NON-PROPRIETARY
SAFTEY ANALYSIS REPORT
FOR THE
NUPAC
N-55 PACKAGING

JULY 1994

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1.0 GENERAL INFORMATION

1.1 Introduction

The NuPac N-55 Packaging, Model No. : N-55, has been developed by Nuclear Packaging, Inc., as a safe means of transporting radioactive material including fissile material in the form of dry solids contained within a containment vessel defined as a DOT Specification 17H or 17C, 55 gallon drum. Dispersible forms such as liquids, powders, and slurries are excluded.

The N-55 overpack surrounds and protects the 55 gallon drum from the normal conditions of transport and the hypothetical accident conditions set forth in 10 CFR 71. No shielding is provided by the overpack.

Authorization is sought for a Type B(U) shipment by cargo vessel, motor vehicle, and rail.

1.2 Package Description

1.2.1 Packaging

The NuPac N-55 Packaging is a cylindrical, surrounding overpack, 48.0 inches tall, 32.0 inches in diameter, with a gross weight, including payload, not to exceed 750 pounds. The cavity is designed to carry a DOT Specification 17H or 17C, 55 gallon drum the cavity height and diameter is 35.5 inches and 24.0 inches, respectively. These dimensions are provided in the general arrangement drawing found in Section 1.3.

The outer shell of the overpack is fabricated of galvanized 20 (or 18) gauge ductile low carbon steel. The inner shell is molded from a high impact fiberglass material. This provides a tough, high strength liner able to take abrasive handling and corrosive materials as well as the normal and hypothetical accident conditions. The volume between the inner and outer shells is filled with a shock and thermal insulating material consisting of rigid polyurethane foam having a density of approximately three pounds per cubic foot. The liquid foam is poured into the cavity between the two shells and allowed to expand, completely filling the void. There it bounds to the shells thereby creating a unitized construction for the packaging.

Once assembled, the overpack takes the shape of a vertical, right angle cylinder with a separation plane located 18.0 inches from the top. In use, the lower unit comprises the body or base of the container while the upper unit serves as the lid. The stepped joint between the two halves is sealed with a neoprene gasket.

Closure of the lid and body is maintained via four high capacity 'over-center' locking latch devices, each with a secondary lock to resist release during normal and hypothetical accident conditions.

The N-55 overpack is not intended to be the containment vessel, but rather provides a prime function of reducing the severity of the hypothetical accident conditions thereby assuring there will be no loss of contents from the 55 gallon drum.

The containment vessel is a gasketed, 55 gallon drum, meeting the requirements of DOT Specification 17H or 17C as delineated in 49 CFR 178.118 or 49 CFR 178.115, respectively. A testing program was designed to qualify this container as meeting the normal conditions of transport. Because the physical form of the package contents excludes dispersible forms such as liquids, powders, and slurries, and because actual hypothetical accident level test conditions has shown only minimal deformation to the drum with no loss of contents, the leakage tests to verify containment under hypothetical accident conditions are not required per current ANSI N14.5 standards.

Four lifting devices are provided on the N-55 Packaging as shown in the general arrangement drawing in Section 1.3. A detailed analysis of their structural integrity is provided in Section 2.5.1. There are no tiedown devices which are a structural part of the package.

There are no special methods utilized for the dissipation of heat. The maximum internal thermal loading is 3.0 thermal watts. A detailed thermal analysis is provided in Section 3.0.

There are no neutron absorbers, receptacles, sampling ports, pressure relief devices or coolants, and no shielding is provided by the N-55 Packaging.

1.2.2 Operational Features

The N-55 Packaging is simple in construction and use as illustrated in the general arrangement drawing in Section 1.3. There are no complex operational requirements connected with the N-55 Packaging and none that have any transport significance. Detailed operating procedures are provided in Section 7.0.

1.2.3 Contents of Packaging

Radioactive material including fissile material in the form of dry solids contained in DOT Specification 17H or 17C steel drums. Dispersible forms such as liquids, powders, and slurries are not permitted. Contents include greater than Type A quantities of radioactive material. Fissile material contents are limited to the generally licensed mass limits as specified in 10 CFR 71.18 and 71.22, and plutonium in excess of twenty (20) curies per package must be in the form of metal, metal alloy, or reactor fuel elements. Internal decay heat shall not exceed 3.0 thermal watts.

For less than full loads, sufficient dunnage, shoring and/or bracing shall be utilized between the contents and the drum to minimize the effects of normal and accident conditions. In particular, protrusions associated with the contents such as lifting eyes, etc., shall be positioned such that they will not contact the drum walls or shoring shall be provided to prevent puncture of the drum walls by the protrusions under normal conditions of transport or hypothetical accident conditions.

Appendix 1.3

General arrangement drawing of the N-55 Packaging, X-60-200D-SP, Rev. B.

FIGURE WITHHELD UNDER 10 CFR 2.390

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12
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CHECK M. Richards	
DRAWN D. KENT	

NUCLEAR PACKAGING, INC.
TACOMA WASHINGTON

NUPAC
MODEL N-55
TYPE B OVERPACK

DWG SIZE D | REV B | DWG NO. X-60-200D-SNP

WT 160LBS | SHEET 1 OF 1

2.0 STRUCTURAL EVALUATION

This Section identifies and describes the principal structural engineering design aspects of the packaging, components, and systems important to safety and to compliance with the performance requirements of 10 CFR 71.

2.1 Structural Design

2.1.1 Discussion

The principal structural members and systems in the N-55 Packaging are:

(1) the containment vessel, as described in Section 1.2.1 above, and

(2) the insulated shipping container, or overpack.

Closure of the overpack is maintained via four (4) over-center type latches. The overpack components are identified on the drawing in Appendix 1.3. The containment vessel consists of a 17C (or 17H), 55-gallon drum. The overpack and containment vessel work together to satisfy the standards set forth in 10 CFR 71. A detailed discussion of the structural design and performance of these components is provided below.

2.1.2 Design Criteria

The primary function of the N-55 overpack is to protect the 55-gallon drum from the hypothetical accident conditions. Since the drums are able to meet the normal conditions of transport as well as those of Type 'A' packaging, their structural integrity is well established. Therefore, the N-55 Packaging has been designed to reduce the severity of the hypothetical accident to limits that can be reacted by the drum.

In order to demonstrate the overpack's ability, a combination of full scale tests and computerized thermal analyses have been run. Since thermal analysis has been reduced to an accurate and routine process, it was determined that an analytic solution would be used for the hypothetical fire test condition. Full scale drop tests would verify the impact attenuating capability.

From testing conducted at Mound Lab on drums, it was concluded that the most critical area was that of the bolt closure ring. Therefore, to insure its integrity, local deformation must be minimized. The design philosophy called for surrounding the drum with a strong fiberglass shell. This shell, when stabilized with a low density foam (approximately 3 PCF), would provide a form, or shape matching that of the drum. In this manner, concentrated loads, such as corner drop, could be uniformly distributed over a large portion of the drum. This distribution would eliminate localized loads that could result in bolt closure ring deformation and subsequent leakage. For this approach to be effective, it must be coupled with an energy absorption system.

Impact energies are absorbed in two ways. The external skin absorbs energy through localized or plastic deformation. Secondly, the superior absorption capability of rigid foam is utilized. This material has a proven performance in Type 'B' packages as well as others referenced in MIL-HDDK-768 (sm) Rigid Polyurethane Foam Packaging Design. It is through this combination of the crushable energy absorbing external shell and foam that the package design criteria is satisfied.

2.2 Weights and Center of Gravity

The weight of the loaded containment vessel (55 gallon drum) will not exceed 550 pounds. The overpack weight is less than 200 pounds making a maximum total gross weight for the Model N-55 Packaging of 750 pounds. The center of gravity for the assembled package is located at the approximate geometric center of gravity. A reference point for locating the center of gravity is shown on the drawing in Appendix 1.3.

2.3 Mechanical Properties of Materials

The Model N-55 Packaging uses an outer shell fabricated of low carbon, hot rolled steel. Material properties of the steel are assumed to be that of ASTM A-36, i.e., F_y = 36,000 psi and F_u = 58,000 psi.

Rigid polyurethane foam fills the cavity between the shells. This material will have a density of approximately 3 pcf and be of a self-extinguishing variety. Typical mechanical properties are as follows:

Compressive Strength = 50 psi

Thermal conductivity, K = 0.17 Btu in/hr-ft^2-°F

Crush strength shall be more precisely controlled per flagnote 10 of the general arrangement drawing, Appendix 1.3.

2.4 General Standards for All Packages

This section demonstrates compliance with the general standards for all packaging, specified in 10 CFR 71.43.

2.4.1 Minimum Size

The minimum dimensions of the N-55 Packaging are 32.0 inches diameter by 48.0 inches long.

2.4.2 Tamper-Indicating Feature

A lock wire will be utilized through the appropriate holes in one of the over-center latching devices. Failure of said device will indicate purposeful tampering in accordance with 10 CFR 71.43(b).

2.4.3 Positive Closure

The positive closure system has been previously described in Section 1.2.1.

