 CFR and 10 CFR. The three specific functions that packaging is required to perform are (1) containment of the radioactive material, (2) minimization of risk to the public from transportation, and (3) the preservation of the material in a subcritical configuration.

OWS PTP implements DOE policies and has established practices and guidance for obtaining certification of packaging used by DOE and its contractors for the transport of radioactive materials. These certification review policies and guidelines have been established to ensure (1) that DOE packaging designs and operations protect the public health and safety, and (2) that they meet or exceed safety criteria equivalent to the standards prescribed by the Nuclear Regulatory Commission (NRC) certification process for packaging (10 CFR Part 71). This guide is current with the April 2002 Federal Register Notice which revised the 10 CFR Part 71, which now conforms with the *International Atomic Energy Agency* (IAEA) *Safety Standard Series TS-R-1 (ST-1, Revised)*, as amended in 1996.

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ACRONYMS AND INITIALISMS

AL	Albuquerque Operations Office
ANSI	American National Standards Institute
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
CFR	Code of Federal Regulations
C of C	Certificate of Compliance (DOE EM-5)
C of CA	Certificate of Competent Authority (NRC, IAEA/DOT)
DOE	Department of Energy
DOE/AL	Department of Energy, Albuquerque Operations Office
DOT	Department of Transportation
DP	Defense Programs
HAC	Hypothetical Accident Conditions
IAEA	International Atomic Energy Agency
NCT	Normal Conditions of Transport
NIST	National Institute of Science and Technology
NNSA	National Nuclear Security Administration
NRC	Nuclear Regulatory Commission
P&TP	Packaging and Transportation Program
OTC	Offsite Transportation Certificate
OWS	Office of Weapons Surety
PCV	Primary Containment Vessel
SARP	Safety Analysis Report for Packaging
SCV	Secondary Containment Vessel
SNM	Special Nuclear Material
USC	United States Code

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1.0 INTRODUCTION

1.1 Scope and Applicability

OWS PTP has established practices and guides for obtaining certification of packaging used by DOE and its contractors for the transport of radioactive weapons materials. These certification review guides have been established to ensure that DOE packaging designs and operations protect the public health and safety and that they meet safety criteria at least equivalent to the standards prescribed by the NRC certification process for packaging (10 CFR Part 71, "Packaging and Transportation of Radioactive Material"). This CFR addresses the testing requirements for Type B packaging (Figure 1-1) which DOE requires for the certification of a new Type B packaging design. The CFR also includes the requirements to evaluate the effects of normal conditions of transport (NCT) and hypothetical accident conditions (HAC) which are to be applied by testing or other methods to determine their effects on a package. The results of these tests are analyzed and reported in the Type B Packaging Safety Analysis Report for Packaging (SARP). The flowchart in Figure 1-2 shows the sequence of testing for the normal conditions of transport and for hypothetical accident conditions.

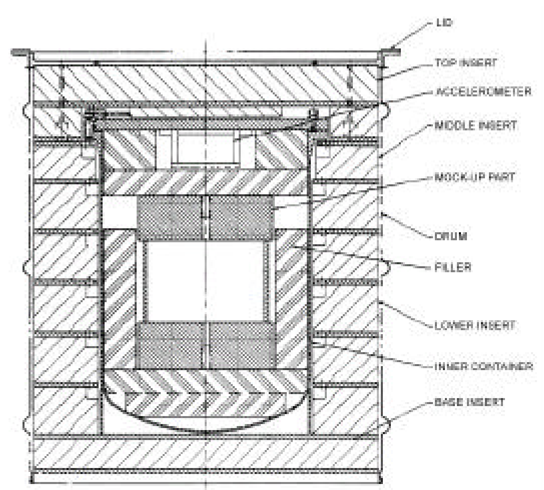

Fig. 1-1. Test configuration for a representative Type B package.

This design guide addresses these requirements as they apply to testing and, specifically, the test methods applicable to the Type B packaging designs. The scope of this design guide does not include the air transport of plutonium.

1.2 Purpose and Objective

The purpose of this design guide is to provide a comprehensive document that presents acceptable methods for planning and conducting the required tests to supplement and verify the structural, thermal, and shielding aspects of the package design. The objective of this document is to cover all elements of a successful testing program, as discussed below.

[1] Required for Fissile materials where water leakage has not been assumed for criticality.

[2] 10 CFR Part 71.71(a) states that separate test units may be used for the free drop test, the compression test, and the penetration test if each test unit is subjected to the water spray test before being subjected to any ot the other tests.

[3] Perform if the inner container includes a secondary containment vessel (SCV) in addition to the primary containment vessel (PCV).

Fig. 1-2. Typical test preparation and performance activities with optional test sequencing.

1.3 Definitions

The following terms are relevant to the overall subject of testing.

Certificate of Compliance - An DOE EM-5 document which certifies that a specific packaging design for specified quantities and types of radioactive materials meets the applicable regulation standards.

Certificate of Competent Authority – An NRC or IAEA/DOT document which certifies that a specific packaging design for specified quantities and types of radioactive materials meets the applicable regulation standards.

Containment System - The assembly of components for the packaging intended to retain the radioactive material during transport.

Containment Vessel - The receptacle in which principal reliance is placed to retain the radioactive material during transport.

Fissile Materials - Uranium-233, uranium-235, plutonium-239, plutonium-241, or any combination of these radionuclides. The following are not included in this definition: (1) unirradiated natural uranium, (2) unirradiated depleted uranium, (3) natural uranium that has been irradiated in a thermal reactor, and (4) depleted uranium that has been irradiated in a thermal reactor.

Hazardous Materials - A substance or a material including a hazardous substance which has been determined by the Secretary of Transportation to be capable of posing unreasonable risk to health, safety, and property when transported in commerce and which has been so designated in 49 CFR 172.101.

Maximum Normal Operating Pressure - The maximum gauge pressure that is expected to develop in the containment system in a period of one year under the heat condition specified in 10 CFR 71.71(c)(1) in the absence of venting, external cooling by an ancillary system, or operational controls during transport.

Moderator - A material used to reduce the kinetic energy of neutrons by scattering collisions without appreciable neutron capture.

Nuclear Components - Those parts of a nuclear explosive, special assembly, test part, or subassembly that contain fissile material and/or radioactive materials and other materials.

Nuclear Criticality Safety - The implementation of procedures and the application of limits to ensure that fissile material remains in a subcritical state. Also, protection against the consequences of an inadvertent nuclear chain reaction, preferably by prevention of the reaction (Ref. ANS/ANSI 8.1). 10 CFR Part 71 and associated regulatory guidance require maintaining a significant margin from criticality.

Offsite Transportation Certificate (OTC) - A DOE document, approved and issued by the DOE/NNSA Certifying Official authorizing a specific packaging for weapons-related transportation activities involving quantities of radioactive and other hazardous materials, for use on a one-time basis or for multiple uses for up to five years.

Package - The packaging, along with its contents, as presented for transport.

Packaging - The assembly of components necessary to comply with the packaging requirements of 10 CFR Part 71. It may consist of one or more receptacles, absorbent materials, spacing structures, thermal insulation, radiation shielding, and devices for cooling or absorbing mechanical shocks. The conveyance, tie down system, and auxiliary equipment may sometimes be designated as part of the packaging.

Radioactive Material - Any material having a specific activity greater than 70 becquerals per gram (0.002 micro curies per gram).

Radioactive Materials Associated with the Nuclear Weapons Program - Type B quantities of weapons-grade special nuclear material, Category I or II quantities of special nuclear material, tritium, and other materials specifically designated by the DOE/NNSA Deputy Administrator for Defense Programs and pertaining to the certification of packaging for weapons, weapon components, and weapon subassemblies only.

Risk - The combination of the probability of an incident releasing radioactive and/or hazardous materials and the consequences of the release to the public and the environment which, taken over all events relating to system operation, provides a meaningful picture of the adverse impact of the operation. (Risk is built into the 10 CFR Part 71 regulations. A packaging that meets the requirements of 10 CFR Part 71 needs no additional assessment of risk.)

Safety Analysis Report for Packaging (SARP) - A document that provides a comprehensive technical evaluation of packaging. The report identifies design, testing, operational procedures, maintenance procedures, and a quality assurance program to demonstrate compliance with NRC safety standards or equivalent standards established by DOE for approving packaging and issuing Offsite Transportation Certificates.

Special Assembly - Major assemblies of nuclear weapon components that do not comprise a complete nuclear explosive and, therefore, are incapable of producing a nuclear detonation.

Special Nuclear Material (SNM) - Plutonium, uranium enriched in the isotope 233 or in the isotope 235, and any other material which the NRC (pursuant to the provisions of Section 51 of the *Atomic Energy Act*) determines to be SNM but does not include source material; any materials artificially enriched by any of the foregoing, but does not include source materials (Ref. *Atomic Energy Act*, 42 U.S.C. 2014).

Type A_1/A_2 Quantity - The maximum activity of a radioactive isotope which can be transported in a Type A package. These levels are listed by isotope in 10 CFR Part 71, Appendix A. A_1 quantities apply to special form radioactive material (material that is either a single solid piece or contained in a sealed capsule). A_2 quantities apply to normal form radioactive material (material which does not qualify as special form radioactive material).

Type B Package - A Type B packaging along with its radioactive contents.

Type B Quantity - A quantity of radioactive material greater than A_1 or A_2 quantities.

Weapons-Grade Radioactive Material - Uranium that contains greater than 20 percent of the isotope U-235, or plutonium that contains less than 7 percent of the isotope Pu-240.

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2.0 TEST REQUIREMENTS

2.1 DOE Requirements

DOE/AL Supplemental Directive, 5610.12, *Packaging and Off-site Transportation of Nuclear Components, and Special Assemblies Associated with the Nuclear Explosive and Weapon Safety Program,* establishes the DOE/AL Operations Office requirements, establishes standards of performance, and assigns authorities and responsibilities for the design, production, test, evaluation, procurement, documentation, independent review, certification, maintenance, quality assurance, and use of packages.

DOE O 460.1A, *Packaging and Transportation Safety* (replaces both DOE O 1540.2 and DOE O 5480.3), establishes safety requirements for the proper packaging and transportation of DOE off-site shipments and on-site transfers of hazardous materials, as well as requirements for modal transport. It specifies that the, "Safety Analysis Report for Packaging must demonstrate that the package will satisfy the standards of 10 CFR 71 Subparts E and F, the quality assurance program of Subpart H. . . ."

DOE O 460.2, *Departmental Materials Transportation and Packaging Management* (replaces DOE O 1540.1A, DOE O 1540.2, and DOE O 1540.3), specifies that "It is the DOE policy that, notwithstanding the exemptions available through the National Security Provision, shipments under this provision will comply with the 49 CFR 106-180 requirements."

DOE O 461.1, *Packaging and Transfer or Transportation of Materials of National Security Interest*, establishes requirements for ensuring compliance with Reg Guide 7.9, 10 CFR 71, and 49 CFR 100-199. Also includes requirements for obtaining an Offsite Transportation Certificate (OTC) or an Offsite Transportation Authorization (OTA), and supporting documentation such as a Safety Analysis Report for Packaging (SARP) or Transportation System Risk Assessment (TSRA).

DOE Implementation Guide, *Packaging and Transportation Safety*, DOE G/460-1.1, dated June 5, 1997, supplements DOE O 460.1 and provides the Department's expectations of its requirements as contained in rules, orders, notices, and regulatory standards.

DOE/AL Safety Guide SG100, Rev. 1, *Design Guide for Packaging and Transfer or Transportation of Materials of National Security Interest*.

2.2 CFR Requirements

10 CFR Part 71, Subpart H, *Quality Assurance,* §71.107, "Package design control," (b), states that "Where a test program is used to verify the adequacy of a specific design feature in lieu of other verifying or checking processes, the licensee should include suitable qualification testing of a prototype or sample unit under the most adverse

design conditions” and should include design control measures to items such as to the “delineation of acceptance criteria for inspections and tests.”

10 CFR Part 71, Subpart H, §71.101(f), allows the use of an existing NRC-approved 10 CFR Part 50, Appendix B quality assurance program that satisfies each of the applicable criteria of paragraphs 71.101 through 71.137. 10 CFR 50, Appendix B, “Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants,” states that a test program should be established to assure that all testing required to demonstrate that structures, systems, and components will perform satisfactorily in service is identified and performed in accordance with written test procedures which incorporate the requirements and acceptance limits contained in applicable design documents.

10 CFR Part 71, Subpart H, §71.123, “Test control,” states that, "The licensee shall establish a test program to assure that all testing required to demonstrate that the packaging components will perform satisfactorily in service is identified and performed in accordance with written test procedures that incorporate the requirements of this part and the requirements and acceptance limits contained in the package approval. The test procedures must include provisions for assuring that all prerequisites for the given test are met, that adequate test instrumentation is available and used, and that the test is performed under suitable environmental conditions. The licensee shall document and evaluate the test results to assure that test requirements have been satisfied.”

10 CFR Part 71, Subpart E, *Package Approval Standards*, states in §71.41(a), “The effects on a package of the tests specified in §71.71 (‘Normal conditions of transport’), and the tests specified in §71.73 (‘Hypothetical accident conditions’), and §71.61 (‘Special requirement for irradiated nuclear fuel shipments’), must be evaluated by subjecting a specimen or scale model to a specific test, or by another method of demonstration acceptable to the Commission, as appropriate for the particular feature being considered.”

10 CFR Part 830.121, *Quality Assurance Program*, states in Section (b), (1) that a DOE contractor must submit a quality assurance program to DOE for approval and conduct work in accordance with the QAP. The quality assurance program should include a discussion of how the criteria of Section 830.122 will be satisfied and should be applied using a graded approach. The contractor should use appropriate standards where applicable (i.e., 10 CFR Part 71, Subpart H) to develop and implement its quality assurance program.

49 CFR 173, Subpart I, *Class 7 (Radioactive) Materials*, §173.413, “Requirements for Type B Packages,” states that “Except as provided in §173.416, each Type B(U) or Type B(M) package must be designed and constructed to meet the applicable requirements of 10 CFR Part 71.”

49 CFR §173.467 states that “Each Type B packaging or packaging for fissile material must meet the test requirements prescribed in 10 CFR Part 71 for ability to withstand accident conditions in transportation.”

2.3 Other Reference Documents

IAEA Safety Standard Series No. TS-R-1 (ST-1, Revised), *Regulations for the Safe Transport of Radioactive Material* (1996 edition), (paragraph 101) states that the purpose of these regulations is to establish standards of safety which provide an acceptable level of control of the radiation, criticality, and thermal hazards to persons, property, and the environment that are associated with the transport of radioactive material. Section VI states the requirements for Type B packaging, and Section VII provides acceptable test procedures.

IAEA Safety Standards Series No. ST-2, *Advisory Material for the Regulations for the Safe Transport of Radioactive Material (1996 Edition),* combines the former IAEA Safety Series No. 37 and Safety Series No. 7 into a single text. This document gives information on individual provisions of TS-R-1 as to their purpose, scientific background, and how to apply them in practice. Its main purpose is to provide advice to users on proven and acceptable ways of achieving and demonstrating compliance with the Regulations. It must be used as a companion to TS-R-1.

ASME NQA-1-2000, *Quality Assurance Requirements for Nuclear Facility*, Applications Requirement 11, “Test Control,” states that required testing (including prototype qualification tests, production tests, proof tests prior to installation, construction tests, preoperational tests, operational tests, etc., as appropriate) should also be controlled. Test requirements and acceptance tests should be controlled. Test requirements and acceptance criteria should be based on specified requirements contained in applicable designs or other pertinent technical documents. 10 CFR Part 830.121, *Quality Assurance,* states that a DOE-approved QAP is required which: describes how quality assurance criteria in 830.122 are met; integrates the quality assurance criteria with safety management system; and use voluntary consensus standards for development and implementation, where practical and consistent with regulatory requirements.

ANSI N14.5-1997, *American National Standard for Radioactive Materials - Leakage Tests on Packages for Shipment of Radioactive Materials*, specifies methods for demonstrating that Type B packages comply with the package containment requirements of Title 10 CFR, Part 71, as amended, and/or requirements of the IAEA Safety Standard Series No. TS-R-1, (ST-1, Revised), *Regulations for the Safe Transport of Radioactive Material*. These requirements are necessary for the following:

(1) Design verification
(2) Fabrication verification
(3) Assembly verification
(4) Periodic verification

ANSI N14.10.3, *Administrative Guide for Verifying Compliance with Packaging Requirements for Shipments of Radioactive Materials.* This standard presents (1) a method by which compliance with packaging requirements may be obtained and documented, (2) guidance to be followed if incidents occur that threaten package integrity, and (3) a plan for receivers to verify the integrity of delivered packages.