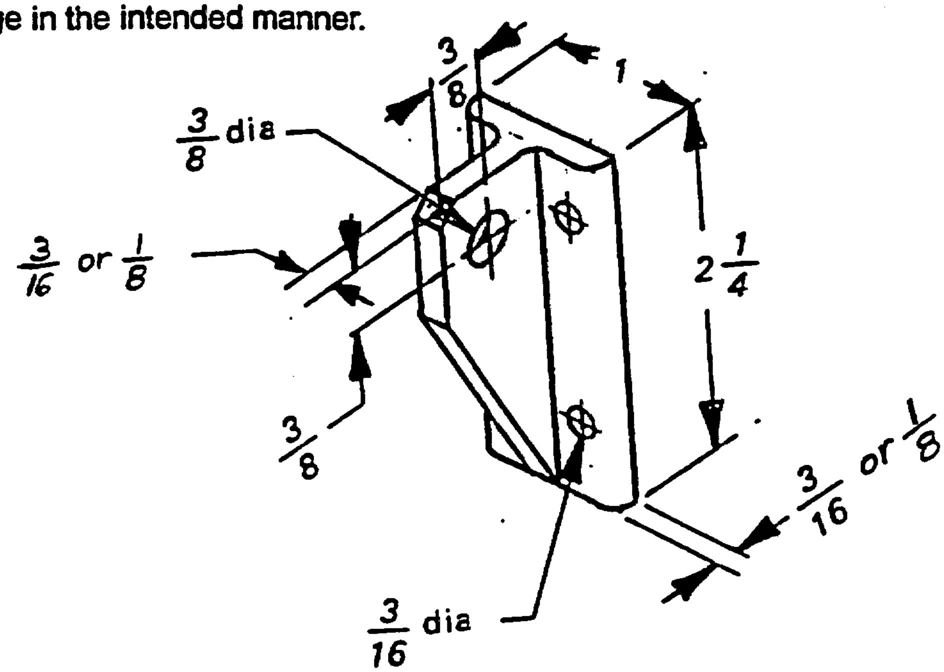
2.4.4 Chemical and Galvanic Reactions

The materials from which the packaging is fabricated (steel, fiberglass, and polyurethane foam), along with the contents of the package, will not cause significant chemical, galvanic, or other reaction in air, nitrogen, or water atmosphere.

2.5 Lifting and Tiedown Standards for All Packages

2.5.1 Lifting Devices

Per the requirements of 10 CFR 71.45(a), any lifting attachment that is a structural part of the package must be designed with a minimum safety factor of three against yielding when used to lift the package in the intended manner.



2.5.1.1 Lug Shearout

Assuming only two of four lugs are effective, the load considered to act on each lug is:

$$P = 3(750/2) = 1{,}125 \text{ lbs}$$

Using the standard 40o Shearout Equation, the load to yield a lug is:

$$P_s = 2F_{sy}t\,[e_d - (d/2)(\cos 40°)]$$

Where:

F_{sy} = 21,600 psi (from Section 2.3 where $F_{sy} = 0.6F_y$)

t = 0.125 in (minimum)

e_d = 0.375 in

d = 0.375 in

Then:

$P_s = 2(21,600)(0.125)[0.375 - (0.375/2)(\cos 40°)] = 1,250$ lbs

The lug shearout Margin of Safety is:

M.S. = $(P_s/P) - 1 = (1,250/1,125) - 1 = \underline{+0.11}$

2.5.1.2 Rivet Capacity

The 3/16 inch rivets carry a combined loading due to a bending moment and a shear. The tensile force in each rivet is found by summing moments about the assumed pivot point 'A':

$2P_a(0.375) + 2Pb(1.75) - P(0.625) = 0$

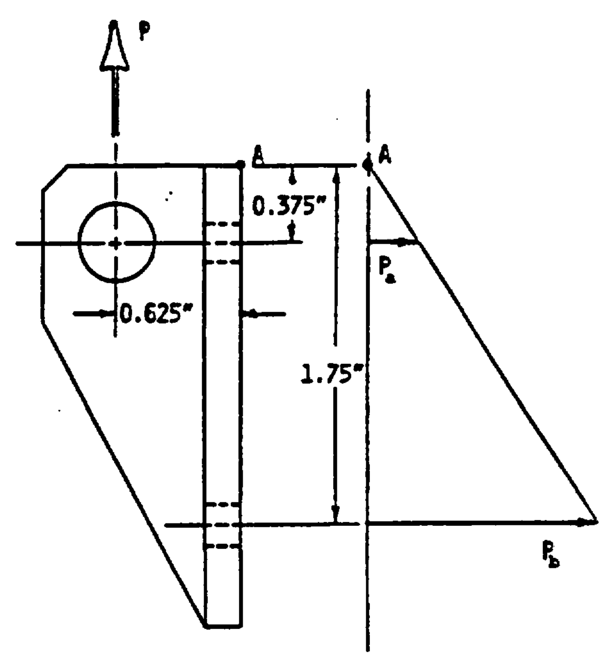
Where:

$P_a = (0.375/1.75)P_b$

Then:

$2P_b[(0.375)^2/1.75] + 2P_b(1.75) = (1,125)(0.625)$

$P_b = 192$ lbs



The shear load in each rivet is found by a vertical force balance:

$P - 4V = 0$

$V = P/4 = 1,125/4 = 281$ lbs

Calculate the vector sum of the maximum rivet tensile force and shear force:

$P_c = [P_b^2 + V^2]0.5 = [(192)^2 + (281)^2]0.5 = 340$ lbs

Per drawing X-60-200D, flagnote 5 (Appendix 1.3), the rivets have tension and shear strengths of 1,100 and 1,450 pounds, respectively, thus the rivet Margin of Safety is:

$$M.S. = (1{,}100/P_c) - 1 = (1{,}100/340) - 1 = \underline{+2.23}$$

2.5.1.3 Latch Capacity

The four (4) CAMLOC 37L33-1-1AA latches each have a manufacturers specified ultimate strength of 4,500 pounds and a working strength of 3,000 lb (Appendix 2.10.1). By inspection, the latch margin of safety will exceed the lug capacity.

2.5.1.4 Conclusion

From the above analyses, it can be seen that lug shearout is the critical load path. Failure of said device under excessive load would not impair the ability of this package to meet other requirements of 10 CFR 71, per the requirements of 10 CFR 71.45(a).

2.5.2 Tiedown Devices

There are no tiedown devices which are a structural part of the package. Per drawing X-60-200D, flagnote 9 (Appendix 1.3), the lift lugs are labeled 'Do not use for tiedown' and will be rendered inoperable for tiedown per Section 7.1. The requirement of 10 CFR 71.45(b)(2) is therefore satisfied.

2.6 Normal Conditions of Transport

The N-55 Packaging has been designed and constructed, and the contents are so limited (as described in Section 1.2.3, above) that the conditions and tests specified in 10 CFR 71.71 meet the standards specified in 10 CFR 71.43 and 71.51. The ability of the N-55 Packaging to satisfactorily withstand the normal conditions of transport has been assessed and is described below.

2.6.1 Heat

A detailed thermal analysis can be found in Section 3.4 wherein the package was exposed to direct sunlight and 100°F still, ambient air. The steady state heat transfer analysis conservatively assumed a 24 hour day maximum solar heat load. A summary of the temperatures at key locations is provided below:

Location	Maximum Temperature (°F)
Outer Shell	153.8
Inner Shell	161.5
55 gal drum	161.9
Payload	161.9

The internal pressure within the 55 gallon drum may be found utilizing the ideal gas law from thermodynamics. Conservatively assume a static loading temperature of -40°F, and a steady state payload temperature of 161.9°F which totals a 201.9°F change in temperature. Assuming air, the change in internal pressure may be found to be:

$$P_1V_1/T_1 = P_2V_2/T_2$$

Assuming a constant volume, the equation reduces to:

$$P_1/P_2 = T_1/T_2$$

$$P_2 = (14.7 \text{ psia})[(201.9 + 459.69)/(-40 + 459.69)]$$

$$= 23.2 \text{ psia} = 8.5 \text{ psig}$$

Since the pressure due to the rise in temperature within the drum is small (at a minimum, the Specification 17H drum is pressure tested to 15 psig per 49 CFR 178.118), stresses due to thermal effects may be considered negligible.

2.6.2 Cold

The effects of a steady-state temperature of -40°F are considered to be negligible due to the materials of construction. All ferric steel components (i.e., the outer shell, 55 gallon drum, etc.) are thin sections (less than 3/16 inch) and constitute no concern from a brittle fracture standpoint (per Section 5.2.3 of NUREG/CR-1815, Recommendations For Protecting Against Failure By Brittle Fracture in Ferritic Steel Shipping Containers Up To Four Inches Thick, for Category II fracture toughness). All other materials of construction are relatively insensitive to the reduced temperature, including the effects of brittle fracture. The package contains no fluids which could freeze and expand such as water.

2.6.3 Reduced External Pressure

As discussed in Section 1.2.1, the overpack is not intended to resist either internal or external pressures. A weather seal located along the package lid/body interface is designed to minimize the entrance of external environmental elements such as rain, dust, etc. In addition, the overpack is designed to vent internal pressure.

The steel, 55 gallon containers are required to be DOT Specification 17C or 17H drums, meeting the requirements delineated in 49 CFR 178.115 and 49 CFR 173.118, respectively. As such, these drums are required to be hydrostatically tested to 20 psig (17C) and 15 psig (17H) internal pressure. Therefore, it may be concluded that the system will adequately resist a reduced external pressure of 3.5 psia (11.2 psig internal pressure) per the requirements of 10 CFR 71.71(c)(3).

2.6.4 Increased External Pressure

The requirement for an increased external pressure of 20.0 psia (5.3 psig) is less stringent than that for the reduced external pressure previously discussed. Although the margin of safety for stresses will be higher than the previous case, the application of an external pressure does create the possibility of shell buckling. This failure mode is presented as Case 20 of Table 35, Roark and Young, Formulas for Stress and Strain, 5th edition, for a simple closed cylinder with lateral and longitudinal external pressure.

$$q' = E(t/r)\{[1/n(1 + u^{-1})]^2 + [(nt/r)(1 + u)]^2/12(1 - \mu^2)\}/(1 + u/2)$$

Where:
n = number of lobes formed by the buckling tube (2,3,4,5...)

E = 30.0(10)6 psi (Young's Modulus for carbon steel)

t = 0.0478 in (for 18 gauge steel)

r = 11.25 in

μ= 0.3 (Poisson's Ratio for carbon steel)

$u = (\pi r/nl)^2$

l = 12.0 in (maximum distance between rolled-in hoops)

The solution process is iterative, starting with a value of n=2, the minimum number of lobes for tube buckling, and solving for the critical tube buckling pressure, q'. A solution is realized when the minimum value for q' is found.

n	q' (psi)
2	7,166.5
3	2,307.0
4	780.9
5	296.5
6	129.6
7	67.2
8	42.9
9	33.8
>> 10	31.6 <<
11	32.8

Thus, it is readily apparent that shell buckling will not occur.

2.6.5 Vibration

Due to the low aspect ratio of this package and the good energy absorbing characteristics of the overpack foam, shock and vibration normally incident during transportation, are considered to have negligible effects upon the N-55 Packaging.

2.6.6 Water Spray

Since the N-55 Packaging is constructed of galvanized and plated steel, water spray would have a negligible effect upon this package.

2.6.7 Free Drop

The N-55 Packaging has a maximum gross weight of 750 pounds. The required free drop of four (4) feet per 10 CFR 71.71(c)(7) is substantially less than the thirty (30) foot drop requirement of Section 2.7. Since the drop testing discussed in Section 2.7 demonstrated package survivability at any angle of drop, a four foot free drop will have negligible effects upon this package.

2.6.8 Corner Drop

The corner drop requirement is not applicable since the N-55 Packaging is fabricated of steel.

2.6.9 Compression

It is the requirement of 10 CFR 71.71(c)(9) that the package resist five (5) times it's weight in direct compression. The effective pressure loading in the polyurethane foam (side of the package) is:

$$p = 5W/A = 5(750)/\pi[(16.0)^2 - (12.5)^2] = 11.97 \text{ psi}$$

Since the polyurethane foam has a nominal compressive strength of 50 psi, compressive loads equal to five times the package weight will have negligible effects.

2.6.10 Penetration

Since it has been demonstrated by test in Section 2.7.2 that a one meter drop onto a six inch diameter puncture pin is inconsequential, the impact of a 13 pound steel rod onto the package exterior will have negligible effects.

2.7 Hypothetical Accident Conditions

The N-55 Packaging has been designed and constructed, and the contents are so limited (as described in Section 1.2.3), that the performance requirements specified in Subpart E of 10 CFR 71 will be met when the package is subjected to the hypothetical accident conditions specified in 10 CFR 71.73. The ability of the N-55 Packaging to satisfactorily withstand the hypothetical accident conditions has been assessed through the use of full scale testing as described below.

2.7.1 Free Drop

Two series of full scale tests were performed to demonstrate package structural integrity. The first series consisted of four tests, three free drops from thirty (30) feet and one 40 inch puncture drop. The tests were performed on a single prototypic N-55 package. Two modifications to the geometry were implemented and three additional 30 foot drop tests were then performed using a newly fabricated N-55.

For the first test series, a full size N-55 overpack was fabricated and the weight was measured to be 180 pounds. A Specification 17H, 55 gallon drum, was filled with sand to a weight of 570 pounds, thereby assuring a gross test weight of 750 pounds. The drum's lid was installed and pressure tested with air to 10 psig. No leaks were noted. The drum was installed into the N-55 overpack body (lower half), followed by the N-55 overpack lid. The four toggle-latches were secured for testing. Below is a summary of the drop orientations and corresponding results. Drop test photos may be found in Appendix 2.10.2.

2.7.1.1 Drop 1 - Lid-End Corner Drop from 30 Feet

The N-55 Packaging was raised to a height of 30 feet above the test pad (see photo P-1, Appendix 2.10.2) and released with an orientation that would provide a corner impact directly over the drum's bolt ring. The angle of impact was set to the c.g. (center of gravity) directly over the impacted corner, i.e., approximately 56.3° from horizontal.

Upon impact, the N-55 overpack crushed to a depth of approximately 8.0 inches as shown in photo P-2. All latches remained firmly intact with no indication of yielding.

2.7.1.2 Drop 2 - Bottom-End Corner Drop from 30 Feet

Following the first test, the N-55 Packaging was reconnected to the quick-release mechanism, positioned so as to impact upon the corner diagonally opposite that impacted in the first test, raised to a height of 30 feet, and released. Upon impact, the N-55 overpack crushed to a depth of approximately 4.5 inches as shown in photos P-2 and P-3. As before, all latches remained firmly intact with no evidence of yielding.

2.7.1.3 Drop 3 - Side Drop from 30 Feet

The N-55 Packaging was again reconnected to the quick-release mechanism, raised to a height of 30 feet, and released in a side impact orientation directly over one of the four latches.

Upon impact, the overpack locally flattened to a depth of approximately 0.75 inches. All latches, including the one receiving the direct impact, remained fully locked.

2.7.1.4 Summary of Results

Since the closure ring end of the drum is more fragile than the formed end, it was protected with a greater foam thickness. This provides increased stopping distance which is directly related to impact acceleration and loads. The difference in crush depth then can be related to impact protection.

Following the 40 inch puncture test (refer to Section 2.7.2), the N-55 overpack was opened for inspection. All four latches worked smoothly. The lid and drum were removed for inspection. As can be seen from photos P-5, P-6, P-8, and P-10, the drum experienced only minor deformations. An examination of the fiberglass liner likewise indicated only minor deformations as shown in photos P-7 and P-9. A few small cracks in the side wall were noted which resulted from the side drop test.

Since deformation to the drum was minimal, there was no loss of the sand payload. A subsequent pneumatic pressure test at 10 psig for twenty-four (24) hours, however, indicated a leak. Further investigation traced the small air leak to the area of the bolt ring.

Subsequent 30 foot drop tests were conducted in 1988 (see Appendices 2.10.3 and 2.10.4). These tests were performed in an essentially identical manner as the first tests, but with two changes to the N-55 Packaging. The first change involved recessing the inside ends of the N-55 overpack to prevent the rims of the drum from directly contacting the inner shell of the overpack. The effects of testing with and without this feature are illustrated in Figure 2.7-1. The second change was the replacement of a two inch thick piece of paper honeycomb on the lid end of the overpack with basic foam. This was done in order to simplify construction and improve the lateral shear capability of the overpack.

The N-55 overpack deformations were nearly identical to those found in the previous tests. The only significant variation was the reduction in damage to the fiberglass liner and drum. The liner showed no indication of cracking at the drum ends, and because the deformation in the drum was significantly less than before, it was able to pass a soap bubble leak test with no indication of leakage.

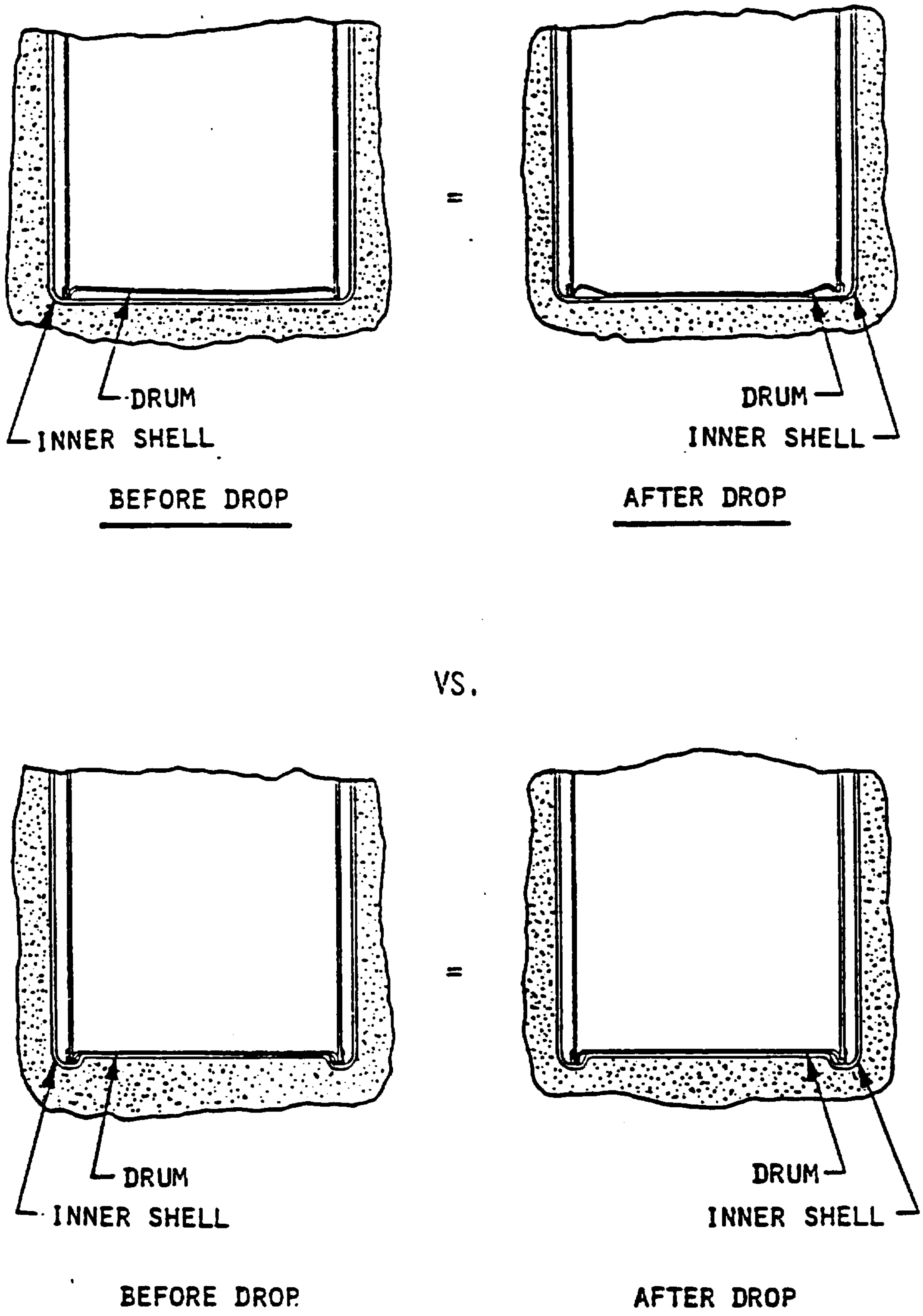
Therefore, it is concluded that addition of the groove (recessed inside ends) and removal of the paper honeycomb improves the package performance. Packages manufactured after March, 1981, incorporate this revision.