Nuclear Regulatory Commission Regulatory Guides, Division 7 - Transportation, are listed below.

7.1, *Administrative Guide for Packaging and Transporting Radioactive Material*

7.2, *Packaging and Transportation of Radioactively Contaminated Biological Materials*

7.3, *Procedures for Picking Up and Receiving Packages of Radioactive Material*

7.4, *Leakage Tests on Packages for Shipment of Radioactive Materials*

7.5, *Administrative Guide for Obtaining Exemptions From Certain NRC Requirements Over Radioactive Material Shipments*

7.6, *Design Criteria for the Structural Analysis of Shipping Cask Containment Vessels*

7.7, *Administrative Guide for Verifying Compliance with Packaging Requirements for Shipments of Radioactive Materials*

7.8, *Load Combinations for the Structural Analysis of Shipping Casks for Radioactive Material*

7.9, *Standard Format and Content of Part 71 Applications for Approval of Packaging of Type B, Large Quantity, and Fissile Radioactive Material*

7.10, *Establishing Quality Assurance Programs for Packaging Used in the Transport of Radioactive Material*

7.11, *Fracture Toughness Criteria of Base Material for Ferritic Steel Shipping Cask Containment Vessels with a Maximum Wall Thickness of 4 Inches (0.1m)*

NUREG/CR-6007, *Stress Analysis of Closure Bolts for Shipping Casks*

3.0 PACKAGING TEST PLAN DEVELOPMENT

This section addresses the requirements for planning and developing packaging test plans that are used to verify conformance of a package to specified requirements or to demonstrate satisfactory performance for its intended service. Each packaging owner/designer is responsible for establishing a practice for controlling the testing of packaging and the associated components identical to the packaging being modeled. Before each test series, the prototype models are to be validated using the same process specified for production packaging. Any differences between the prototype model and the production model should be evaluated for impact on test performance. The results of this evaluation should be included in the test reports. The pedigree verification of each test package must be completed prior to assembly. Pedigree verification is a quality assurance process which documents that the test specimen meets all safety and performance critical requirements of the package design (e.g., materials, dimensions, surface finish, and leak tightness).

The DOT, NRC and international regulations are developed on the premise that multiple hazards involving Type B quantities are not very frequent. When there are multiple hazards, the material is classified as radioactive and the regulations address predominantly the containment requirements for Class 7 materials. Some DOE shipments of nuclear components contain multiple hazards. Therefore, the item to be transported should be completely identified and classified based upon these distinct hazards. Based upon this proper identification, test planning activities should include concerns related to these additional hazards. For example, if an item contains a DOT explosive device, the test should include the effects that fire, vibration, and dropping would have on this device, including any increase of inside containment pressure, release rates, etc.

3.1 Requirements for the Packaging Test Plan

10 CFR Part 71, Subpart H, §71.123, states that the licensee (packaging owner), “shall establish a test program to assure that all testing required to demonstrate that the packaging components will perform satisfactorily in service is identified and performed in accordance with written test procedures that incorporate the requirements of this part and the requirements and acceptance limits contained in the package approval. The test procedures must include provisions for assuring that all prerequisites for a given test are met, that adequate test instrumentation is available and used, and that the test is performed under suitable environmental conditions. The test plan shall require the documentation and evaluation of the test results to assure that test requirements have been satisfied.”

ASME NQA-1-2000, Requirement 11, “Test Control,” states that required tests (including prototype qualification tests, production tests, proof tests prior to installation, construction tests, preoperational tests, operational tests, etc., as appropriate) should be controlled. Test requirements and acceptance tests should also be controlled. Test requirements and acceptance criteria should be based on specified requirements contained in applicable design or other pertinent technical documents.

3.2 Planning

The planning for and the development of a packaging test plan involves the evaluation of each package design for normal conditions of transport and for hypothetical accident conditions. Package testing should be performed, if possible, under the most adverse design conditions to the specific features being verified. If the test program is intended to confirm the adequacy of the overall design, all pertinent operating modes should be considered in determining these design conditions. A decision must be made as to whether simulated content(s) or mockup(s) will be used in testing. If a mockup is used, the impact on test results should be considered. No radioactive or hazardous materials should be used for test contents. Every attempt should be made to utilize test content that simulates (as close as practical) the weight, size, and other characteristics of the actual contents. Test content should be specified in the test plan. Hypothetical accident conditions are to be based on sequential application of the tests as specified in 10 CFR Part 71 in the order indicated to determine their cumulative effect on a package.

As applicable a test plan should:

- Identify which test requirements will be satisfied by analysis, similarity testing, or a combination thereof.
- Determine whether a specific test is required, and describe how the test is to be performed.
- Identify the implementing documents to be developed to control and perform tests.
- Identify items to be tested and the test requirements and acceptance limits, including required levels of precision and accuracy.
- Identify test methods to be employed and instructions for performing the test.
- Identify test prerequisites that address instrument calibration, appropriate and adequate test equipment and instrumentation, trained personnel, the condition of test equipment and the item to be tested, suitably controlled environmental conditions, and provisions for data acquisition.
- Identify mandatory hold points.
- Identify methods to record data and results.
- Identify or develop safety plans.

- Specify records retention.

- Identify provisions for ensuring that prerequisites for the given test have been met.

- Select and identify the measuring and test equipment to be used to perform the test to ensure that the equipment is of the proper type, range, accuracy, and tolerance to accomplish the intended function.

ASME NQA-1-2000 provides an acceptable outline for a packaging test plan, including the provisions for implementing procedures. The test plan is usually prepared by the packaging design organization and approved by the appropriate packaging function and the quality assurance organization or its representative.

During the planning process, the following items must be addressed and the resultant information placed in the packaging test plan:

- Description of packaging preparation/configuration prior to testing
- Test equipment to be used
- Monitoring to be performed
- Environmental conditions to be maintained

3.3 Acceptance Criteria

10 CFR 71, §71.41 (a) states that the effects of the tests specified in §71.71 (NCT) and §71.73 (HAC) "must be evaluated by subjecting a specimen or scale model to a specific test, or by another method of demonstration acceptable to the Commission, as appropriate for the particular feature being considered."

§71.51 states that for Type B packages, in addition to satisfying the requirements of §71.41 through 71.47, the packaging must be designed, constructed, and prepared for shipment with the criteria listed below.

(1) For the tests for all Type B packages specified in §71.71 (NCT), there would be:

- No loss or disposal of radioactive contents (as demonstrated to a sensitivity of 10^{-6} A_2 per hour)
- No significant increase in external surface radiation levels
- No substantial reduction in the effectiveness of the packaging

(2) For the tests specified in §71.73 (HAC), there would be:

- No escape of krypton-85 exceeding 10 A_2 in one week
- No escape of other radioactive material exceeding a total amount of A_2 in one week

- No external radiation dose rate exceeding 10 mSv/h (1 rem/h) at 1 m (40 in) from the external surface of the package

For fissile material packages, §71.55 provides additional acceptance criteria following the NCT and HAC testing.

(1) For the tests specified in §71.71 (NCT) for fissile material packages:

- The contents would be subcritical.
- The geometric form of the package contents would not be substantially altered.
- There would be no leakage of water into the containment system unless, in the evaluation of undamaged packages under §71.59(a)(1), it has been assumed that moderation is present to such an extent as to cause maximum reactivity consistent with the chemical and physical form of the material.
- There would be no substantial reduction in the effectiveness of the packaging, including:
  - No more than 5 percent reduction in the total effective volume of the packaging on which nuclear safety is assessed
  - No more than 5 percent reduction in the effective spacing between the fissile contents and the outer surface of the packaging
  - No occurrence of an aperture in the outer surface of the packaging large enough to permit entry of a 10 cm (4 in) cube

(2) For the tests specified in §71.73 (HAC) for fissile material packages, the package would be subcritical. For this determination, the following must be assumed:

- The fissile material is in the most reactive credible configuration consistent with the damaged condition of the package and the chemical and physical form of the contents.
- Water moderation occurs to the most reactive credible extent consistent with the damaged condition of the package and the chemical and physical form of the contents.
- There is full reflection by water on all sides, as close as is consistent with the damaged condition of the package.

3.4 Test Prerequisites

The following prerequisites should be included and addressed in the packaging test plan:

- Calibrated instruments
- Appropriate equipment
- Documentation of test prototype condition
- Suitable site-specified environmental conditions

3.5 Provisions for Data Acquisition and Recording (Including Photography/Video)

The packaging test plan, which may include associated test procedures, should discuss provisions for acquisition of testing data. This equipment should be selected and determined to be capable of properly functioning during the period of the test. If required, backups of selected equipment should be made available during the test.

Sufficient evidence, such as evidence to demonstrate regulatory compliance, should be provided to document all tests as appropriate. For example, video cameras may be used to document live action of drops, burn tests, etc. The requirement for collecting such evidence should be identified in the test plan.

Strip chart recordings, computer printouts, charts, and graphs of the tests may be identified specifically in the test plan and included in the test report.

3.6 Test Controls

During the planning process, all test controls (including environmental, health and safety controls) should be identified and included in either the packaging test plan and/or the testing procedures or instructions.

3.7 Test Procedures and Instructions

Tests should be performed in accordance with approved implementing procedures or instructions that, as applicable:

- Include or reference test objectives and provisions for ensuring that prerequisites for the given test have been met, that adequate calibrated instrumentation is available and used, that necessary monitoring is performed, and that suitable environmental conditions are maintained.
- Include test requirements and acceptance criteria provided or approved by the organization responsible for the design of the package to be tested unless otherwise designated.
- Identify potential sources of uncertainty and error. Test parameters affected by potential sources of uncertainly and error should be identified and controlled.

3.8 Use of Other Testing Documents

When testing packaging components, other testing specifications (such as from American Society for Testing and Materials [ASTM], American National Standards Institute [ANSI], or other testing specifications containing acceptance criteria) may be used instead of preparing special test implementing documents. If these sources are used, then the information should be incorporated directly into the approved test implementing document, or it should be incorporated by reference in the approved test implementing document. Implementing documents should include supplemental instructions as required to ensure the required quality of the testing work.

3.9 Test Results

Test results are to be documented, and their conformance with acceptance criteria will be evaluated by a qualified individual(s) within the responsible organization to ensure that test requirements have been satisfied. The test configuration should be clearly defined and documented. If testing indicates that modifications to the packaging are needed to obtain acceptable performance, the packaging should be modified and retested, or otherwise verified to assure satisfactory performance. If any test data from the premodified design is used in the SARP, the original configuration tested should be identified, as well as a description of all of the modifications incorporated in the final packaging. When tests are being performed on models or mockups, scaling laws should be established and verified. The results of model test work should be subject to error analysis as applicable prior to use in final design work.

3.10 Equipment Calibration

Equipment (e.g., gauges, fixtures, reference standards, and devices used to measure product characteristics) used during test-related activities should be calibrated, adjusted, and maintained at prescribed intervals or prior to use. The measuring and test equipment should be labeled or tagged to indicate the planned date of its next calibration, and the calibration date and identification number should be identified and recorded on the test records and be traceable.

All test equipment should be selected in accordance with the range, accuracy, and type needed to conform to the established test requirements. All equipment requiring calibration will be calibrated with standards traceable to the National Institute of Science and Technology (NIST) or an equivalent nationally recognized source. If no nationally recognized standards exist, the basis for calibration should be documented.

3.11 Personnel Qualifications, Experience and Training

All personnel performing packaging testing activities will have the necessary training and qualifications before they perform those activities. Training includes an orientation and indoctrination session with packaging participants to ensure that personnel understand the overall goals and methods of the packaging test program's quality assurance program. This training is in addition to the specific provision of the implementing procedures and instructions which each individual has read and understood. Emphasis will be placed on the following points:

- Individual responsibility for quality and quality assurance
- Importance of teamwork among all packaging test program participants
- Importance of identifying and resolving problems

- Importance of being alert for trends that indicate systemic problems
- Prime importance of the customer's need for confidence in the work

3.12 Safety

Many of the tests described in this document involve potentially dangerous activities. The safety, health, and well-being of personnel, property, the environment, and neighboring communities are of utmost importance, and every testing activity must be performed with this fully in mind. No job is so urgent or so important that it cannot be done safely. Safety is the responsibility of every employee, including management. Each employee is responsible for his or her own safety and must work to protect others. Management is responsible for providing proper training in health and safety matters, equipment, controls, and the environment to ensure the safety of all personnel involved. The safe use of equipment includes equipment design and maintenance. Equipment should be removed from use immediately if it is found to be in an unsafe condition. Personnel should be trained in the safe use of all testing equipment and related hoisting, rigging, and handling gear.

3.13 Changes to the Test Plan Procedure

Changes to the test plan or implementing procedures will be documented and initialed by the responsible engineering designer and the cognizant packaging function. Onsite redlining, deletions or changes to an approved test plan should be acknowledged by the Test Engineer and Package Design Engineer prior to proceeding with a test. The test report should reflect what was actually done, and the SARP will show how the testing satisfies the requirements of 10 CFR Part 71. If any test requirements are changed, the packaging owner must be notified for final approval.

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4.0 TESTING ACTIVITY METHODS

During the design and structural validation activities, structural validation can be accomplished by using analysis techniques or through physical testing. As stated in the DOE/AL Safety Guide (SG 100, Rev. 1, dated 11/7/94), in most cases it is advantageous to combine testing and analysis to validate the packaging design. Various analysis techniques can be used to identify the conditions for the test (e.g., worst case orientation for free drop tests) and for obtaining test data (e.g., identifying the locations for thermocouples to be installed for thermal testing). Figure 4-1 depicts the 10 CFR Part 71 overall structural review process which includes the analysis and testing activities described in this guide.

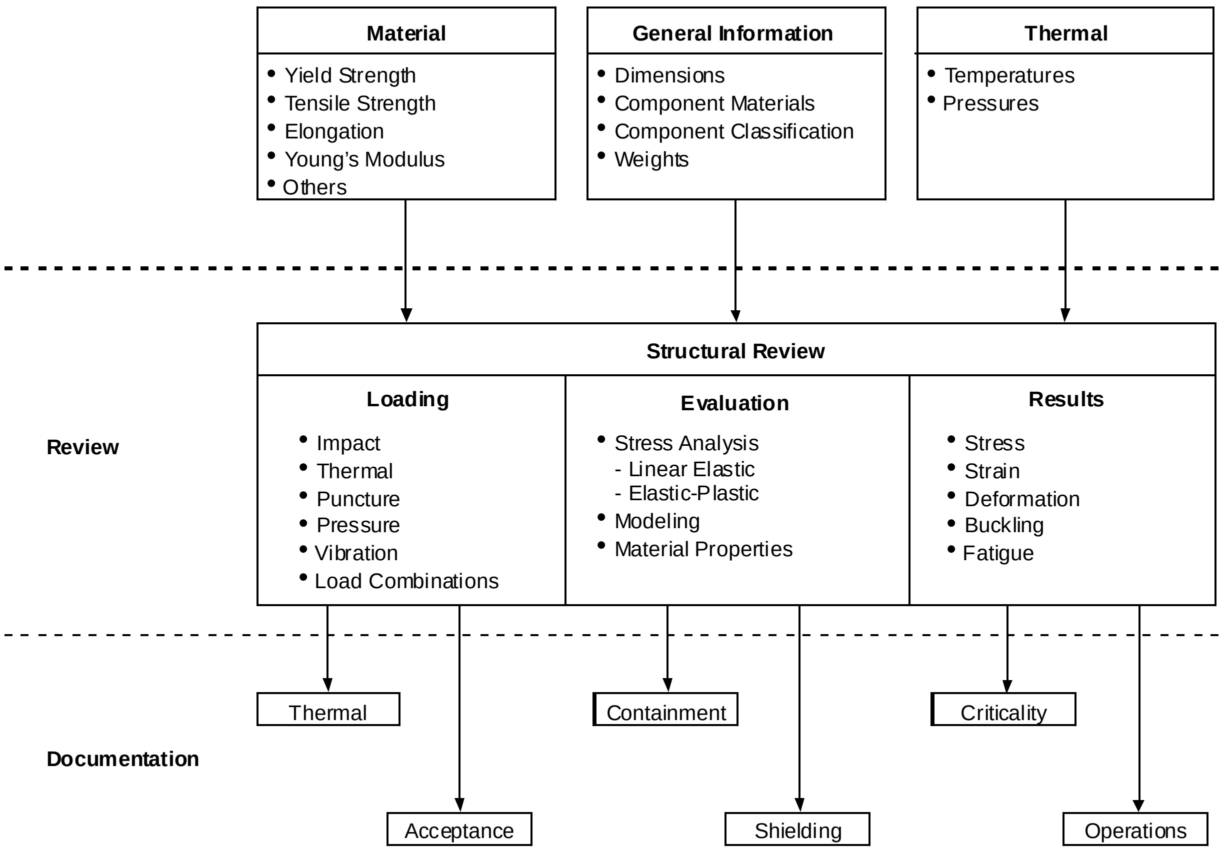

Fig. 4-1. 10 CFR 71 structural review process.