2.7.2 Puncture

A 40 inch drop onto a 6.0 inch diameter puncture pin produced a local indentation in the N-55 overpack of approximately 1.0 inch (see photos P-3 and P-4, Appendix 2.10.2). Examination of the drum indicated no apparent effects from the drop. Therefore, it can be concluded that the drum experienced no detrimental effects from the puncture test.

The 40 inch drop in the second series of tests (see Appendices 2.10.3 and 2.10.4) also produced no serious damage from the drop. This test, however, was executed on the previously damaged side of the package, and as a result, drum deformation from this impact was observed for this test. Nevertheless, the drum successfully passed a soap bubble leak test following the drop test.

FIGURE 2.7-1
Effects of N-55 Fiberglass Liner Modifications



2.7.3 Thermal

A detailed thermal analysis can be found in Section 3.5 wherein the package was exposed to 100°F still, ambient air as a pre-fire condition for the hypothetical accident fire scenario. A summary of the temperatures at key locations for this condition is provided below:

Location	Maximum Temperature (°F)
Outer Shell	100.2
Inner Shell	108.0
55 gal drum	108.5
Payload	108.5

The corresponding maximum transient temperatures are presented in the following table:

Location	Maximum Temperature (°F)
Outer Shell	1,471.8
Inner Shell	135.3
55 gal drum	117.4[1]
Payload	117.4[1]

1. Rising at a rate less than 0.03°F/hour.

Since maximum temperature within the package does not exceed that presented in Section 2.6.1 for normal conditions of transport, the pressure rise and stresses due to thermal effects may be considered negligible.

2.7.4 Immersion - Fissile Material

Immersion of the N-55 Packaging under water to a depth of 3 feet per 10 CFR 71.73(c)(4) will have negligible effects.

2.7.5 Immersion - All Packages

The effect of a 21 psig external pressure due to immersion in 50 feet of water as required by 10 CFR 71.73(c)(5) is of small consequence for the N-55 Packaging. From Section 2.6.4, the external pressure required to collapse the drum is 31.6 psig. Therefore, immersion to a depth of 50 feet in water will present no detrimental effect.

2.7.6 Summary of Damage

As determined by testing, only localized crushing of the N-55 overpack was present and is only of consequence for determining thermal properties. As such, the damage was modeled in the Section 3.0, thermal analysis.

As a result of the above assessments, it is concluded that should the N-55 Packaging be subjected to the hypothetical accident conditions, no radioactive material would be released into the environment.

2.8 Special Form

Since special form material is not claimed within this application, this section is not applicable.

2.9 Fuel Rods

Since the N-55 Packaging is not designed to transport fuel rods, this section is not applicable.

2.10 Appendix

2.10.1 Data Sheet - Toggle Clamps

2.10.2 Drop Test Photos

2.10.3 Supplemental Drop Test Program

2.10.4 Supplemental Drop Test Procedure Excerpts, DT-0018-NP

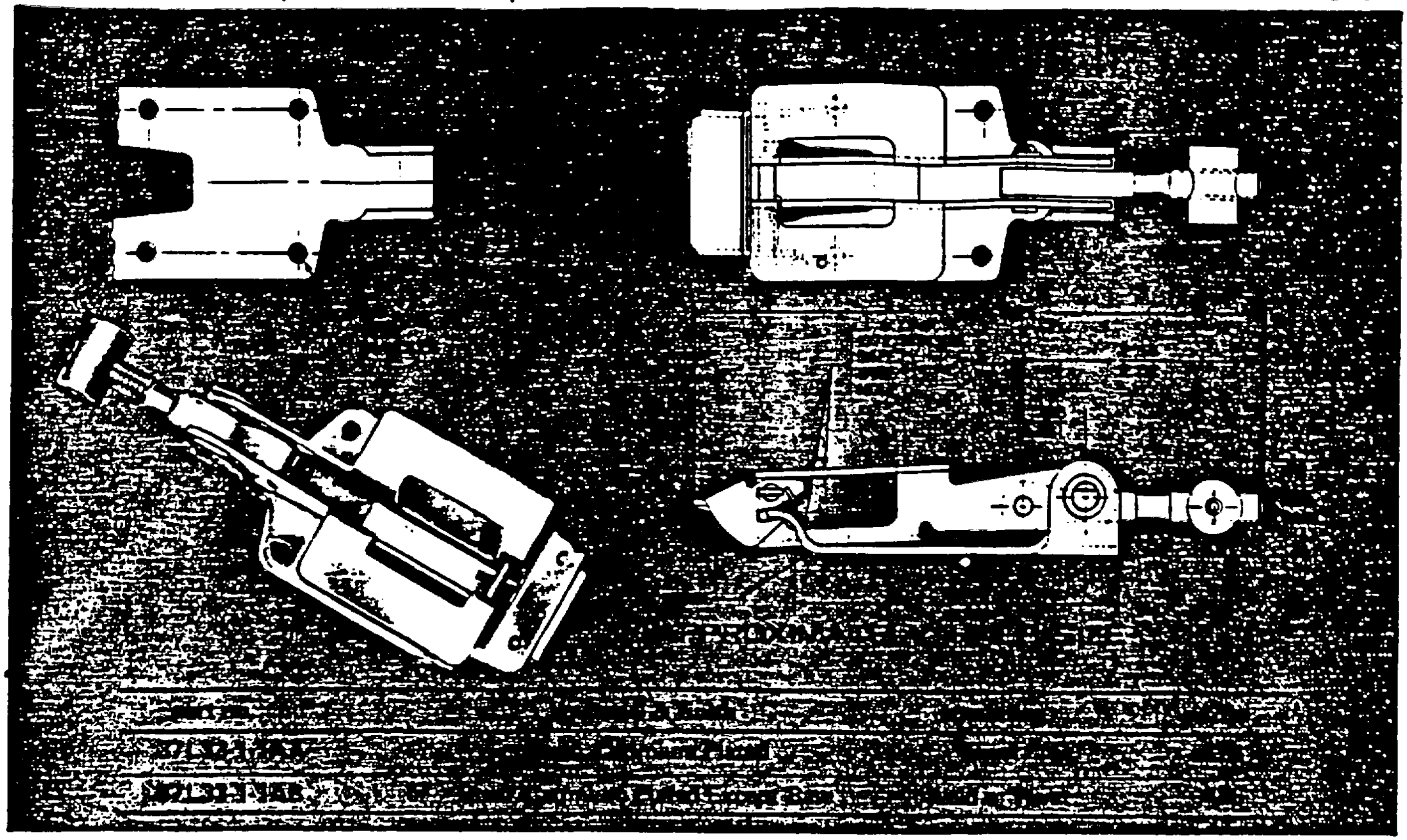
Appendix 2.10.1

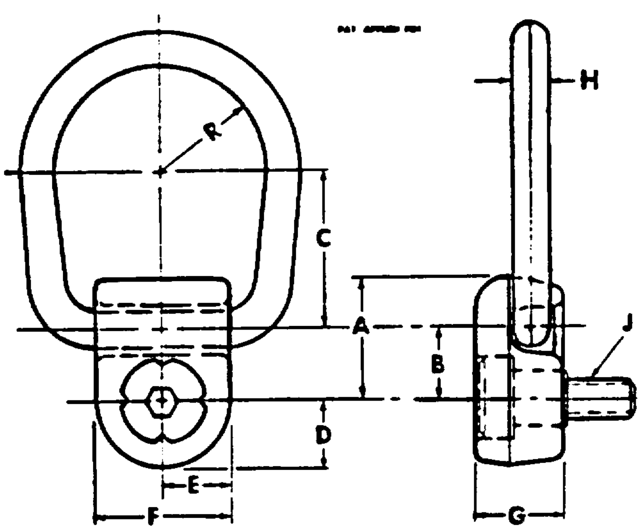
Data Sheet - Toggle Clamps

SECONDARY LOCK

SHORT HANDLE, STEEL BASE, RIVET MOUNTING

4500 LBS ULTIMATE STRENGTH
3000 LBS WORKING STRENGTH





SAFETY HOIST RINGS . . . Forged alloy base block actuates 360° while the forged alloy lift ring pivots 180° in the base slot which is off center, allowing the ring to be solid construction and assuring the base block rotating in the direction of the applied load.

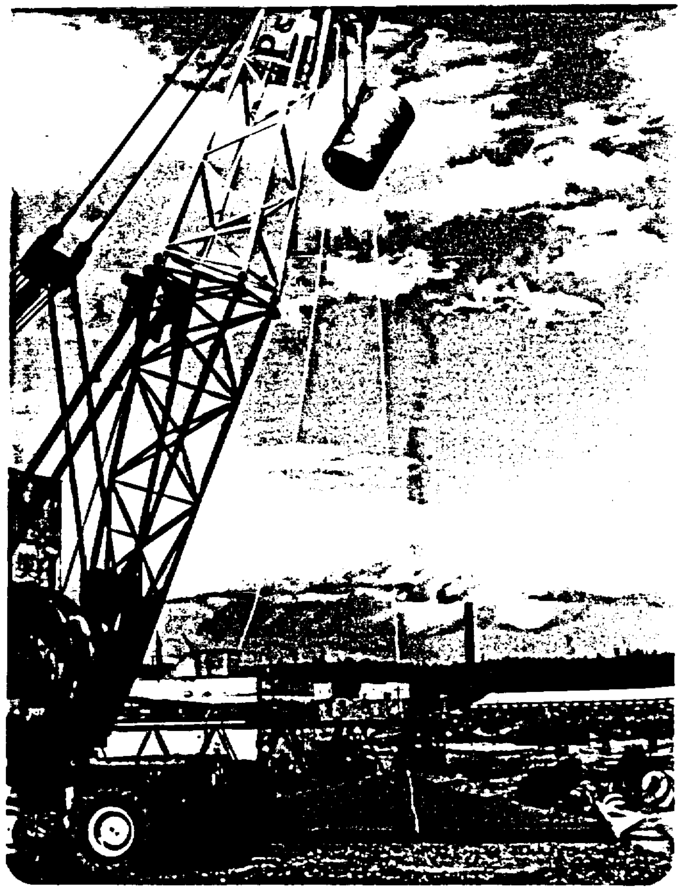
ALLOY STEEL, HEATED AND CERTIFIED TO MIL-1-6868

Part No.	A	B	C	D	E	F	G	H	J	R
CL-10-SHR	1-1/8	5/8	1-1/2	5/8	5/8	1-1/4	13/16	5/16	3/8-16 TH'D.-5/8 LG.	13/16
CL-25-SHR	1-5/8	7/8	1-7/8	7/8	7/8	1-3/4	1-1/4	7/16	5/8-11 TH'D.-7/8 LG.	1-1/8
CL-50-SHR	2-3/16	1-1/8	2-3/4	1"	1"	2	1-11/16	5/8	3/4-10 TH'D.- 1" LG	1-3/8