This section provides guidance for conducting and reporting the structural and thermal tests used to demonstrate the safety performance of shipping packages. Federal regulations in 10 CFR Part 71 specify tests to be used to demonstrate the safety performance of Type B packages. This section is not intended to discuss the theory of each test determination or for use as a detailed test procedure. Rather, techniques that have been successfully used and proven in practice are described as illustrations of acceptable methods that are currently being used by DOE contractors and laboratories for testing Type B packaging. Some organizations may require a readiness review to be conducted before commencement of a testing activity. Examples of acceptable test forms are provided in Appendix A. They show the type of information which should be recorded.

4.1 Assembly

Prior to assembly of the test package, the primary containment unit should undergo a dimensional inspection to ensure compliance of the tested units with the design specifications. Explanations should be provided for any nonconforming items, and the pretest condition pedigree verification should be recorded. The test unit inspection results should be documented on appropriate forms. The temperature of the simulated content, the inner container, and the outer container of the test units should be measured during thermal testing in accordance with the approved instructions or assembly procedures. (Temperature indicator labels have been used successfully.)

During the assembly process, the various components are to be identified and weights are to be recorded, if required, on the test record form. Identifying markings can be made with spray paint or other means so that markings are clearly legible and durable on the surface to which they are applied and will remain legible after testing. Photographs should be taken as required in order to show the pretest condition of the test packaging components, particularly those views which will also be photographed after testing. As needed to orient the package for drop tests, each test unit's center of gravity should be established and marked or painted on the outside of each test unit (see Figure 4-2).

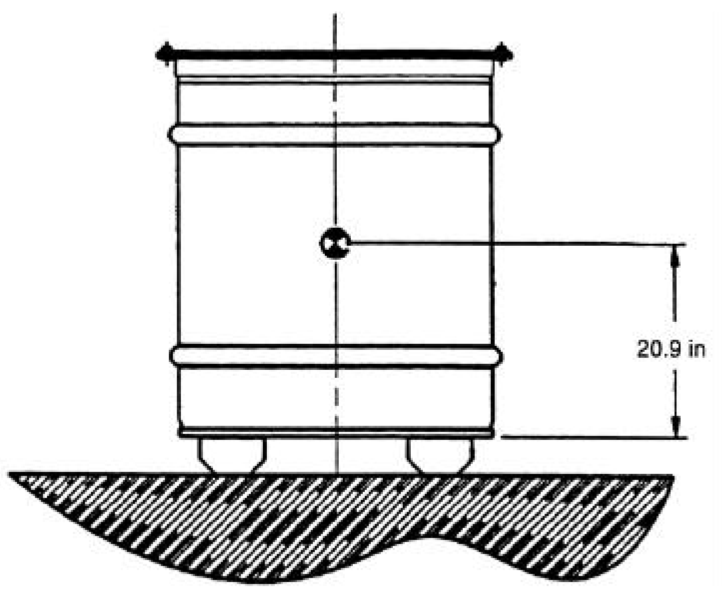

Fig 4.2. Test unit center of gravity marking.

Proper closure of the inner container (e.g., torquing fasteners to the value designated by the package design) shall be documented on the test record form. The assembly process should ensure that temperature monitors are installed as specified by the package designer or in the test procedure for packages that will undergo thermal testing. If seams exist in the inner and outer containers, the seams shall be aligned as specified by the package designer or in the test procedure (e.g., the inner and outer containers shall be assembled so that their weld seams are radially aligned). The inner container(s) must be leak tested in accordance with an approved leak test procedure that conforms to ANSI N14.5 before being assembled into the outer drum.

The assembly should be done in accordance with production processes and documented on the test record forms. The instructions for assembly of the test units should contain any special directions for assembly of each unit, along with appropriate directions on the installation of thermocouples, accelerometers, heat sources, etc. For example, testing requirements may indicate the need for installing a self-contained three-axis accelerometer to be mounted inside the inner container. The instructions for using any accelerometer should be included in the test plan or procedures. Following assembly, the test package should be prepared in a manner to preclude damage during shipment to another location for testing.

4.2 Tests for Normal Conditions of Transport

4.2.1 Evaluation

10 CFR 71.71, "Normal conditions of transport," paragraph a, states that "Evaluation of each package design under normal conditions of transport must include a determination of the effect on that design of the conditions and tests specified in this section." This subsection describes in general terms methods for coordinating the physical tests required to evaluate the results necessary to satisfy the requirements of 10 CFR Part 71.

4.2.2 Initial Conditions

§71.71. "Normal conditions of transport," states that with respect to the initial conditions for the tests in this section, the demonstration of compliance with the requirements of this part must be based on the ambient temperature preceding and following the tests remaining constant at the value between -29°C (-20°F) and 38°C (100°F) which is most unfavorable for the feature under considerations. The initial internal pressure within the containment system must be considered to be the maximum normal operating pressure, unless a lower internal pressure consistent with the ambient temperature considered to precede and follow the tests is more unfavorable.

4.2.3 Conditions and Tests

Following are test methods used by DOE contractors and laboratories for performing the listed tests. Additional information regarding satisfying steps 1-5 below can be found in the DOE/AL Safety Guide, SG-100, Rev. 1, *Design Guide for Packaging and Transfer or Transportation of Materials of National Security Interest.*

(A) *Heat:* Per 10 CFR 71.71(c)(1), the test package must be evaluated for: heated conditions with an ambient temperature of 38°C (100°F) in still air, decay heat and solar insolation. This requirement may be met through the use of analysis using the solar heat flux in the following table. (NOTE: Additional information regarding this subject can be found in the ASME Paper, “Thermal Modeling of Packages for Normal Conditions of Transport with Insolation.” J. C. Anderson and M. R. Feldman, 11/95).

Table 1. Insolation Data.

Form and location of surface	Total insolation for a 12-hour period (g cal/cm^{2})
Flat surfaces transported horizontally:	
- Base..	None
- Other surfaces	800
Flat surfaces not transported horizontally	200
- Curved surfaces.................................	400

(B) *Cold*: Per 10 CFR 71.71(c)(2), the test package must be evaluated for cold conditions with an ambient temperature of -40°C (-40°F) in still air and in the shade. Typically, this requirement is met through the selection of metal components which have a nil ductility transition temperature of less than -40°F. Seals are also selected for acceptable performance characteristics at this temperature. The package designer also needs to consider the effects of expansion and contraction of dissimilar materials.

(C) *Reduced External Pressure:* Per 10 CFR 71.71(c)(3), the test package must be evaluated for an external pressure of 25 kPa (3.5 lbf/in^2) absolute. This requirement may be met through the structural analysis of the package and is included in the load combinations.

(D) *Increased External Pressure:* Per 10 CFR 71.71(c)(4), the test package must be evaluated for an external pressure of 140 kPa (20 lbf/in^2) absolute. The requirement may be met through the structural analysis of the package and is included in the load combinations.

(E) *Vibration:* Per 10 CFR 71.71(c)(5), the test package must be evaluated for vibration normally incident to transport. The vibration test is not performed in conjunction with any other tests. This requirement can be verified using either analysis by calculation or by performing actual vibration testing.

a. Fatigue analysis

Fatigue analysis per NRC Reg. Guide 7.6 may be performed if determined applicable or appropriate by the packaging designer. (The worst condition for vibration should be determined by the design agency, or it may be incorporated in the design requirements document.) Vibration testing should approximate, as closely as possible, the actual shipping arrangement, including tie-down method.

For example, for one package, the worst condition from a vibration standpoint may be a single package mounted on and secured to the floor of the transporter since it is excited directly during transport; thus, the vibration mode acts as a linear system. It is stated in Schaum's *Outline of Theory and Problems of Mechanical Vibrations* that in the case of a transport system with a nonlinear restoring force, resonance does not occur in the same manner as in the case of a linear restoring force (a single package shipment). In a nonlinear shipment (not mounted directly to the floor of the transporter), the amplitude of vibration can never become very large for a driving force of any given frequency. This is due to the fact that the natural frequency of the system for small amplitudes of vibration is different from the natural frequency for large amplitudes of vibration.

The radioactive vessel contents are usually shipped within a containment vessel with monothane inserts placed around the content can as cushioning against the primary vessel wall and heads during transport. Once the configuration of the test package is defined, this is then used as the basis of the model assumption. With the use of a single package shipment, an analysis similar to the calculations in Appendix D determines whether the test packaging is acceptable for vibration normally incident to transport. The example calculation in Appendix D is for the use of the DC-1 Packaging shipped in a Safe Secure Trailer (SST). Consideration must also be given to shipments made in a SafeGuards Transporter (SGT) which may have a different vibration profile.

b. Vibration testing

- Pretest conditions

1. During transportation to the vibration test facility, proper handling should be performed to preclude damage to the test units during transport and handling.

2. The test engineer should select the proper vibration equipment necessary to create the required vibration.

3. The test engineer ensures that the test package temperature is within the specified limits. The temperature and time should be recorded prior to the vibration test. Environmental conditions should be monitored as required.

4. If the closure is bolted, the test package bolt torque should be recorded on the test record form.

5. Prior to initiation, the vibration input should be determined by the design engineer, including the upper limit on the frequency to be recorded.

6. A calibrated accelerometer may be installed on the outside of the test package as determined by the test design engineer.

7. The test package should be secured to the vibration table with the vibration test tie-down fixture.

8. Documentary photographs of the test setup may be taken, or line drawings may be made to document the test setup. Photos or drawings should be included as a part of the test record.

9. The test package should be thermally conditioned by placing it in a climatic chamber set at a specified temperature for the duration determined by the designer or test engineer. This information should be properly documented.

- Conduct of vibration test

  All recording and monitoring equipment must be verified to be functioning.

- Post vibration test activities

  Based on the acceptance criteria noted in the applicable test plan, the following may apply:

1. If the closure is bolted, the test package fasteners should be checked for looseness by determining if they are finger-tight. Results of this check should be documented on test record form.

2. The test package may be disassembled and inspected to verify that the vibration test has not resulted in dimensional changes to the package configuration to ensure that there is no substantial reduction in the effectiveness of the packaging.

3. The results of the inspection should be documented on the test record form.

(F) *Water Spray Test:* Per 10 CFR 71.71(c)(6), the test package must be evaluated for a water spray that simulates exposure to rainfall of approximately 5 cm (2 in) per hour for at least one hour. The following steps should be included in the water spray test:

1. Transport the test package to the water spray test area.
2. Position the test package as specified in the test plan (see Figure 4-3). (Note that the orientation indicated is not appropriate for all package designs.)
3. Ensure that the spray pattern is from above and from at least four sides.
4. Ensure that the water spray test simulates exposure to rainfall of approximately 5 cm (2 in) per hour for at least 1 hour.
5. After the water spray test, observe the test package for any apparent water leakage or damage.
6. Record all observations on the test record form.
7. Document the water spray test setup using photography and/or video.

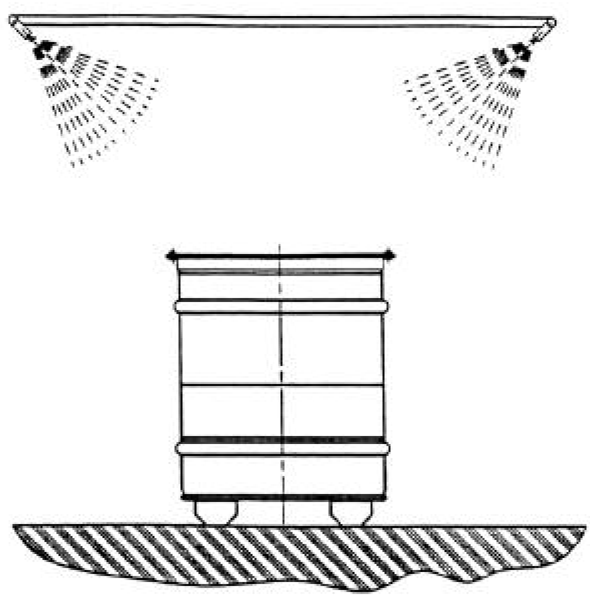

Fig. 4-3. Positioning for water spray test.

(G) *Free Fall Drop Test:* Between 1.5 and 2.5 hours after the conclusion of the water spray test, a free drop should be performed through the distance specified in the table below onto a flat, essentially unyielding horizontal surface. The test package should strike the surface in a position for which the maximum damage is expected. (As stated in IAEA ST-2, the mass of the target should be at least 10 times that of the specimen for the tests.") The package orientation for the free fall drop should be in the most damaging packaging orientation as determined by the designer and test engineer.

Table 2. Criteria for Free Drop Test (Weight/Distance).

Package weight		Free drop distance	
Kilograms	**(Pounds)**	**Meters**	(**Feet**)
Less than 5,000	Less than (11,000)	1.2	(4)
5,000 to 10,000	(11,000 to 22,000)	0.9	(3)
10,000 to 15,000	(22,000 to 33,100)	0.6	(2)
More than 15,000	(More than 33,100)	0.3	(1)

For weapons program Type B packages, the weight is normally less than 11,000 pounds. Therefore, the following discussion addresses a 1.2 m (4 ft) free fall drop. Below are the typical steps for a free fall drop test.

- The test package should be attached to a lifting mechanism and raised to a height at which the lowest point of the test package is 1.2 m (4 ft) from the impact surface, with the center of gravity over the lowest point of impact.

- The test package should be dropped from an oblique position with the top down. For example, the test package should make a free fall with the initial contact being between the top corner and the impact surface.

- This activity should be recorded on the test record form.

The steps for a typical free fall lid and seam drop test are as follows:

1. Attach the test package to a lifting mechanism and raise it to a height at which the lowest point of the test package is 1.2 m (4 ft) from the impact surface, with the center of gravity over the lowest point of impact.

2. Drop the test package from an oblique position with the seam and top down. The test package should make a free fall with the initial contact being between the top corner and the impact surface (see Figure 4-4).

3. Record this activity on the test record form.

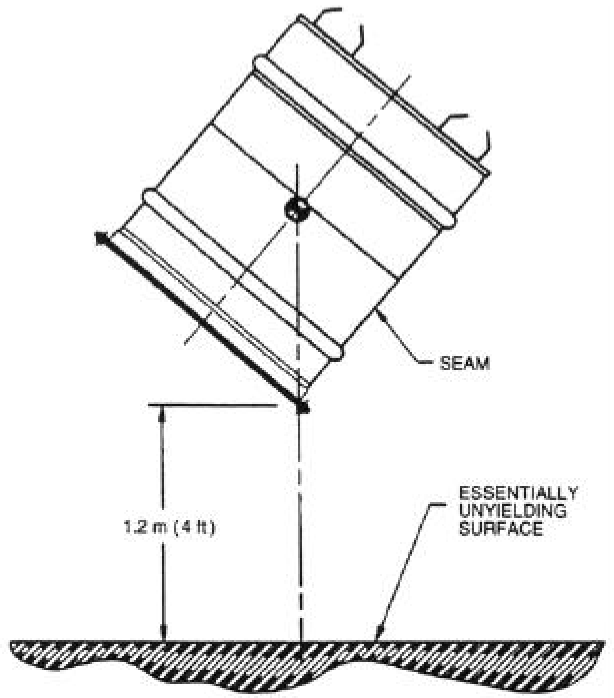

Fig. 4-4. Drop test from an oblique position with the seam and top down.

(H) *Corner Drop Test 0.3 m (1 ft):* A free drop should be performed onto each corner of the test package in succession (or in the case of a cylindrical package, onto each quarter of each rim) from a height of 0.3 m (1 ft) onto a flat, essentially unyielding horizontal surface. This test should use the same test package as used in the free drop test. The steps listed below should be included in the corner drop test:

NOTE: These corner drop tests are not required for all containers. Specifically, the tests are not required for fissile material rectangular packages weighing more than 110 lbs and cylindrical packages weighing more than 220 lbs in accordance with §71.72(c)(8).

1. Attach the test package to the lifting mechanism and raise it to a height at which the lowest point of the corner being tested will be 0.3 m (1 ft) from the impact surface.

2. Drop the test package successively on each corner (or each quarter of each rim) with the center of gravity over the lowest point of impact onto an essentially unyielding horizontal surface (see Figure 4-5).