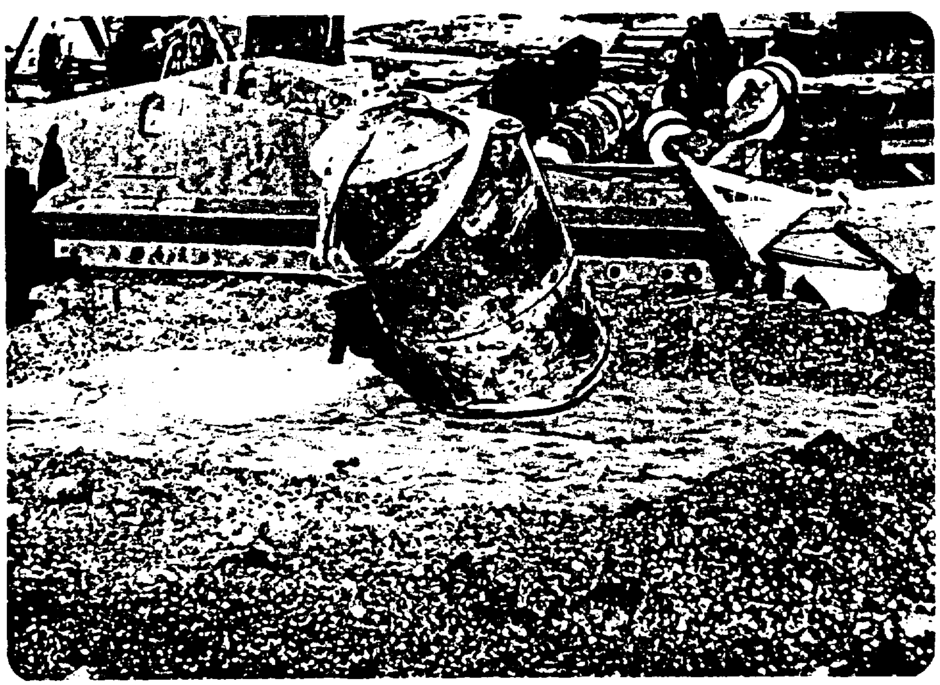
Carr Lane®

MANUFACTURING CO.
4200 Krause Court • St. Louis, Mo. 63119

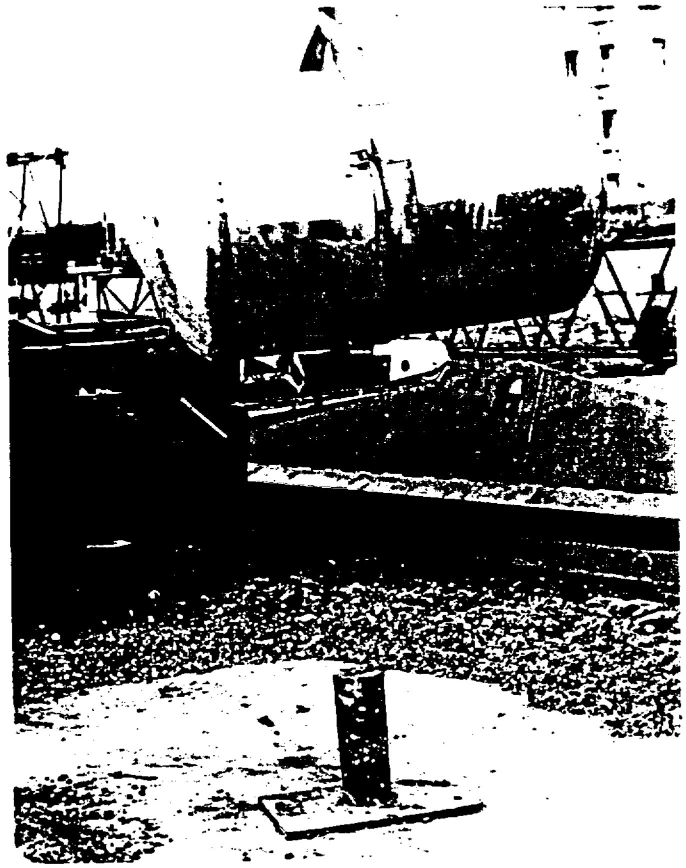
Appendix 2.10.2
Drop Test Photos



P-1
30 Foot Drop



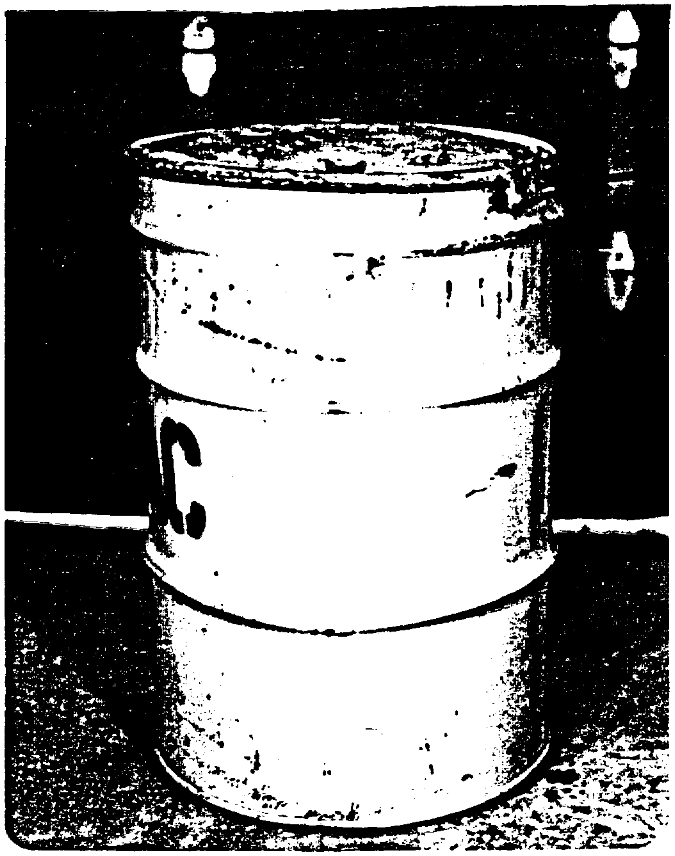
P-2 - Second 30 Foot Drop



P-3
Pin Drop

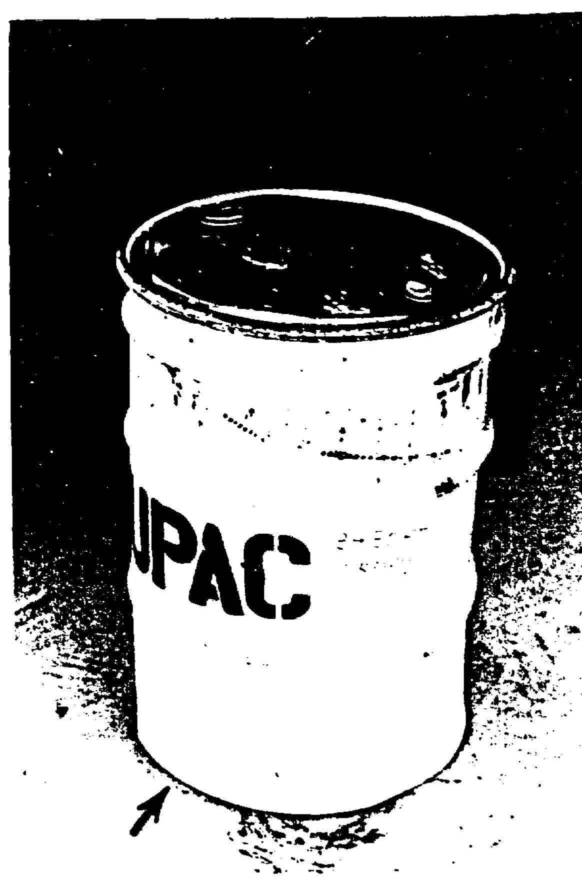
30 Foot Side
Drop Impact Area

P-4
40" Puncture
Drop Test

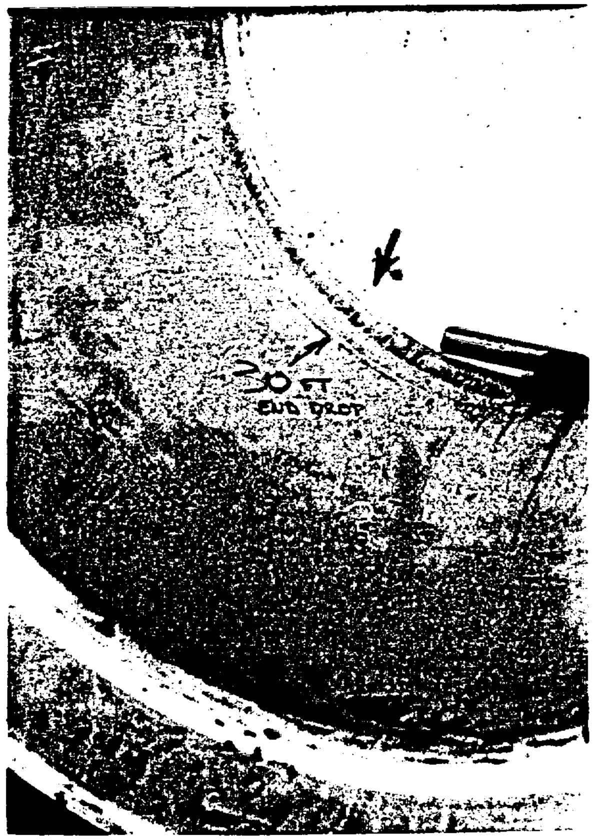


First 30 Foot
Corner Drop

P-5
17H Drum after
three 30 Foot Drops



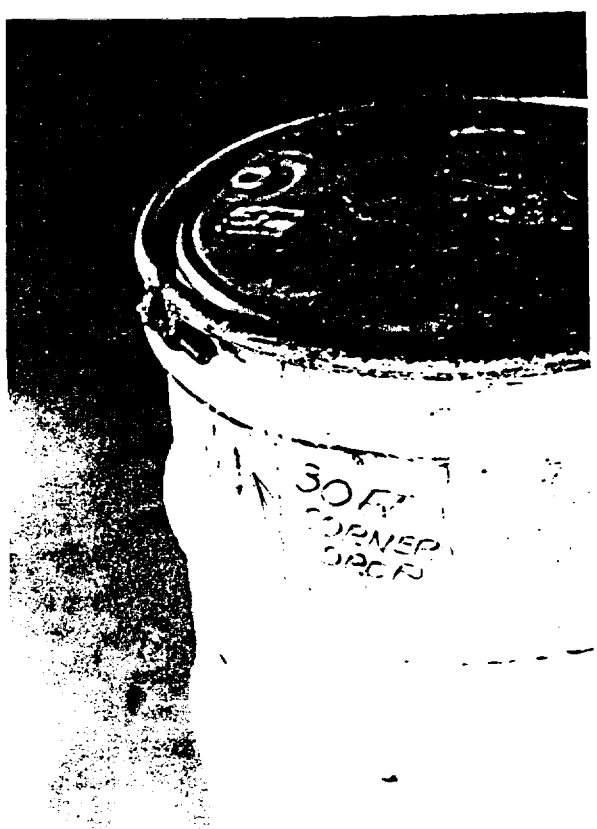
P-6
Second 30 Foot
Corner Drop



P-7

Inner Fiberglass Shel

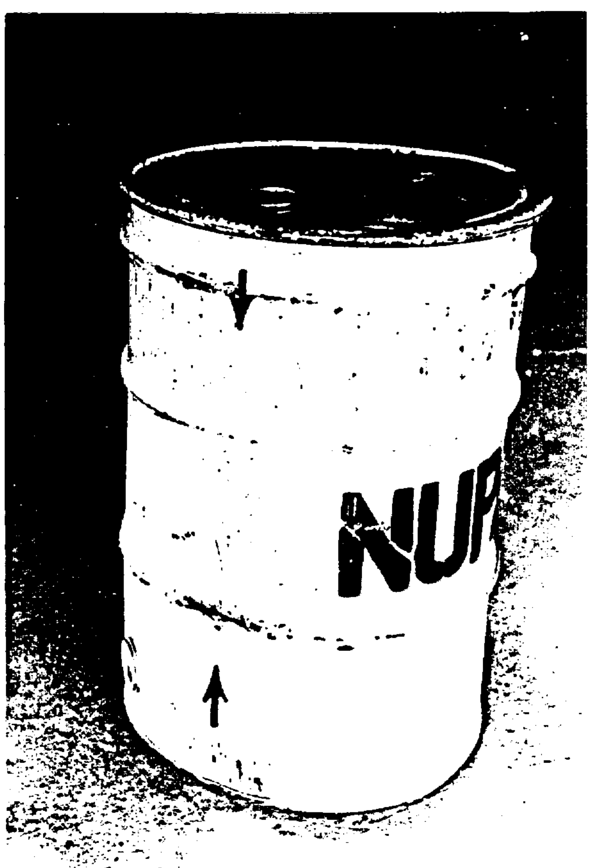
30 Foot Corner Drop Produced No Damage to Shell



P-8

Point of Impact for 30 Foot Corner Drop

P-9
Inner Fiberglass Shel
Showing effects of 30
Foot Side Drop



P-10
17H Drum Showing
Area of 30 Foot Side
Drop

Appendix 2.10.3
Supplemental Drop Test Program

2.10.3.1 Introduction

The NuPac N-55 packaging system has been subjected to several drop tests in addition to the tests performed to support the initial license application. For example, as part of a revision to the original application, several changes were made to the package to render it more economical to fabricate. These minor changes were tested in conjunction with a new, optional containment system. However, when equipped with the optional containment system, the total weight of the package including payload was considerably less than the licensed weight, rendering the test series inapplicable to a fully loaded N-55. Although NuPac had previoulsy performed a drop test of a fully loaded N-55 which did include the minor changes and did result in satisfactory performance, results of that test were never included in the license applicaiton.

As a means of clearing up any confusion relative to past testing, providing a justification for further economies in fabrication, and fully addressing performance issures raised by other tests*, a new series of drop test was performed to demonstrate package saftey. These tests were performed in accordance with NuPac procedure DT-00018-NP, included herein as Appendix 2.10.4. The test included three 30-foot drop tests (one corner drop on each end plus one side drop directly onto a latch) and one 40-inch drop onto a 6-inch diameter mild steel post, impacting the same latch previoulsy struck in the 30-foot side drop test.

To fully verify the packaging's ability to protect the 55-gallon drum containment boundry, soap bubble leak tests were preformed before and after the drop test series and no leaks were observed. As a result, these tests have fully demonstrated the N-55's ability to withstand the effects of the hypothetical accident drop events in a satisfactory manner.

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* For example, during tests of the much heavier NuPac PAS-2 system designed around the current N-55, the 55 gallon drum developed a through crack. Since the drum does not form a containment boundry in the PAS-2 system, the crack was considered acceptable; but such a crack would not be acceptable in the NuPac N-55 system.

2.10.3.2 Test Preparation

As stated above, the drop tests were performed per the requirements of procedure DT-0018-NP (Appendix 2.10.4 herein). The 55-gallon drum was fitted with two pipe thread flanges in the drum lid, and was filled with sand until the combined weight of the drum and the N-55 was slightly greater than 750 pounds. Then, the lid was placed on the drum and clamped in place using the normal clamp ring method of closing such a drum. The drum was pressurized to 1 psig and leak-detecting soap solution was applied to the cover-drum interface. No leaks were observed.

After the leak test, the pressurization equipment was removed from the drum and replaced with pipe plugs. The drum was placed inside the N-55, and the N-55 upper section placed over the package. The cam-lock devices were secured using the following method: First, the devices were adjusted to pull the upper section down tightly to the lower section of the package. Then, the adjustable T-bar was readjusted to a point such that when the device was secured, the T-bar just contacted the latch on the upper section. All four closure devices were adjusted in this manner, closed, and inspected to assure that all devices were set to this criteria. Then, each device was opened and each T-bar was rotated four complete rotations in the clockwise direction. Finally, all four devices were closed, assuring a tight, secure, closure.

2.10.3.3 Testing

The supplementary drop testing was performed on October 7, 1988, at NuPac's drop test pad in Tacoma, Washington, the same pad where all other N-55 tests had been performed. The tests were carefully videotaped, and photos summarizing the testing are included as section 2.10.3.6 below.

2.10.3.4 Results

Top-end Corner Impact from 30 Feet

The first drop occurred on the top end corner, approximately at the longitudinal seam of the N-55. The impact caused seven rivets along the seam to release, as well as one around the closure plane. All closure devices held firm. Because of the long, 3/4 inch overlap in the circumferential steel, no significant amount of foam was exposed as a result of the damage.

After all testing was completed and the package disassembled, the interior fiberglass liner of the N-55 was inspected. There was no significant damage to the liner as a result of this drop.

Bottom-end Corner Impact from 30 Feet

This impact was performed on a part of the package not broken by a longitudinal seam. For this impact, no additional rivets released, and no closure devices became loose in any way. Again, an inspection after the testing revealed that no significant damage to the liner occurred as a result of this impact.

Side Impact from 30 Feet

The package was dropped so that one of the latches was directly in the center of the impact zone. The drop flattened the side as much as two inches, but did not cause any of the latches or rivets to release, including the latch crushed by the impact.

Side impact onto 6-Inch Diameter Post from 40 Inches

The package was dropped so that the impact between the package and the post occurred directly on the latch in the center of the area previously damaged by the side impact from 30 feet. This last impact, onto a previously damaged latch, had not been previously performed in any of the preceding drop test programs.