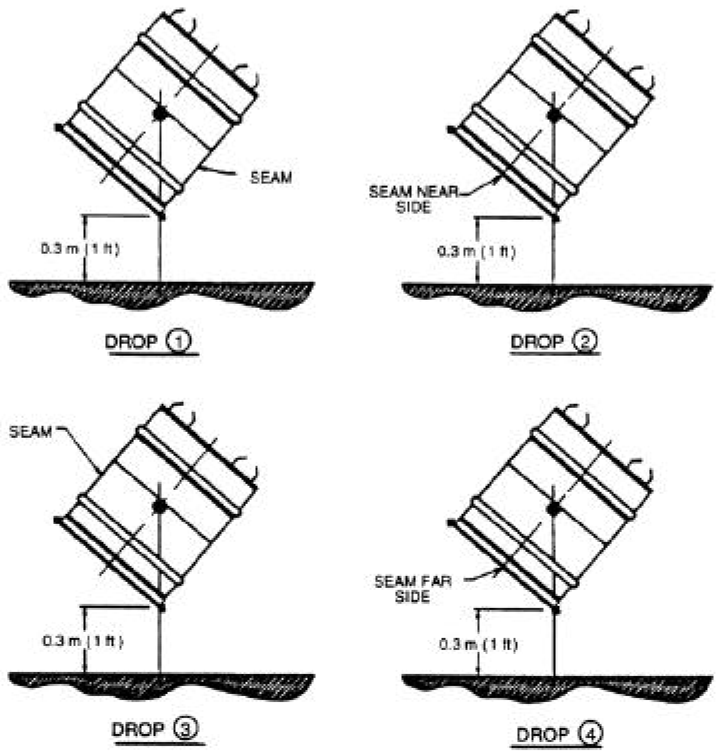

Fig. 4-5. Corner 0.3m (1ft) drop test for a cylindrical package.

3. For cylindrical packages, drop the test package from an oblique position with the rim down. The test package should make a free fall, with initial contact being between the rim corners and the impact surface through the center of gravity.

4. After each corner drop, visually examine the test package for damage, and take measurements of any damage.

5. Record observations and measurements on the test record form.

(l) *Compression Test (Normal Stacking Test):* This test is only required for packages weighing up to 5,000 kg (10,000 lbs). Compressive load is applied uniformly to the top and bottom of the package in the position in which the package would normally be transported. The steps below should be included in the compression test.

NOTE: Any test package which has undergone the water spray test may be used for this test.

1. Place the test package on a horizontal surface in the selected position.

2. Measure the initial condition (top to bottom) of the test package and record it on the test record form.

3. Uniformly apply a vertical load of at least five times the maximum package weight, or the equivalent of 13 kPa (2 lbf/in^2) multiplied by the vertically projected area of the package (whichever is greater), to the top of the test package for a period not less that 24 hours (see Figure 4-6). (Constraints may be used to obtain a stable loading condition so long as the constraint does not result in a load less than five times the package weight.)

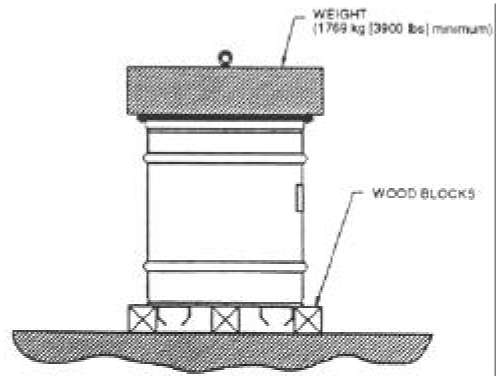

Fig. 4-6. Compression test.

4. After the load is removed, visually inspect the test package for damage, and its dimensions, including overall height, remeasured.

5. Record any damage or other observations and the overall height on the test record form.

(J) *Penetration Test:* The steps listed below should be included in the penetration test.

NOTE: Any test package which has undergone the water spray test may be used for this test.

1. Place the test package on a horizontal surface in a position specified by the designer (see Figure 4-7).

2. Hoist the steel bar (cylinder) to a height of 1 m (40 in) over the “surface of the package that is most vulnerable to puncture” (§71.71(c)[10]). The steel cylinder should have a hemispherical end of 3.2 cm (1.25 in) diameter and 6 kg (13 lbs) mass. The long axis of the cylinder must be perpendicular to the test package surface. The cylinder should be dropped onto the exposed surface of the package that is expected to be most vulnerable to puncture, so that if it penetrates sufficiently, it will hit the containment system.

3. Release the steel bar (cylinder) to impact, and allow it to free fall, with its long axis vertical.

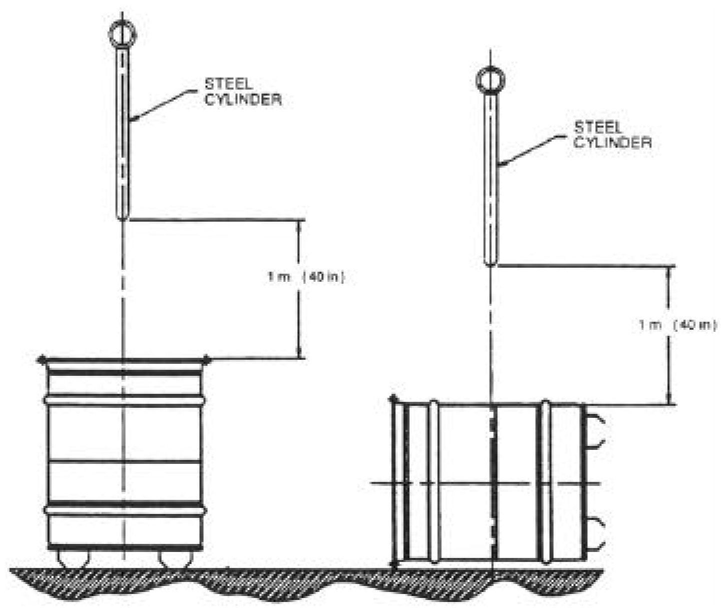

Fig. 4-7. Penetration test.

4. After the drop, visually examine the test package for damage.

5. Record this activity on the test record form.

(K) *Disassembly and Inspection:* The steps shown below should be included in the disassembly and inspection actions. (See acceptance criteria in Section 3.3 of this guide.)

- Move the inner assembly (i.e., containment vessel or boundary) to the leak test station and leak test it in accordance with an approved procedure based on the requirements of ANSI N14.5, *Leakage Test on Packages for Shipment* (1997).

- Disassemble the inner assembly, and inspect the sealing surfaces should be inspected for damage.

- Document the results of the leak test and the visual inspection on the test record form.

4.3 Tests for Hypothetical Accident Conditions

4.3.1 Evaluation

Evaluation for the hypothetical accident conditions is to be based on sequential application of the following tests in the order indicated to determine their cumulative effect on a test package or array of packages. An undamaged test package may be used for the 15 m (50 ft) water immersion test noted below.

4.3.2 <u>Initial Conditions</u>

Except for the water immersion tests, in order to demonstrate compliance with the requirements of §71.73 during testing, the ambient air temperature before and after the tests must remain constant at that value between -29°C (-20°F) and +38°C (+100°F). The temperature should be the most unfavorable for the feature under consideration. The initial internal pressure within the containment system must be the maximum normal operating pressure, unless a lower internal pressure consistent with the ambient temperature assumed to precede and follow the tests is more unfavorable.

4.3.3 <u>Conditions and Tests</u>

Tests for the hypothetical accident conditions must be conducted as follows:

(A) *9 m (30 ft) Free Fall Drop Test*

The following steps may be included in the free fall drop test:

1. Transport the test packages to the drop test facility. The striking surface should be a flat, essentially unyielding horizontal surface. ("Unyielding" is defined by IAEA Safety Standard Series No. ST-2 as a steel plate or plates or other convenient materials with a mass at least ten times that of the package.)

2. Locate two high-speed cameras at a 90 degree angle to each other to record the free fall drop from separate views.

3. Orient the test package so that maximum damage is expected. Pretest evaluations should consider the following orientations and may result in multiple tests:

(a) Horizontal with seam side down
(b) Top up
(c) Bottom up
(d) Center of gravity over contact
(e) Orientation to provide maximum slap down force

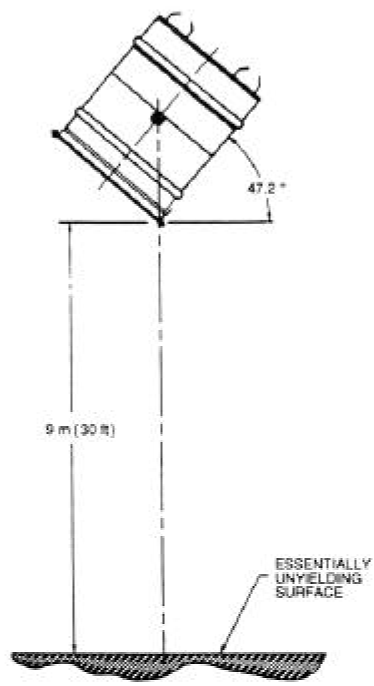

Fig 4-8. 9 m free fall drop test.

4. Raise the test package to a height at which the lowest point of the test package is 9 m (30 ft) from the impact surface (see Figure 4-8).

5. Drop the test package and allow it to free fall.

NOTE: To ensure that impact is at the desired location, the center of gravity must be determined and must be directly above the impact surface to preclude rotation of the package during free fall. If a guided drop is allowed, documentation should be provided to demonstrate that the guided drop and the analysis meet free drop requirement (i.e., §71.41[a]).

6. Record the drop and observations of the damage to the test package on the test record form.

7. Document the damaged areas of the package (for example, photographs and/or videotape).

(B) *Crush Test*

This test is required only when the test package has a mass not greater than 500 kg (1100 lbs), an overall density not greater than 1000kg/m^3 (62.4 lbs/ft 3) based on external dimensions, and radioactive contents greater than 1000 A_2 not as special form radioactive material. The following steps should be included in the crush test.

1. Position the test package on the target so that it will suffer maximum damage by the drop of the 500 kg mass from 9 m onto the test package.

2. Raise the 500 kg (1100 lbs) mild steel plate (1m × 1m) (40 in × 40 in) to a height at which the lowest point of the steel plate will be 9 m (30 ft) from the uppermost surface of the test package (see Figure 4-9).

3. Measure the height of the drop from the underside of the steel plate to the highest point of the test package.

4. Drop the steel plate in a horizontal position, with the center of the plate over the center of the desired impact area.

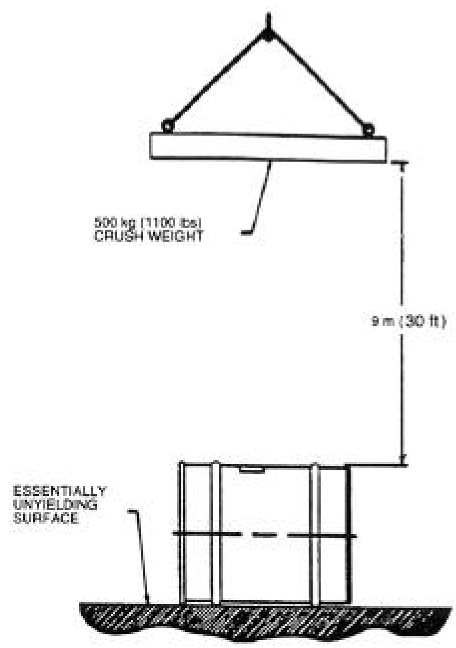

Fig. 4-9. Crust test.

5. Record observations of the damage sustained by the test package on the appropriate test record data form.

(C) *1 m (40 in) Puncture Drop Test*

The following steps should be included in the puncture drop test:

1. Orient the test package in a position which has been determined to be the worst case.

2. Raise the package to a height at which its lowest point is 1 m (30 in) above the steel punch bar (see Figure 4-10). The bar must be 15 cm (6 in) in diameter, with the top horizontal and the edges rounded to a radius of not more than 6 mm (0.25 in), and a length which should cause the maximum damage to the package, but not less than 20 cm (8 in) long. The long axis of the bar must be vertical. The test bar should be rigidly mounted on an essentially unyielding surface.

3. Drop the test package and allow it to free fall, with initial contact on the top of the punch bar.

4. Record the observations of the puncture drop and damage sustained by the test package on the test record form.

5. Photograph and/or videotape, if required, the damaged areas of the containers to document their conditions following the test.

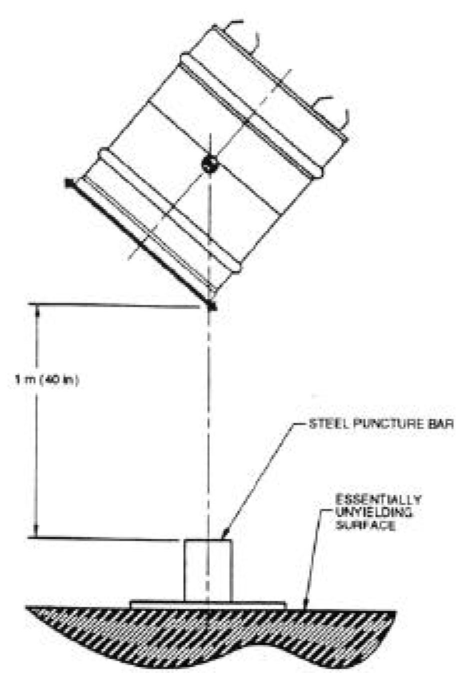

Fig. 4-10. 1 m puncture drop test.

(D) *Thermal Testing*

This subsection does not contain detailed and exhaustive methods for thermal testing. The thermal testing of a package represents a challenge to the packaging designer and test engineer. Along with this testing challenge may come some details that cannot be foreseen. This testing guide cannot address all possible circumstances and, therefore, it is the responsibility of the packaging designer to apply good engineering judgment.

In general, there are three methods of thermal physical packaging techniques that are commonly employed: pool-fire testing, furnace testing (gas fired or electric), and radiant heat lamp testing. Any of these methods can be used satisfactorily, but caution and good sense must be exercised.

The thermal test consists of the exposure of a test package fully engulfed, except for a simple support system, in a hydrocarbon fuel/air fire of sufficient extent and in sufficiently quiescent ambient conditions to provide an average emissivity coefficient of at least 0.9, with an average flame temperature of at least 800°C (1475°F). The test package is engulfed for a period of 30 minutes. Any other thermal test may be conducted if it provides the equivalent total heat input to the package and if it provides a time averaged environmental temperature of 800°C.

a. Thermal exposure - pool fire

For purposes of calculation, the surface absorptivity coefficient must be either that value which the package may be expected to possess if exposed to the fire specified, or 0.8, whichever is greater. The convective coefficient must be that value which may be demonstrated to exist if the package were exposed to the fire specified. Artificial cooling may not be applied after cessation of external heat input, and any combustion of materials of construction must be allowed to proceed until it terminates naturally.

The steps listed below should be included in the pool fire test.

- Pretest conditions:

1. Position test packages and connect temperature indicators and/or thermocouples.

2. Preheat the test packages to a stable temperature condition to simulate transport conditions, and hold for a minimum soaking period determined by the designer.

3. If drum heaters are used to preheat the package, conduct the pool fire test within a pre-selected time period following removal of the drum heaters.

4. If test package thermocouples are used, read and record information immediately prior to the time the pool fire test is performed.

5. When testing multiple packages, position the test packages a minimum of 1 m from each other and the nearest pool boundary. The fuel source boundary must extend at least 1 m (40 in) from the package, but may not extend more than 3 m (120 in) from the package. The package must be positioned 1 m (40 in) above the surface of the fuel source.

6. Orient the test package so that it will incur the greatest damage. If a different orientation is used, the test or design engineer should document both the orientation and the justification on the test record form.

7. Check the wind speed at the pool fire test facility to verify that it is less than 2 m/s (4.5 MPH).

8. Record the setup activities in order to sufficiently document the conditions prior to the pool fire test.

9. If required by the test plan, install predetermined thermocouples in the pool fire pit and on the test package support stand.

10. If used, attach thermocouples from the test packages and the pool fire pit to the data acquisition system, and conduct a systems test prior to the pool fire test.

- Conduct of burn test:

1. Advise all personnel in the pool fire test area of the environmental, safety and health requirements pertaining to the test packages.

2. When wind conditions are favorable, ignite a hydrocarbon (i.e., JP4/JP8) fuel it should continue to burn for a period of 30 minutes (+5 min. -0 min.).

3. Monitor the burn and by video cameras to determine if fire and smoke plumb rise vertically and to verify that the test packages are fully engulfed in flame. Document observations on the test record form.

4. Monitor the wind conditions and any note variations to wind speed.

- Post-burn activities:

1. Allow the fire pit flames to die out naturally after the 30-minute fire test.

2. Allow the burning test packages (combustion of materials) to continue burning naturally until the flames stop. The test packages should cool naturally.