The only damage of significance from this impact was the failure of the rivets securing the upper section of the impacted latch, rendering this closure device ineffective. However, none of the remaining three (3) latches were affected in any way. An examination of the package after disassembly revealed that the fiberglass liner crushed at the closure interface directly between the post impact point and the payload. The damage to the package was limited such that there was no significant opening of the joint between the upper and lower sections of the N-55.

After this final test, the package was taken to a warehouse and disassembled. A second soap bubble leak test was performed on the drum, and no leaks were found.

2.10.3.5 Conclusions

None of the tests performed on the N-55 packaging system caused damage to the system which would compromise its ability to successfully survive the subsequent hypothetical accident events required by 10 CFR 71. Further, even though the contents of the package are restricted to non-particulate solids, the drum containment boundary was demonstrated by a soap bubble leak test to remain sealed after the rigorous series of 4 drop tests. Thus, the N-55 has been demonstrated to satisfactorily withstand the effects of both a 30-foot drop onto an unyielding surface, as well as a 40-inch drop onto a 6-inch diameter post. Further, damage to this package was not significantly different from the damage observed from earlier tests on other N-55 packages.

2.10.3.6 Photographs

Photo 1: Impact of first drop
Photo 2: Damage from first drop
Photo 3: Impact of second drop
Photo 4: Damage from second drop
Photo 5: Impact of third drop
Photo 6: Damage from third drop
Photo 7: Impact from last drop
Photo 8: Damaged latch, last drop
Photo 9: Liner damage, last drop

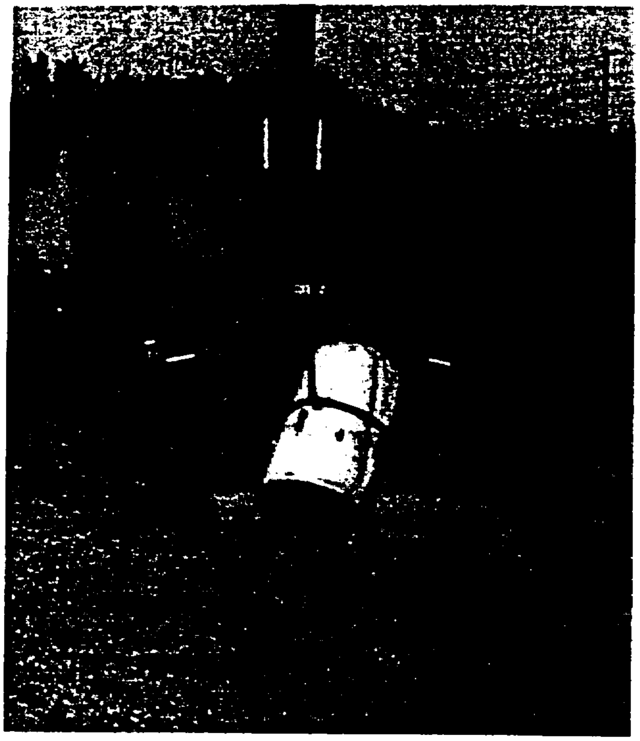


Photo 1

Photo 2

Photo 3

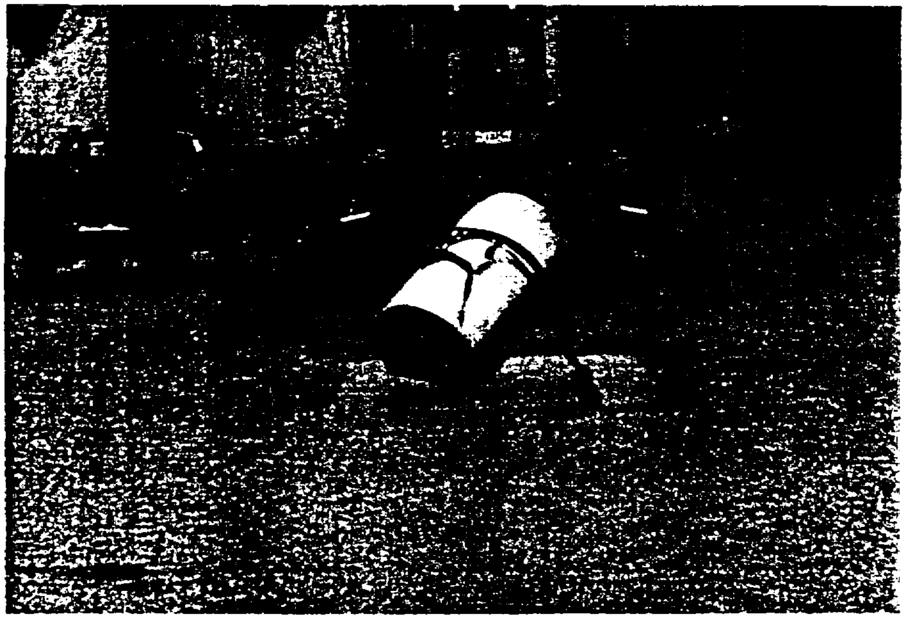
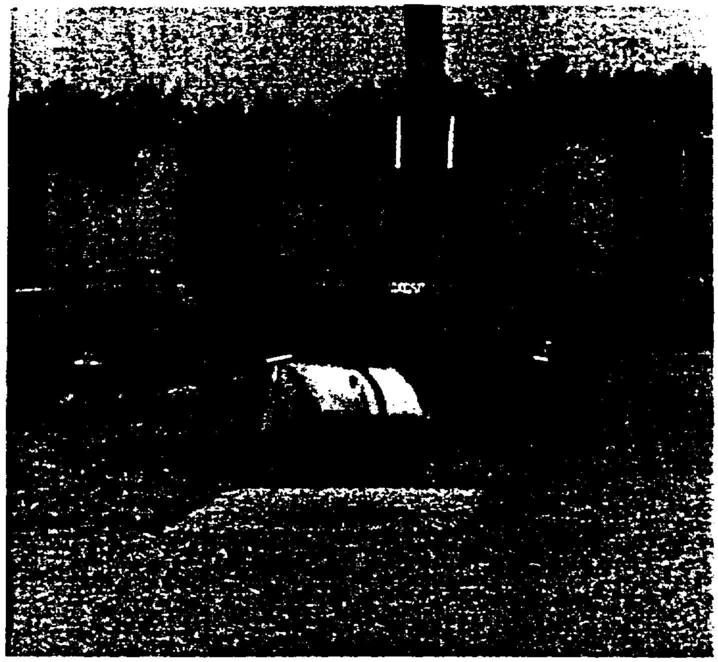