3. The data acquisition system should continue to record the thermocouples on the test packages and the fire pit for two hours, or until peak temperatures have been met.

4. If required by the test plan, take documentary photographs and videos after the fire test is completed.

5. Document post-test inspection and observations on the test record form.

6. Collect and include strip chart recordings, videos, and other data recording device printouts as part of the test record.

b. Thermal exposure - furnace testing

The steps shown below should be included in the thermal exposure test using a gas-fired or an electric induction type furnace.

NOTE: Appendix B contains further detail regarding the combination test/analysis method used to demonstrate compliance to DOE/AL Type B container thermal test requirements.

- Furnace preparation:

1. Prior to the beginning of the thermal test, characterize the furnace for temperature, emissivity, heat recovery times, and radiant viewing factors.

2. Install thermocouples in the furnace as shown in each applicable test plan. (An example of thermocouple locations in a furnace is shown in Figure 4-11.) Test package support stand(s) should be placed into the furnace on the floor prior to preheating. The stands typically have thermocouples attached as shown in Figure 4-12. It is noted that each test stand must be test package specific. One thermocouple should record the ambient temperature in the furnace area. These figures are for visual information only, and do not suggest thermocouple placement as shown.

3. The furnace temperature controller may have several zone thermocouples and an overall temperature thermocouple. Preheat the furnace and allow it to soak at a temperature and time period determined by the furnace characterization study. If used, the thermocouple recorder should record data continuously on a strip chart or data recorder. The test engineer may adjust the furnace set point during testing to ensure that minimum temperatures are maintained.

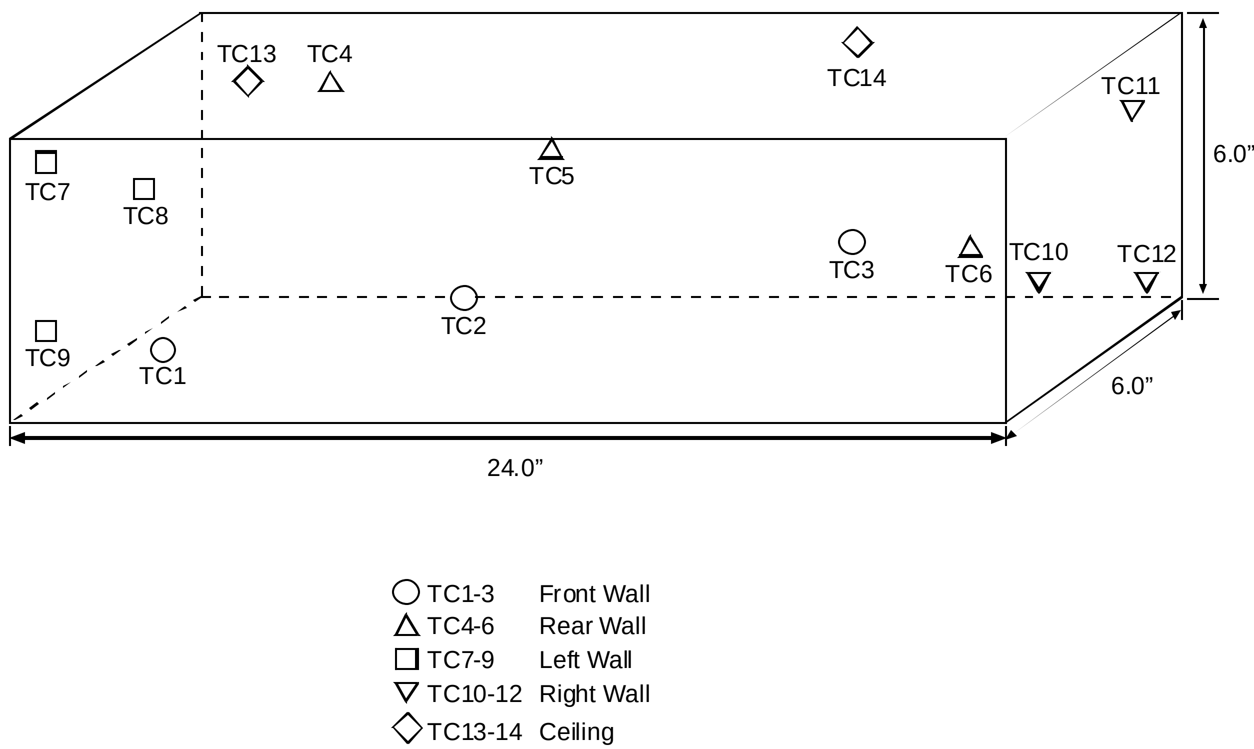

Fig. 4-11. Example of thermocouple (TC) locations in a furnace.

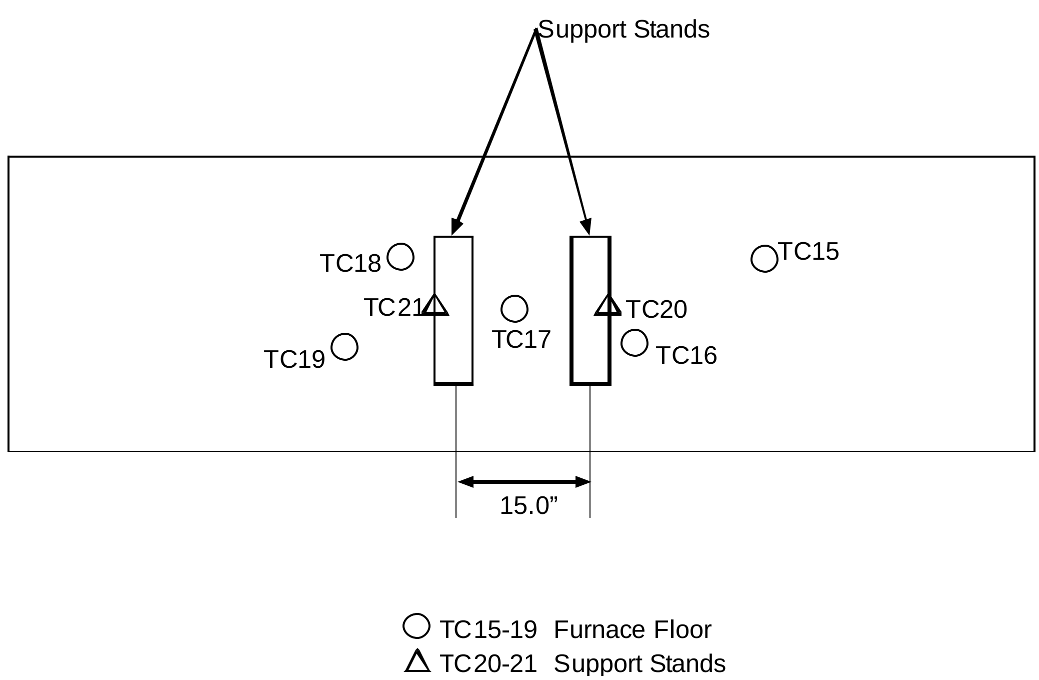

Fig. 4-12. Example of thermocouple (TC) locations on package test stands.

- Preparation of the testing packages:

  1. If required, Attach a predetermined number of thermocouples to the exterior of each test package (example shown in Figure 4-13) after completion of the drop tests. The operability of thermocouples installed on test record form should be recorded and verified. Figure 4-13 shows an acceptable method for thermocouple lead wires to be held in place by the use of metal retainer clips welded in place. The clips are to be made of 304 stainless steel approximately 1.27 cm (0.5 in) wide, 5 cm (2 in) long and .15 cm (0.06 in) thick. Lead wires should be inserted underneath the metal clips.

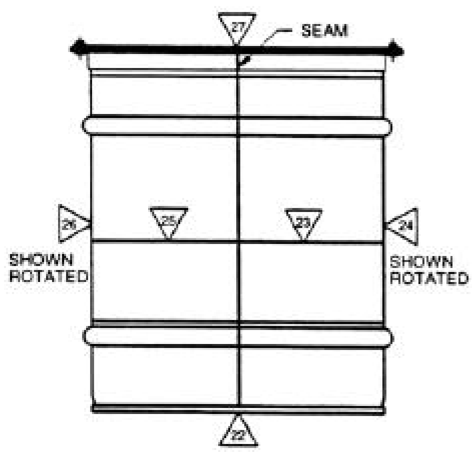

Fig 4-13. Location of thermocouple lead wires.

  2. The thermocouple direction on the drum's surface should not be exposed to heat transfer by radiation from the furnace walls, ceiling, or floor plate. In order to eliminate any radiant viewing factors, fill the clips with refractory cement. Examples include #36 refractory cement from A. P. Green Industries, Inc. (or an equivalent), which is a sodium silicate base cement. The refractory cement should completely enclose the tip of each thermocouple lead wire.

  3. If required by the test plan, install drum heaters with insulation around each test package for preheating. The packages should be preheated to a temperature predetermined by the designer until the inner container thermocouples have reached this temperature. The thermocouple temperatures of the inner container should be recorded on the test record form every 15 minutes for one hour prior to the burn test to assure that the package has reached a steady temperature.

- Conduct of test:

1. Load the first test package in the furnace on the preheated support stand in a position with an orientation that is most damaging. During testing of individual packages, the temperature recorder should be set to record data every minute. The test engineer may adjust the furnace set point during testing to ensure that the proper temperature is maintained.

2. Expose the package to this radiation environment for a minimum of 30 minutes after the minimum number of furnace thermocouples have recovered to a temperature of 800°C (1475°F), and four of the six thermocouples on the package drum have also attained that temperature also. Record the thermal test data on the test record form.

   NOTE: There is no regulatory requirement that the package skin be maintained at 800°C. In fact, for thick-walled outer containers it would result in significant over-test.

3. Upon completing the 30 minute soak time, remove the test package from the furnace and place it in an area in which it will not be exposed to artificial cooling. Caution should be exercised during movement to limit artificial cooling. Combustion of packaging materials must be allowed to extinguish naturally and the package allowed to cool to room temperature unless the test package has an outer heat source. The thermocouple readings on the drum and inner container may be recorded every minute for three hours after removal. Then the readings from thermocouples on the inner container of at least one test package may be recorded according to the test plan for the next 48 hours of the cool down.

4. If multiple test packages are to be fired, allow the furnace to reheat for a minimum of one hour (or according to the test plan thermal characteristics of the furnace used) between each individual test. Between packages, the furnace control temperature data should be recorded continuously on the strip chart recorder.

c. Thermal exposure - radiant heat lamp

The following steps should be included in the radiant heat lamp test:

- Facility preparation:

1. Characterize the radiant heat test facility for temperature, emissivity, and radiant viewing factors.

2. Determine the thermal effect of the test stand for the test package and prepare the test stand be prepared for the test (e.g., the test stand should be preheated to a temperature determined by the design and test engineer).

3. Determine the required temperature for the radiant heat test facility elements (e.g., the shroud which will surround the test package), and test the necessary controls and data acquisition system for the heating system.

- Preparation of the test package:

1. If required, attach a predetermined number of thermocouples to the exterior of each test package after the completion of the drop tests. The number and operability of the thermocouples installed should be recorded and verified, along with the operability of any internal thermocouples. Document the results on the test record form.

2. If required by the test plan, install drum heaters with insulation around each test package for preheating. The packages should be preheated to a temperature determined by the designer. Completion of this preheating may be determined by either all installed thermocouples reaching the temperature specified by the design engineer, or may be determined by the duration of the preheating period specified by the designer.

- Conduct of test:

1. Position the test package in the center of the radiant heat assembly in the orientation specified in the test plan.

2. Reposition the shroud in the heating configuration.

3. Energize the radiant heat assembly and bring the shroud to the specified temperature. The shroud temperature should be monitored to increase to the specified temperature within the time identified in the characterization study.

4. Use if possible infrared thermography with the test configuration to monitor surface temperatures to confirm that the testing process matches the predicted heat transfer characteristics.

5. Allow the test package and shroud to cool naturally upon completion of the 30-minute exposure period. The shroud should not be removed from the test package until it has returned to near ambient temperatures and there are no longer any flames visible from the test package.

6. Monitor any installed thermocouples on the test package following the test for a duration specified by the designer.

d. Post-burn activities:

1. Disassemble and inspect the test packages. Each test package should be weighed, and weights should be recorded on test record form. Damage should be photographed. The inner container should be weighed and the weight recorded. The insulation should be visually inspected for damage, distortion, warping, burn depth, etc., in accordance with the test plan requirements.

2. Document the condition of the package.

3. Move the test package to the leak test station to ensure adequate containment. The leak test activity is noted below in Section 4.3.3(6) and 4.3.3(9).

(E) *Test Package Disassembly*

The following steps should be included in the test package disassembly:

1. Move the test package to the disassembly area. Open the drum assembly and remove the inner container assembly.

2. If the inner container includes a secondary containment vessel (SCV), record the condition of components outside of the SCV and any support structure. If necessary, conduct a dimensional inspection of the SCV and record for comparison to original hardware requirements.

3. If the inner container does not have an SCV, then record the condition of components outside of the PCV and any support structure. If necessary, conduct a dimensional inspection of the PCV and record for comparison to original hardware requirements.

(F) *SCV Leak Test (If Applicable*)

The SCV should be leak tested according to an approved leak test procedure, and the results reported on the test record form. The maximum acceptable leak rate should satisfy the acceptance criteria specified in Section 3.3 of this guide.

NOTE: The leak test should either demonstrate leak tightness or should be backed up by an analysis showing that the leak rate is acceptable.

(G) *SCV Immersion Test, 0.9 m (3 ft) Fissile Material (If Applicable)*

NOTE: This test is applicable for fissile material subject to §71.55 in those cases where water inleakage has not been assumed for criticality analysis.

The steps below should be included in the immersion test.

1. Transport the SCV to the immersion test area. (This test is not required when criticality analysis has assumed water in-leakage.)

2. Fully immerse the SCV under a 0.9 m (3 ft) head of water in an upright attitude (or other attitudes for which maximum leakage is expected).

(H) *SCV Disassembly and Inspection (If Applicable)*

The following steps should be included in the inner package disassembly.

1. Move the SCV package to the disassembly area and dry the exterior of the SCV.

2. Open the top half of the SCV and examine it for inleakage of water.

3. Remove the PCV from the SCV.

4. Record the condition of components outside of the PCV and any support structure. If necessary, conduct a dimensional inspection of the PCV and record for comparison to original hardware requirements.

(I) *PCV Leak Test*

The PCV should be leak tested according to an approved leak test procedure, and the results should be reported on the test record form. The maximum acceptable leak rate should satisfy the acceptance criteria specified in Section 3.3 of this guide.

NOTE: The leak test should either demonstrate leak tightness or should be backed up by an analysis showing that the leak rate is acceptable.

(J) *PCV Immersion Test, 0.9 m (3 ft) Fissile Material*

This test is applicable for fissile material subject to §71.55 in those cases where water in-leakage has not been assumed for criticality analysis.

The steps below should be included in the immersion test.

1. Transport the PCV to the immersion test area. (This test is not required for cases in which criticality analysis has assumed water inleakage.)

2. Fully immerse the PCV under a 0.9 m (3 ft) head of water in an upright attitude (or other attitudes for which maximum leakage is expected).

NOTE: With the proposed loading and a conceptual design of the containment system (i.e., inner container dimensions and volume), the criticality safety analyst must first determine if the contents would remain adequately subcritical if water inleakage were to occur (to the most reactive and most credible extent).

(K) *Immersion Test, 15 m (50 ft) for 8 Hours, All Packages*

An undamaged test package may be used for the water immersion tests specified below. The following steps should be included in the immersion test:

1. Transport a separate, undamaged test package to the disassembly area and remove the inner container.

2. Place the PCV into the immersion test fixture in the attitude for which maximum leakage is expected.

3. Immerse the PCV so that water pressure equivalent to immersion under a head of water of at least 15 m (50 ft).

   NOTE: For test purposes, an external pressure of water of 150 kilopascal ($21.7\ lbf/in^2$) gauge is considered to meet these conditions.

4. Remove and inspect the package and record the results on the test record form.

4.4 Disassembly and Post-test Inspections

After physical testing activities are complete, the test packages should be disassembled and inspected. Any damage or leakage of water should be recorded on the appropriate test record form. The temperature indicator readings will be recorded on the test record form. If applicable, once the lid has been removed, the O-ring, O-ring groove and the seal surface should be inspected for damage. Observations are to be recorded on the test record form. If necessary, a dimensional inspection of the inner container (i.e., containment vessel or boundary) may be conducted and recorded for comparison to original hardware requirements. Conditions of the mockup components and foam support structure should also be recorded on the test record forms.

The following steps should be included in the disassembly and inspection activity:

- Transport the PCV to the disassembly area, and dry the exterior of the PCV.

- If the locking mechanism is used, examine it for damage. Bolts should be removed and the loosening torque of each inner container bolt should be recorded on the test record form. The top half of the PCV should be removed.

- Once the top half has been removed, inspect the PCV for in-leakage of water. The sealing area should be inspected for damage and the observations recorded on the test record forms.

- Record the readings from any temperature indicators or accelerometers on the inner container and mockup on the test record form.

- Document the disassembly activities and resultant components , particularly the areas of resulting test package damage.

- Record actual dimensions of the package components.

5.0 TESTING REPORTING

5.1 SARP Requirements

DOE O 461.1, Section 4.b.(1)(a), states all packages to be transported by TSS must be authorized by an Offsite Transportation Certificate (OTC) or an Offsite Transportation Authorization (OTA), approved and issued by the Manager, DOE/AL, certifying a specific packaging for nuclear weapons-related cargo. It is issued if a DOE package meets applicable requirements of 10 CFR 71, 49 CFR 100-178, and Reg Guide 7.9. Section 4.b.(1)(b) states that the request for an Offsite Transportation Certificate shall be supported by the Safety Analysis Report for Packaging (SARP), or a Transportation System Risk Assessment (TSRA) for an Offsite Transportation Authorization. The recommendation for approval/disapproval of the OTC or OTA will be documented in a Safety Evaluation Report.

Section 5.e(1) states the applicants ensure that the SARP or TSRA or other required supporting documents, are submitted to the Albuquerque Operations Office at least 9 months prior to the first required shipment date.

DOE/AL Supplemental Directive AL 5610.12, Section 10.c.(16), states that the DOE/AL Procurement Engineer ensures that all DOE contractors requiring packaging to ship nuclear components, special assemblies, and other associated material have developed and submitted a SARP to OWS PTP at least 40 weeks in advance of the projected date for use of the packaging.

5.2 Evaluation and Reporting of Test Results

Each test package design will be considered as acceptable for normal conditions of transport as specified in 10 CFR 71.71, and hypothetical accident conditions as specified in 10 CFR Part 71 §71.73 if the acceptance criteria in Section 3.0 of this document are met at the end of the respective tests.

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6.0 TEST RECORDS

The test record forms developed and used during all the physical and thermal testing should be completed during or immediately following each test. Each test form should be witnessed and signed off by the test technician or engineer and a witness at the time of the test.

Color photographs should be taken of the test arrangements before and after all tests and of any resulting damage to the test package. The photographs should be printed at 8 in × 10 in format for ease of examination and use in reports. Also, two high-speed video/movie cameras could be employed to record the drop tests. The cameras should be located at 90 degrees to each other. A video camera should be used to record test results, along with a verbal narrative of the visible damage to each test package. Other means can be used as defined in the respective test plan.

6.1 Test Record Attributes

The following should be considered when developing test record forms:

- Item tested
- Date of test
- Tester or data recorder
- Type of observation
- Results in connection with any deviations noted
- Action taken in connection with any deviations noted
- Persons evaluating test results

Figure 6-1 depicts the testing requirements and the applicable test forms. Examples of test record forms are attached in Appendix A.

6.2 Verification Plan and Actions

The contractor or laboratory quality assurance function responsible for monitoring the packaging testing activities should plan and conduct assessments of the testing program to ensure that the requirements specified are being satisfied.

6.3 SARP Requirements for Testing Documentation

DOE/AL Supplemental Directive 5610.12 states that the package SARP must demonstrate that the proposed packaging design meets the compliance tests specified by 10 CFR 71.71 and 71.73 regulations for normal and hypothetical conditions for transport. The objective of the SARP structural design evaluation section and the thermal evaluation section is to ensure that the design uses acceptable analytical and/or test methods and that it complies with 10 CFR Part 71 regulations.

Testing Requirement	NA*	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
												TEST FORMS											
Normal Conditions of Transport																							
10 CFR 71.71(c)(1), *Heat*	•																						
10 CFR 71.71(c)(2), *Cold*	•																						
10 CFR 71.71(c)(3), *Reduced External Pressure*	•																						
10 CFR 71.71(c)(4), *Reduced Internal Pressure*	•																						
10 CFR 71.71(c)(5), *Vibration*	•					•																	•
10 CFR 71.71(c)(6), *Water Spray*							•																•
10 CFR 71.71(c)(7), *Free Drop*							•																•
10 CFR 71.71(c)(8), *Corner Drop*								•															•
10 CFR 71.71(c)(9), *Compression*									•														•
10 CFR 71.71(c)(10), *Penetration*										•													•
Hypothetical Accident Conditions																							
10 CFR 71.73(c)(1), *Free Drop*											•												
10 CFR 71.73(c)(2), *Dynamic Crush*												•											
10 CFR 71.73(c)(3), *Puncture*													•										
10 CFR 71.73(c)(4), *Thermal*														•	•	•	•	•	•	•			
10 CFR 71.73(c)(5), *Immersion – fissile material*																					•		
10 CFR 71.73(c)(6), *Immersion – all packages*																						•	

*For tests outside the scope of this procedure, refer to the appropriate SARP for explanation of how test requirements are satisfied or why they do not apply.

Fig. 6-1. Testing requirements matrix.

7.0 REFERENCES

1. Anderson, J.C. and M.R. Feldman. *Characterization of Furnaces for Hypothetical Thermal Accident Testing in Accordance with 10 CFR 71*. Presentation to the Transportation of Hazardous Materials Thermal Specialists Meeting, Albuquerque: 1992. Also presented at ASME Heat Transfer Division Conference, 1995.

2. Anderson, J.C. and M.R. Feldman. *Thermal Modeling of Packages for Normal Conditions of Transport with Insolation*. ASME Paper, 1995

3. Bronowski, D. R. *Performance Testing of Elastomeric Seal Materials Under Low- and High-Temperature Conditions: Final Report*, SAND94-2207, June 2000.

3. Byington, G.A. *A Comparison of Radioactive Material Package Leakage Tests, Between ANSI N14.5-1987 and the Proposed ANSI N14.5-1995*. Packaging Conference, 1995.

4. Feldman, M.R. *Furnace Characterization for Horizontal Shipping Container Thermal Testing*. ORNL/ENG-12, 1994.

5. Feldman, M.R. *Hypothetical Accident Condition Thermal Testing Methods*. Packaging Conference, 1995.

6. *Guide for Conducting Impact Tests*. UCRL ID-121673

7. *A Guide to Thermal Testing Transport Packages for Radioactive Material – Hypothetical Accident Conditions*. UCRL ID-110445, Rev. 5

8. Schaum. *Outline of Theory and Problems of Mechanical Vibrations*.

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APPENDICES

Appendix A: Examples of Test Record Forms

Form 1	Assembly of the PCV and SCV
Form 2	Assembly of Test Package
Form 3	Component Weights
Form 4	Accelerometer
Form 5	Vibration Test
Form 6	1.2 m (4 ft) Free Fall Drop
Form 7	0.3 m (1 ft) Corner Drop
Form 8	Compression Test
Form 9	Penetration Test
Form 10	9 m (30 ft) Free Fall Drop
Form 11	9 m (30 ft) Dynamic Crush Test
Form 12	1 m (40 in) Puncture Drop
Form 13	Pool Fire Test Checklist
Form 14	Pool Fire Test Data Sheet
Form 15	Thermocouple Verification
Form 16	Thermal Preheat Test
Form 17	Thermal Testing
Form 18	Temperature Indicator Readings
Form 19	Post-Thermal Testing Inspection
Form 20	0.9 m (3 ft) Immersion Test
Form 21	15 m (50 ft) Immersion Test
Form 22	Disassembly and Inspection

Appendix B: A Combination Test/Analysis Method Used to Demonstrate Compliance to DOE Type B Container Thermal Test Requirements (30 Minute Fire Test), DOE/AL Defense Programs Guideline for Packaging, Jan. 30, 1992.

Appendix C: Vibration Environments for the AT-400R (Klenke to Glass, Sandia Lab Memo)

Appendix D: Calculations for Normal Vibrations During Safe-Secure Trailer Shipment of the DC-1 Package with HEU Oxide Contents

Appendix A
Test Forms
(Examples)

APPENDIX A

TEST FORM 1
ASSEMBLY OF THE PCV (AND SCV*)

Test Plan______________
Test Unit______________
Test Location:______________

VERIFIED TASK

_________ PCV test unit serial number: ____________________________

_________ SCV test unit serial number:______________________________(if not applicable, write “N/A.”)

_________ All primary containment vessel (PCV/SCV) components have been dimensionally verified to comply with drawing specifications.

_________ Temperature indicators have been affixed to the interior surface of the PCV/SCV. (No temperature indicators are required on prototype for normal conditions testing.)

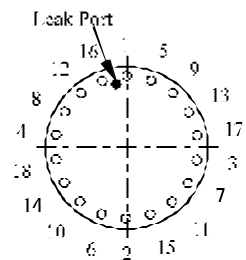
_________ None of the temperature indicators indicate exposure to a temperature in the measured range.

_________ The containers, lids, mock-up, and inserts have been clearly marked as “_____, Unit ____.”

_________ The PCV/SCV O-rings, O-ring glands, and sealing surfaces have been inspected for defects and found acceptable.

_________ Foam inserts and mock-up have been weighed and weights have been recorded on Form 3.

_________ The foam inserts and mock-up have been inserted into the PCV/SCV, the lid installed with the leak port aligned as close to the PCV/SCV seam as possible, and the bolts torqued to __±__ in-lb (__±__ ft-lb) in the sequence shown at right. Ambient temperature at closure was ___°C (___°F).



Typical Bolt Pattern

Torque wrench # _________ Expiration Date

Actual torque	1-______	6-______	11-______	15-
for each bolt in	2-______	7-______	12-______	16-
in-lb or **ft-lb**	3-______	8-______	13-______	17-
(circle one)	4-______	9-______	14-______	18-
	5-______	10-		

_________ The PCV/SCV assembly has been leak tested and found leak-free in accordance with leak-test procedure___.
Leak Rate Test Stand # ______ Expiration Date

________ The PCV/SCV assembly has been leak tested and found leak-free in accordance with leak-test procedure ___.
Leak Rate Test Stand # ______ Expiration Date

________ The PCV/SCV assembly has been weighed and the weight has been recorded on form 3.

________ Thermocouples have been attached to the exterior surface of the PCV/SCV if this unit is to obtain time-temperature data. These thermocouples have been surveyed to ensure they are working, which has been noted on form 15.

________ **Photographs of the assembly have been taken.

Comments:

I certify that the above tasks have been performed and that the observations and comments are correct.

______________________	____________	________________	________________
Testing Technician	Date	Witness	Date

* Applicable only if SCV is being tested. If not applicable, write “N/A.”

** All photographs/movies shall be uniquely identified with test unit, date and time of test unit, roll and frame to ensure that the proper sequence can be reconstructed.

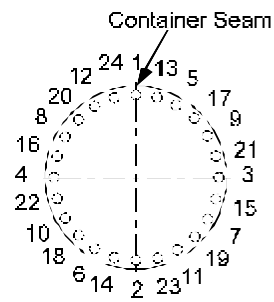
TEST FORM 2
ASSEMBLY OF TEST PACKAGE

Test Plan_____________
Test Unit_____________
Location: _____________

VERIFIED	TASK
_________	The test unit has been clearly marked "_______, Unit ___."
_________	Record the test unit serial number:_________
_________	The center of gravity targets have been applied to the test unit as shown
_________	Each insulation insert has been clearly marked "_______, Unit ___."
_________	The insulation inserts were weighed together and the weight has been recorded on form 3.
_________	The lower and middle insulation inserts have been loaded into the test unit.
_________	The SCV assembly has been loaded into the test unit with the seams aligned.
_________	The top insulation inserts have been loaded into the test unit.
_________	The gap between the top insulation inserts and the top of the test unit is ______.

CENTER OF GRAVITY MARKING

_________ The test unit lid has been installed and the bolts torqued to ____±__ ft-lb (___±__ in-lb) in a crossing sequence like that shown at right.
Torque wrench # ___________ Expiration Date ___________



Typical Bolt Torquing Pattern

Actual torque for each bolt in **in-lb** or **ft-lb** (circle one)						
	1-_____	5-_____	9-_____	13-_____	17-_____	21-_____
	2-_____	6-_____	10-_____	14-____	18-_____	22-_____
	3-_____	7-_____	11-_____	15-____	19-_____	23-_____
	4-_____	8-_____	12-_____	16-____	20-_____	24-_____

_________ A security seal has been attached to the test unit.

_________ The test package assembly has been weighed and the weight recorded on form 3.

Comments:

I certify that the above tasks have been performed and that the observations and comments are correct.

________________	__________	____________	___________
Testing Technician	Date	Witness	Date

TEST FORM 3
COMPONENT WEIGHTS

Test Plan______________
Test Unit______________
Test Location: ______________

PRE-TEST WEIGHTS

PART NAME	WEIGHT	BY	DATE
Mock-up	______lb	_______	_______
PCV inserts	______lb	_______	_______
PCV assembly	______lb	_______	_______
SCV inserts*	______lb	_______	_______
SCV assembly*	______lb	_______	_______
Test unit insulation	______lb	_______	_______
Test package	______lb	_______	_______

POST THERMAL TEST WEIGHTS

PART NAME	WEIGHT	BY	DATE
PCV assembly	______lb	_______	_______
SCV inserts	______lb	_______	_______
SCV assembly	______lb	_______	_______
Test package	______lb	_______	_______

EQUIPMENT

Pre-Test:
Scale # _____________ Expiration date_______
Accuracy ± _______ _______

Scale # _____________ Expiration date_______
Accuracy ± _______ _______

Scale # _____________ Expiration date_______
Accuracy ± _______ _______

Post-thermal test:
Scale # _____________ Expiration _______
Accuracy ± _______ _______

Scale # _____________ Expiration _______
Accuracy ± _______ _______

Scale # _____________ Expiration _______
Accuracy ± _______ _______

Comments:

I certify that the above tasks have been performed and that the observations and comments are correct.

______________________ ____________ ______________________ ____________
Testing Technician Date Witness Date

* Applicable only if SCV is being tested. If not applicable, write "N/A."

TEST FORM 4
ACCELEROMETER

Test Plan ____________
Test Unit ____________
Test Location: ____________

VERIFIED TASK

________ Identification of accelerometer

Model ___________ Serial No. __________

________ The battery was functioning properly and the chart was installed correctly.

________ The accelerometer chart drive was started at

Date: ______________ Time: ___________

________ The accelerometer chart drive was read at

Date: ______________ Time: ___________

________ The maximum spike values and their times are listed below.

Vertical	Lateral	Longitudinal	Time	Date

________ The strip chart used in the test is attached to the form.

________ The certification of the commercial accelerometer is attached to the form.

Comments:____

I certify that the above tasks have been performed and that the observations and comments are correct.

____________________ ____________ ____________________ ____________
Testing Technician Date Witness Date

* All photographs/movies shall be uniquely identified with test unit, date and time of test unit, roll and frame to ensure that the proper sequence can be reconstructed.

TEST FORM 5
VIBRATION TEST

Test Plan______________
Test Unit ______________
Test Location:______________

Test Date/Time: __________________________ Test Name/Test____________________________________

Test Location & Organization: ____

Test Conducted by: ____

Hardware

Test Unit Number ___________________________________ Test Unit Weight: ________________________

Vessel Initial Temp.: _________________________________ Ambient Temp.: ________________________

Position of Mock-up: Pre-test: ____

Test Unit Fastener (Finger-tight Test)

Screw #1 ___________________________________ Screw #7 ___________________________________
Screw #2 ___________________________________ Screw #8 ___________________________________
Screw #3 ___________________________________ Screw #9 ___________________________________
Screw #4 ___________________________________ Screw #10 ___________________________________
Screw #5 ___________________________________ Screw #11 ___________________________________
Screw #6 ___________________________________ Screw #12 ___________________________________

Vibration Input:
____

Instrumentation and Data Acquisition

Accelerometer Manufactured by: ____

Model Number: ___________________________________ Calibration Expiration Date: ________________

Data Acquisition System Manufactured by: ____

Model Number: ________________________________ Calibration Expiration Date: __________________

The activities listed in this procedure have been completed by:_____________________________________

Date: _______________________________

TEST FORM 6
1.2 m (4 ft) FREE FALL DROP

Test Plan______________
Test Unit______________
Test Location: ______________

VERIFIED TASK

_________ The test unit shall be subjected to a water spray that simulates exposure to a rainfall of approximately 5 cm/h (2 in/h) for at least 1h.
Start Date: _________ Start Time:_________
End Date: _________ End Time: _________

_________ Still, video, and high-speed video/movie cameras are set up to take photographs/movies* of the drop testing.

_________ Photographs* of the arrangements for the drop have been taken.

_________ The test unit has been raised so that the lowest point is 1.2 m (4 ft) above an essentially unyielding, horizontal impact surface.
Measuring device # ________ Exp. Date ______

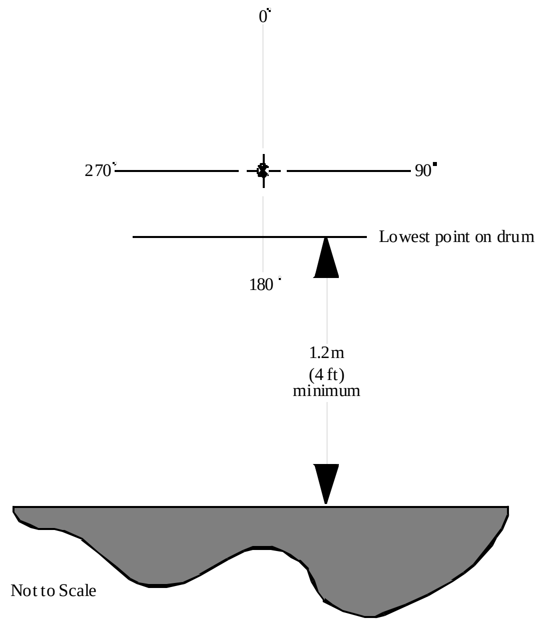
_________ Ambient temperature at the time of the test:
___°C (_____°F)

_________ The test unit was dropped from a minimum of 1.2 m (4 ft), oriented as shown at the right, onto an essentially unyielding, horizontal impact surface.

_________ Video/high speed movies* of the drop were made.

_________ Photographs* of the damage resulting from the drop have been taken.

PRE-DROP TEST UNIT ORIENTATION



(Indicate tolerance on orientation)

Testing Damage Observations:_________________________
____
____
____
____
____
____
____

POST-DROP SKETCH OF TEST UNIT

Comments:____
____
____

I certify that the above tasks have been performed and that the observations and comments are correct.

Testing Technician	Date	Witness	Date

* All photographs/movies shall be uniquely identified with test unit, date and time of test unit, roll and frame to ensure that the proper sequence can be reconstructed.

TEST FORM 7

0.3 m (1 ft) CORNER DROP

Test Plan_____________

Test Unit_____________

Test Location: _____________

VERIFIED	TASK
________	The test unit has been dropped on the top and bottom corners. (Test Form 6 has been completed.)
________	The test unit has been raised to a height of 0.3 m (1 ft) at an oblique angle with the corner (a) of the package at the lowest point and the center of gravity directly over the corner.
________	The test unit was dropped from a minimum of 0.3 m (1 ft) on each of the four corners of the top/bottom (cross out one) of the test unit between 1½ and 2½ h after the water spray test.
________	Following the water spray, the test unit has been raised to a height of 0.3m (1ft) at an oblique angle with the corner (b) of the package at the low est point and the center of gravity directly over the corner.
________	Following the water spray, the test unit has been raised to a height of 0.3m (1ft) at an oblique angle with the corner (c) of the package at the lowest point and the center of gravity directly over the corner.
________	Following the water spray, the test unit has been raised to a height of 0.3m (1ft) at an oblique angle with the corner (d) of the package at the lowest point and the center of gravity directly over the corner.
________	Photographs* of the arrangements for the test have been taken
________	Ambient temperature at the time of the test: Date: ____________ Time: ________ °C (________ °F)

Test Damage Observations:____________________________

____

____

____

____

PRE-DROP SKETCH	
Orientation (a)	Orientation (b)
Orientation (c)	Orientation (d)

POST TEST SKETCH	
Orientation (a)	Orientation (b)
Orientation (c)	Orientation (d)

Comments:

I certify that the above tasks have been performed and that the observations and comments are correct.

Testing Technician	Date	Witness	Date
____________	______	____________	____________

* All photographs/movies shall be uniquely identified with test unit, date and time of test unit, roll and frame to ensure that the proper sequence can be reconstructed.

TEST FORM 8
COMPRESSION TEST

Test Plan______________
Test Unit______________
Test Location: ______________

VERIFIED	TASK	TEST UNIT CONFIGURATION
________	The drop tests have been performed and test form 6 is complete.	
________	The test unit has been placed vertically on a horizontal surface as shown at right.	
________	Photographs* of the arrangements for the test have been taken.	
________	Initial test unit overall height is ______in.	
________	An unconstrained load of at least five times the weight of the package or the equivalent of 12.75 kPa (1.85 lb/in^2) multiplied by the vertically projected area of the package (whichever is greater) was applied to the top of the test unit for a minimum of 24 hours. Vertically projected area of test unit: ____________________ Based on weight of test unit from test form 3, actual load applied: __________ Start Date ________ Start Time ________ End Date ________ End Time ________	
		POST-TEST SKETCH
________	After the load was removed the final height of the test unit was measured, and the unit was inspected for damage.	
________	Final test unit overall height is ______in.	
________	Photographs* of the damage resulting from the test have been taken.	

Testing Damage Observations:______________________
____
____
____

Comments:____
____
____
____

I certify that the above tasks have been performed and that the observations and comments are correct.

____________________ Testing Technician   __________ Date   ____________________ Witness   __________ Date

* All photographs/movies shall be uniquely identified with test unit, date and time of test unit, roll and frame to ensure that the proper sequence can be reconstructed.

TEST FORM 9
PENETRATION TEST

Test Plan_______________
Test Unit_______________
Test Location:_______________

VERIFIED TASK

________ The test unit has been placed vertically on a horizontal surface as shown at right.

________ Still, video, and high-speed video/movie cameras are set up to take photographs/movies* of the penetration testing.

________ Photographs* of the arrangements for the drop have been taken.

________ The test rod is a steel cylinder, 3.2 cm (1.25 in) in diameter, with a hemispherical end and weighing 6 kg (13 lb), M&TE # ________.

________ The hemispherical end of the rod was dropped with its long axis perpendicular (±5°) to the test unit surface from a height of at least 1 m (40 in) onto the center (± 2 inches) of the test unit lid.

________ Photographs* of the damage resulting from the drops have been taken.

Following the drop, the unit was examined for damage.
Depth of penetration: ________
Observations:

________ The test unit has been placed on its side on a horizontal surface as shown to the right.

________ Photographs* of the arrangements for the drop have been taken.

________ The hemispherical end of the test rod was dropped with its long axis perpendicular (±5°) to the test unit surface from a height of at least 1 m (40 in) onto the side of the test unit.

Following the drop, the unit was examined for damage.
Depth of penetration ________
Observations:____
____
____

________ Photographs* of the damage resulting from both drops have been taken.

TEST UNIT CONFIGURATION

POST-TEST SKETCH OF TEST UNIT

Comments:____
____
____
____

I certify that the above tasks have been performed and that the observations and comments are correct.

Testing Technician	Date	Witness	Date

* All photographs/movies shall be uniquely identified with test unit, date and time of test unit, roll and frame to ensure that the proper sequence can be reconstructed.

TEST FORM 10
9 m (30 ft) FREE FALL DROP

Test Plan______________
Test Unit______________
Test Location: ______________

VERIFIED	TASK
________	The test unit has been prepared in accordance with the test plan. Forms 1, 2, 3, and 4 are complete and the pre-test weights are recorded on form 3.
________	Still, video, and high-speed video/movie cameras are set up to take photographs/movies* of the drop testing.
________	Photographs* of the arrangements for the drop have been taken.
________	The test unit has been raised so that the lowest point is 9 m (30 ft) above an essentially unyielding, horizontal impact surface. Measuring device # _______ Exp. Date ______
________	Ambient temperature at the time of the test: ___°C (_____°F)
________	The test unit was dropped from a minimum of 9 m (30 ft), oriented as shown at right, onto an essentially unyielding, horizontal impact surface.
________	Video/high speed video/movies* of the drop were made.
________	Photographs* of the damage resulting from the drop have been taken.

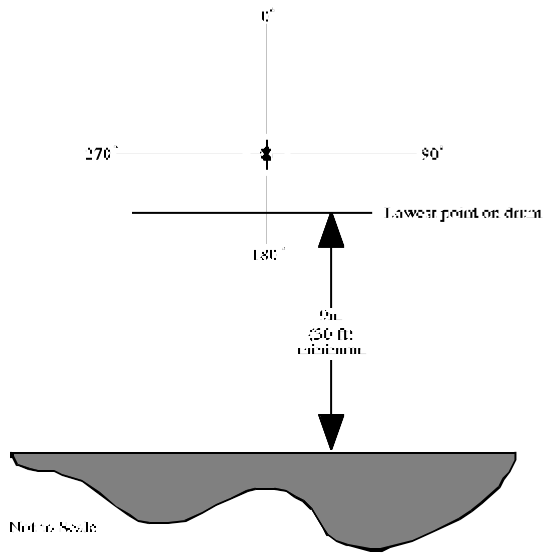
Testing Damage Observations:________________________

____

____

____

PRE-DROP TEST UNIT ORIENTATION



(Indicate tolerance on orientation)

POST-DROP SKETCH OF TEST UNIT

Comments:____

____

____

____

____

I certify that the above tasks have been performed and that the observations and comments are correct.

____________________	__________	______________________	____________
Testing Technician	Date	Witness	Date

* All photographs/movies shall be uniquely identified with test unit, date and time of test unit, roll and frame to ensure that the proper sequence can be reconstructed.

TEST FORM 11
9 m (30 ft) DYNAMIC CRUSH TEST

Test Plan______________
Test Unit______________
Test Location:______________

VERIFIED | TASK

________ The test unit has been prepared in accordance with the test plan. Forms 1 and 2 are complete, and the pre-test weights have been recorded on form 3.

________ Ambient temperature at the time of the test:
_____°C (_____°F)

________ The test unit has been placed on an essentially unyielding surface, configured as shown at right.

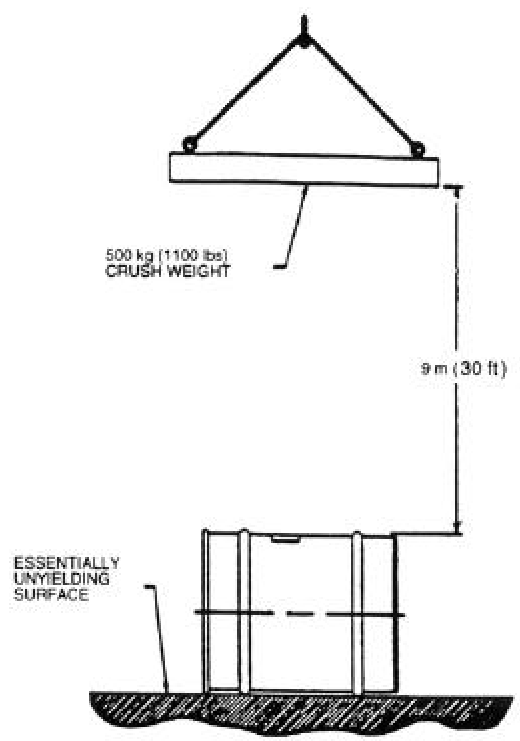
________ The 500 kg (1100 lb), 1m (3.28 ft) square, mild steel test weight, M&TE # _______, has been raised to a height of 9 m (30 ft), with the center of the plate directly over the intended impact point.

Measuring device # _______ Exp. Date ______

________ The test weight is dropped in a free fall from 9 m (30 ft) onto the test unit.

________ Photographs* showing the damage resulting from the test have been taken.

TEST UNIT CONFIGURATION



POST-DROP SKETCH OF TEST UNIT

Testing Damage Observations:___________________
____
____
____
____

Comments:____
____
____
____
____

I certify that the above tasks have been performed and that the observations and comments are correct.

Testing Technician	Date	Witness	Date

* All photographs/movies shall be uniquely identified with test unit, date and time of test unit, roll and frame to ensure that the proper sequence can be reconstructed.

TEST FORM 12
1 m (40 in) PUNCTURE DROP

Test Plan_______________
Test Unit_______________
Test Location:_______________

VERIFIED TASK

_________ The test unit has been prepared in accordance with the test plan. Forms 1 and 2 are complete and the pre-test weights are recorded on form 3. The free fall drop has been completed as recorded on Form 10.

_________ Still, video, and high-speed video/movie cameras are set up to take photographs/movies* of the drop testing.

_________ Photographs* of the arrangements for the drop have been taken.

_________ The steel puncture bar is no greater than 15 cm (6 in) in diameter and no less than 20 cm (8 in) long, with the corners having a radius of no more than 6 mm (0.25 in) and rigidly attached to on an essentially unyielding, horizontal impact surface.

_________ Ambient temperature at the time of the test: ___ °C (_____ °F)

_________ The test unit was raised to 1m (40 in), oriented as shown at right.
Measuring device # _______ Exp. Date ______

_________ The test unit was dropped from a minimum of 1 m (40 in) onto the steel bar.

_________ Video/high speed video/movies* of the drop were made.

_________ Photographs* of the damage resulting from the drop have been taken.

Testing Damage Observations:_________________________

____

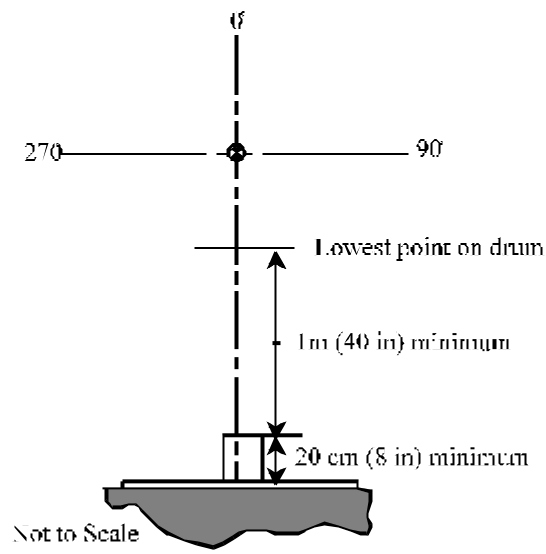
____

____

____

____

PRE-DROP TEST UNIT ORIENTATION



(Show tolerance on orientation)

POST-DROP SKETCH OF TEST UNIT

Comments:____

____

____

____

____

I certify that the above tasks have been performed and that the observations and comments are correct.

Testing Technician	Date	Witness	Date

* All photographs/movies shall be uniquely identified with test unit, date and time of test unit, roll and frame to ensure that the proper sequence can be reconstructed.

TEST FORM 13
POOL FIRE TEST CHECKLIST

Test Plan_______________
Test Unit_______________
Test Location:_______________

Test Description: ____________________________________
Test Unit No. ______________________________________

VERIFIED TASK

_________ The assemble of the test unit was recorded on form 1
Comments:____

_________ The pretest weight of the test unit was recorded on form 1
Comments:____

_________ The test unit was thermally conditioned to a minimum of 70°C.
Comments: ____

_________ All personnel in the test area were advised of the Environment, Safety, and Health requirements pertaining to the testing of the test unit.
Comments:____

_________ The test unit was positioned as specified in the Pool Fire Test Facility requirements.
Comments:____

_________ The temperature of the test unit was required prior to the Pool Fire test.
Comments:____

_________ The wind speed was checked and was than less than 2 m/s (4.5 MPH)
Comments:____

_________ Thermocouples were attached to the data acquisition system and a systems test was conducted prior to the test unit Pool Fire Test.
Comments:____

_________ Documentary photographs were taken or a line drawing made of the test setup.
Comments:____

_________ Post-test observations were documented.
Comments:____

_________ Observations were documented by taking photographs.
Comments:____

_________ The post-test weight of the test unit was recorded.
Comments:____

I certify that the above tasks have been performed and that the observations and comments are correct.

____________________	__________	____________________	__________
Testing Technician	Date	Witness	Date

TEST FORM 14
POOL FIRE TEST DATA SHEET

Test Plan_______________
Test Unit_______________
Test Location:_______________

Test Unit No.________________________

Test Unit Pretest Weight:_______________

Test Unit Orientation:_________________

Personnel shall monitor the temperature of the test unit and record the time , temperature, and thermocouple number. The test unit temperature shall be recorded prior to the time the pool fire test is performed.

Test Unit

Time: __________________ Temperature: _____________ Thermocouple Number:__________________

Time: __________________ Temperature: _____________ Thermocouple Number:__________________

Thermocouple Type:____

Temperature Indicator:____

Calibrated using:____

Model No: ________________________________ Calibration Expiration Date:______________________________

Time that the pool of JP4/JP8 fuel was ignited:____

Time that the Pool Fire Test ended:____

Test Unit Post-test Weight:____

Test Unit weight change: ____

Observations:____

I certify that the above tasks have been performed and that the observations and comments are correct.

______________________	___________	_______________________	_______________
Testing Technician	Date	Witness	Date

TEST FORM 15
THERMOCOUPLE VERIFICATION

Test Plan_______________
Test Unit_______________
Test Location:_______________

THERMOCOUPLE	VERIFIED
1	________
2	________
3	________
4	________
5	________
6	________
7	________
7	________
9	________
10	________
11	________
12	________
13	________
14	________
15	________
16	________
17	________
18	________
19	________
20	________
21	________
22	________
23	________
24	________
25	________
26	________
27	________
28	________
29	________
30	________
31	________
32	________
33	________
34	________
35	________
36	________
37	________

I certify that the thermocouples have been verified to be working as indicated above.

____________________	__________	____________________	______________
Testing Technician	Date	Witness	Date

TEST FORM 16
THERMAL PREHEAT TEST

Test Plan______________
Test Unit______________
Test Location:______________

Record test unit serial number

Thermocouple Description	S/N#	Time ______ Temp	Time ______ Temp	Time _____ Temp	Time Temp
________	________	________	________	________	________
________	________	________	________	________	________
________	________	________	________	________	________
________	________	________	________	________	________
________	________	________	________	________	________
________	________	________	________	________	________
________	________	________	________	________	________
________	________	________	________	________	________
________	________	________	________	________	________
________	________	________	________	________	________

Arrange Thermocouples Per Figure ___________.

1. Preheat the test package until the inner container thermocouples have indicated at least 38°C (100°F) for at least 2 hours. Record the drum and inner container thermocouples at 15 minutes for 1 hour.

2. All thermocouples shall be surveyed to ensure that they are working. (Any erratic or malfunctioning thermocouples shall be recorded in the comments section of this form.)

3. Photographs* have been taken to show test set-up.

Comments:____
____
____
____
____
____

I certify that the above tasks have been performed and that the observations and comments are correct.

____________________	__________	______________________	______________
Testing Technician	Date	Witness	Date

* All photographs/movies shall be uniquely identified with test unit, date and time of test unit, roll and frame to ensure that the proper sequence can be reconstructed.

TEST FORM 17
THERMAL TESTING
(Furnace)

Test Plan_______________
Test Unit_______________
Test Location:_______________

VERIFIED	TASK
________	The test plan calls for __ thermocouples attached to the test unit primary containment vessel (or inner container if only one), ___ thermocouples attached to the test unit secondary containment vessel, ____ thermocouples attached to the test unit drum, __ thermocouples in the furnace, and ____ thermocouples on the test stand.
________	The test package weight has been recorded on test form 3 and thermocouples have been attached to the test unit as shown in the test plan.
________	Thermocouples and test stand have been installed in the furnace as shown in the test plan.
________	Photographs* of the arrangements for the test have been taken.
________	All thermocouples have been surveyed to ensure that they are working, and this has been recorded on form 14. (Any malfunctions or erratic performance will be addressed in the comments section below.)
________	The furnace reached set point temperature of ____°C (____°F) at _____, and has soaked at this temperature for a minimum of 24 hours. The unit has reheated at least one hour between tests. Date __________ Time__________
________	The thermocouple recorder(s) is (are) set to read at least once a minute.
________	The unit has been placed in the furnace on the support stand with the damaged area up at: Date __________ Time ____________ Open furnace door time: ____ sec.
________	The 30-minute timed test began when a minimum of ___ test unit thermocouples reached the test temperature of 800°C (1475°F) as specified in the test plan. Date __________ Time
________	Immediately following the timed test (a minimum of 30 minutes at 800°C), the test unit was taken out to cool naturally. Date __________ Time ____________ Ambient Temperature ___°C (___°F)
________	The unit stopped outgassing (flames) at _____; outgassing/burnout lapsed time was _____.
________	The thermocouple recorder has been reset to record at 5-minute intervals.

Comments:____
____
____
____
____

I certify that the above tasks have been performed and that the observations and comments are correct.

____________________	__________	______________________	____________
Testing Technician	Date	Witness	Date

* All photographs/movies shall be uniquely identified with test unit, date and time of test unit, roll and frame to ensure that the proper sequence can be reconstructed.

** Figure identifiers to be filled in.

TEST FORM 18
TEMPERATURE INDICATOR READINGS

Test Plan______________
Test Unit______________
Test Location:______________

A visual inspection of each temperature indicator on the SCV*, PCV, and mock-up shall be made to determine the values of the blackouts which occurred. Those values recorded below:

RECORDED BLACKOUT TEMPERATURES:

SCV SURFACE:

	#1	#2	#3	#4	#5	#6	#7	#8
ROW A	_______°F	_______°F	_______°F	_______°F	_______°F	_______°F	_______°F	_______°F
ROW B	_______°F	_______°F	_______°F	_______°F	_______°F	_______°F	_______°F	_______°F
ROW C	_______°F	_______°F	_______°F	_______°F	_______°F	_______°F	_______°F	_______°F
ROW D	_______°F	_______°F	_______°F	_______°F	_______°F	_______°F	_______°F	_______°F
ROW E	_______°F	_______°F	_______°F	_______°F	_______°F	_______°F	_______°F	_______°F

PCV SURFACE:

	#1	#2	#3	#4	#5	#6	#7	#8
ROW A	_______°F	_______°F	_______°F	_______°F	_______°F	_______°F	_______°F	_______°F
ROW B	_______°F	_______°F	_______°F	_______°F	_______°F	_______°F	_______°F	_______°F
ROW C	_______°F	_______°F	_______°F	_______°F	_______°F	_______°F	_______°F	_______°F
ROW D	_______°F	_______°F	_______°F	_______°F	_______°F	_______°F	_______°F	_______°F
ROW E	_______°F	_______°F	_______°F	_______°F	_______°F	_______°F	_______°F	_______°F

MOCK-UP SURFACE:

	#1	#2	#3	#4	#5	#6	#7	#8
ROW F	_______°F	_______°F	_______°F	_______°F	_______°F	_______°F	_______°F	_______°F
ROW G	_______°F	_______°F	_______°F	_______°F	_______°F	_______°F	_______°F	_______°F
ROW I	_______°F	_______°F	_______°F	_______°F	_______°F	_______°F	_______°F	_______°F

Comments:____

I certify that the above temperature readings and comments are correct.

Testing Technician	Date	Witness	Date

* Applicable only if SCV is being tested. If not applicable, write "N/A."

TEST FORM 19
POST-THERMAL TESTING INSPECTION

Test Plan____________
Test Unit____________
Test Location:____________

VERIFIED	TASK
________	Following the thermal test and after cooling, the test package was weighed and the weight recorded on Form 3.
________	The drum, lid, and bolts have been visually examined to determine the extent of damage. Observations: ____
________	The camera(s) is (are) set up to take photographs* of the damage due to thermal testing.
________	The upper inserts have been removed and visually inspected to determine the extent of damage and char depth. Observations: ____
________	The SCV assembly has been removed and visually examined for damage. Observations: ____
________	The SCV assembly has been weighed and the weight recorded on Form 3.
________	The lower inserts have been removed and visually inspected to determine the extent of damage and char depth. Observations: ____
________	All inserts have been placed in separate polyethylene bags, marked "_______, Unit ___," taped closed, and prepared for storage with the test package.
________	Photographs* of the damage resulting from the testing have been taken.

Comments:____
____
____
____
____
____

I certify that the above tasks have been performed and that the observations and comments are correct.

____________________	__________	__________________	______________
Testing Technician	Date	Witness	Date

* All photographs/movies shall be uniquely identified with test unit, date and time of test unit, roll and frame to ensure that the proper sequence can be reconstructed.

TEST FORM 20
0.9 m (3 ft) IMMERSION TEST

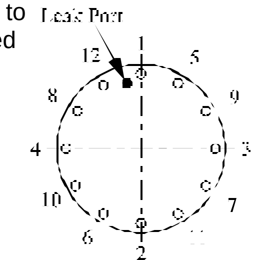
Test Plan_______________
Test Unit_______________
Test Location:_______________

VERIFIED	TASK
________	A leak test in accordance with procedure _______________ was performed on the SCV* assembly following the termal inspection and Test Form 19 is complete.
________	The SCV* assembly was immersed under a head of water of at least 15 m (50 ft or 21.6 psig) to highest point of SCV* assembly for a period not less than 8 hours.

Facility ____________________________ Gauge # __________ Expiration Date __________

Date In __________ Time In __________ Date Out __________ Time Out __________

________ Following the immersion test, the SCV assembly was opened and examined to determine if any in-leakage of water had occurred. The SCV lid was removed with the bolts untorqued in the sequence shown at right. Note: Leak Port as reference point for bolt numbering.



SCV - Typical Bolt Pattern

Torque wrench # ___________ Expiration Date __________

Actual torque for each bolt in **in-lb** or **ft-lb** (circle one)			
	1-_____	5-_____	9-_____
	2-_____	6-_____	10-_____
	3-_____	7-_____	11-_____
	4-_____	8-_____	12-_____

________ Photographs* have been taken of the opened SCV to show the amount of water inleakage.

Observations:____

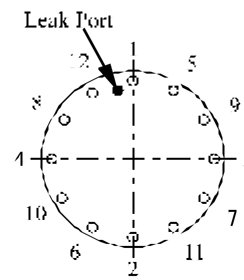
________ A leak test in accordance with procedure _______________ was performed on the PCV assembly.

________ The PCV assembly was taken to the Equipment Testing and Inspection Department in Building 9201-1, where it was immersed under a head of water of at least 15 m (50 ft or 21.6 psig) to highest point of PCV assembly for a period not less than 8 hours.

Facility ____________________________ Gauge # __________ Expiration Date _______

Date In __________ Time In __________ Date Out __________ Time Out __________

________ Following the immersion test, the PCV assembly was opened and examined to determine if any in-leakage of water had occurred. The PCV lid was removed with the bolts untorqued in the sequence shown at right. Note Leak Port as reference point for bolt numbering.



PCV - Typical Bolt Pattern

Torque wrench # ___________ Expiration Date __________

Actual torque for each bolt in **in-lb** or **ft-lb** (circle one)			
	1-_____	5-_____	9-_____
	2-_____	6-_____	10-_____
	3-_____	7-_____	11-_____
	4-_____	8-_____	12-_____

________ Photographs** have been taken of the opened SCV to show the amount of water inleakage.

Observations: ____

I certify that the above tasks have been performed and that the observations and comments are correct.

____________________	__________	____________________	__________
Testing Technician	Date	Witness	Date

* Applicable only if SCV is being tested. If not applicable, write "N/A."

** All photographs/movies shall be uniquely identified with test unit, date and time of test unit, roll and frame to ensure that the proper sequence can be reconstructed.

TEST FORM 21
15 m (50 ft) IMMERSION TEST

Test Plan_______________
Test Unit_______________
Test Location:_______________

VERIFIED TASK

________ The SCV* assembly was immersed under a head of water of at least 15m (50ft or 21.6psig) to the highest point of SCV* assembly for a period not less than 8 hours.

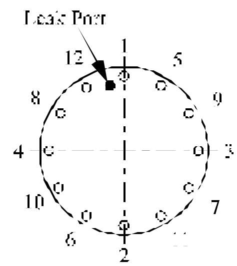
Facility ____________________________ Gauge # __________ Expiration Date __________

Date In __________ Time In __________ Date Out __________ Time Out __________

________ Following the immersion test, the SCV* assembly was opened and examined to determine if any in-leakage of water had occurred. The SCV* lid was removed with the bolts untorqued in the sequence shown at right. Note: Leak Port as reference point for bolt numbering.

Torque wrench # ___________ Expiration Date __________

Actual torque	1-_____	5-_____	9-_____
for each bolt in	2-_____	6-_____	10-_____
in-lb or **ft-lb**	3-_____	7-_____	11-_____
(circle one)	4-_____	8-_____	12-_____



SCV - Typical Bolt Pattern

________ Photographs** have been taken of the opened SCV to show the amount of water inleakage.

Observations:____

________ The PCV assembly was taken to the Equipment Testing and Inspection Department in Building 9201-1, where it was immersed under a head of water of at least 15 m (50ft or 21.6psig) to the highest point of PCV assembly for a period not less than 8 hours.

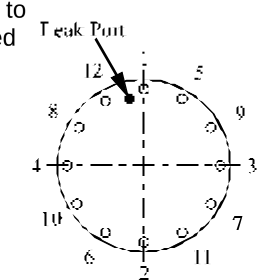
Facility ____________________________ Gauge # __________ Expiration Date _______

Date In __________ Time In __________ Date Out __________ Time Out ___________

________ Following the immersion test, the PCV assembly was opened and examined to determine if any in-leakage of water had occurred. The PCV lid was removed with the bolts untorqued in the sequence shown at right. Note Leak Port as reference point for bolt numbering.

Torque wrench # ___________ Expiration Date __________

Actual torque	1-_____	5-_____	9-_____
for each bolt in	2-_____	6-_____	10-_____
in-lb or **ft-lb**	3-_____	7-_____	11-_____
(circle one)	4-_____	8-_____	12-_____



PCV - Typical Bolt Pattern

________ Photographs** have been taken of the opened SCV to show the amount of water inleakage.

Observations:____

I certify that the above tasks have been performed and that the observations and comments are correct.

____________________	__________	____________________	__________
Testing Technician	Date	Witness	Date

* Applicable only if SCV is being tested. If not applicable, write "N/A."

** All photographs/movies shall be uniquely identified with test unit, date and time of test unit, roll and frame to ensure that the proper sequence can be reconstructed.

TEST FORM 22
DISASSEMBLY AND INSPECTION

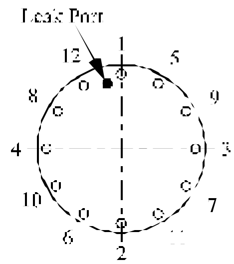
Test Plan_______________
Test Unit_______________
Test Location:_______________

This form shall be used to record the disassembly of the test package, PCV, and SCV*.

VERIFIED TASK

________ The SCV* lid was removed with the bolts untorqued in the sequence shown at right. Note Leak Port as reference point for bolt numbering.
Torque wrench # ____________ Expiration Date ___________

Actual torque for each bolt in **in-lb** or **ft-lb** (circle one)			
	1-_____	5-_____	9-_____
	2-_____	6-_____	10-_____
	3-_____	7-_____	11-_____
	4-_____	8-_____	12-_____



SCV - Typical Bolt Pattern

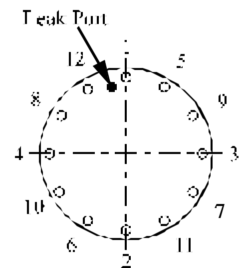
________ Photographs** have been taken of the opened SCV.

Observations:____

________ The PCV lid was removed with the bolts untorqued in the sequence shown at right. Note Leak Port as reference point for bolt numbering.

Torque wrench # ____________ Expiration Date ___________

Actual torque for each bolt in **in-lb** or **ft-lb** (circle one)			
	1-_____	5-_____	9-_____
	2-_____	6-_____	10-_____
	3-_____	7-_____	11-_____
	4-_____	8-_____	12-_____



PCV - Typical Bolt Pattern

________ Photographs** have been taken of the opened SCV*.

Observations:____

Tests/Tasks: Following the drop tests, the inner container was removed from the outer drum, and the unit was inspected to detemine the extent of damage to the insulation. The results of this visual inspection were:

____
____
____

The exterior of the inner container was visually inspected to determine the extent of any damage. The results of this inspection were: ____
____
____

I certify that the above tasks have been performed and that the observations and comments are correct.

____________________	__________	____________________	__________
Testing Technician	Date	Witness	Date

* Applicable only if SCV is being tested. If not applicable, write "N/A."
** All photographs/movies shall be uniquely identified with test unit, date and time of test unit, roll and frame to ensure that the proper sequence can be reconstructed.

Appendix B
Combination Test/Analysis Method Used to Demonstrate Compliance to DOE Type B Container Thermal Testing Requirements (30 minute fire test), DOE/AL Defense Programs Guideline for Packaging, February 10, 1992

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Appendix C
Vibration Environments for the AT-400R
(Klenke to Glass, Sandia Lab Memo)

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Appendix D
Calculations for Normal Vibrations During Safe-Secure Trailer Shipment of the DC-1 Package with HEU Oxide Contents

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Appendix E
Recommended Random Vibration and Shock Test Specifications for Cargo Transported on SST and SGT Trailers

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