Photo 4

Photo 5



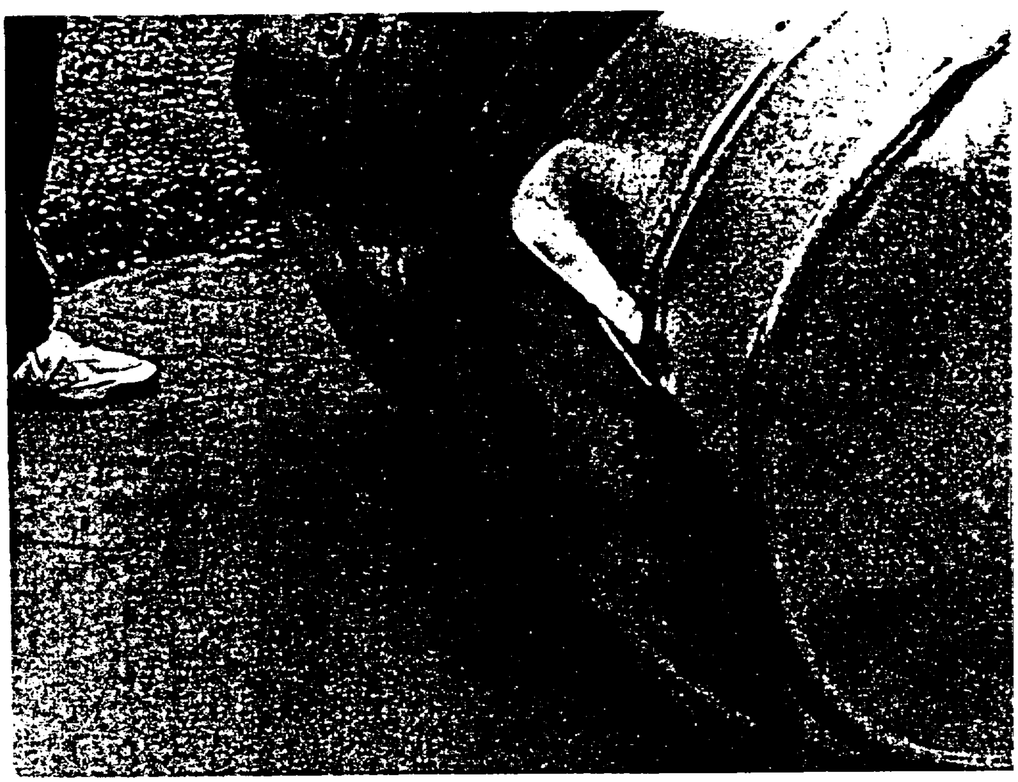


Photo 6

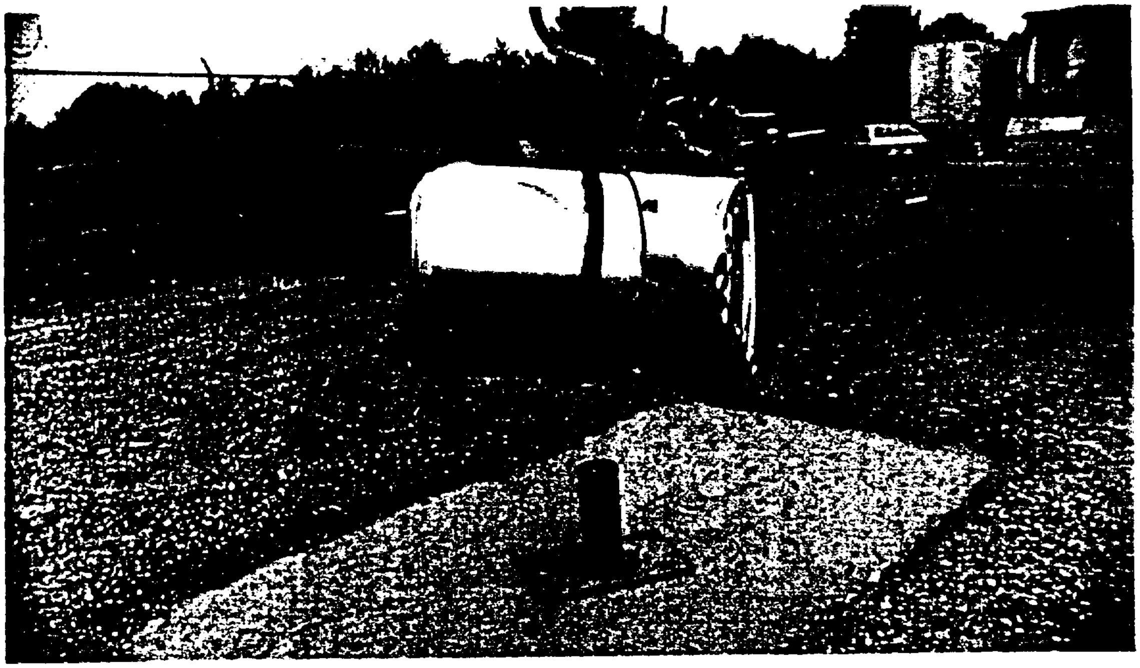


Photo 7

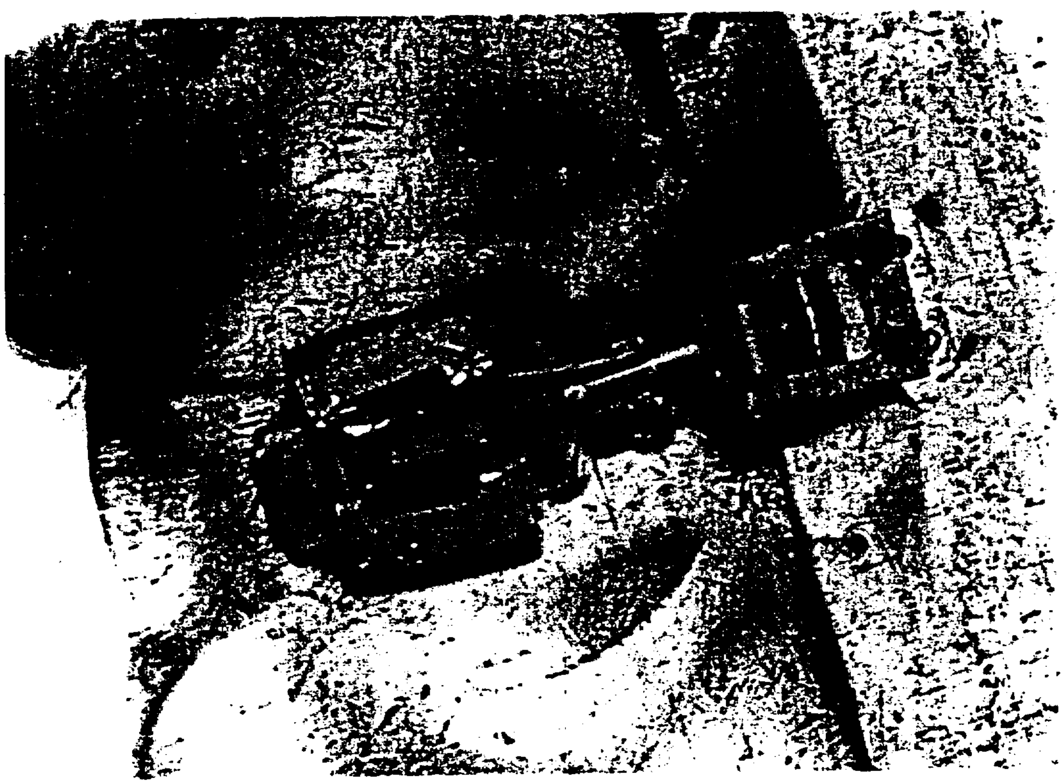


Photo 8

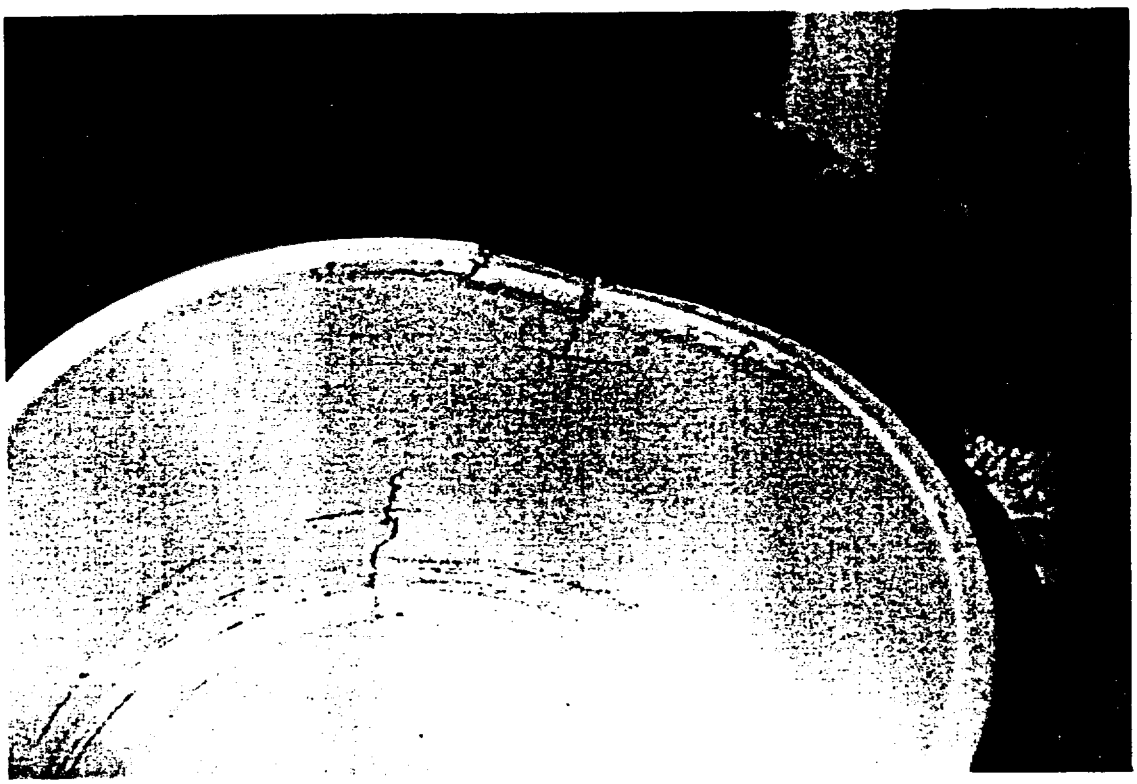


Photo 9

Appendix 2.10.4

Supplemental Drop Test Procedure Excerpts, DT-0018-NP

1.0 SCOPE

This procedure describes the procedure for performing certain supplemental drop tests to be performed on the NuPac N-55 packaging system. These tests are designed to demonstrate that the minor design changes made to the packaging since its initial licensing have resulted in identical or improved performance over that observed in the original drop test series.

2.0 REFERENCE DOCUMENTS

2.1 United States Code of Federal Regulations Title 10, Part 71.

2.2 Safety Analysis Report on the NuPac N-55 Packaging System, Rev. 2.

2.3 Drawing X-60-200D, NuPac N-55 Type B Overpack.

2.4 NPQ 038 Drop Test Data Sheet and Check List.

2.5 NPQ 038A Drop Test Damage Record.

2.6 NuPac Procedure LT-04, Soap Bubble Leak Test.

2.7 QP-5 Quality Planning

2.8 QP-6 Inspection and Verification

2.9 QP-7 Discrepancy Reporting and Control

3.0 REQUIRED EQUIPMENT

3.1 NuPac N-55.

3.2 ICC 17H 55-gallon drum.

3.3 Approximately 490 lbs. of sand and water to be used as payload weight.

3.4 Mobile crane capable of lifting and releasing 1000 lbs. without damaging itself. Hook must be capable of being raised to a height of 45 feet. It is suggested that a crane rated at least 10 tons be employed.

3.5 NuPac Drop Test Pad.

3.6 35-mm camera and film.

3.7 Video Camera and recorder, VHS type.

3.8 Quick Release Load Drop mechanism, rated in excess of 1 ton.

3.9 Six Inch Diameter Mild Steel Post with stand, per Ref. 2.1.

3.10 Appropriate rigging as required (e.g., nylon straps and shackles)

4.0 DROP TEST PROCEDURE

4.1 Test Preparation

4.1.1 Prepare four NPQ 038 forms for use in recording data verifying proper execution of this test procedure.

4.1.2 Place the bottom half of the N-55 on a strong pallet, and place the 55-gallon drum in the bottom half of the N-55 packaging.

4.1.3 Fill the 55-gallon drum with at least 490 lbs. of wet sand. Install the drum cover.

4.1.4 Perform a soap bubble leak test per the requirements of Ref. 2.6 on the drum cover.

4.1.5 Place the upper half of the N-55 onto the lower half of the N-55 and secure per the requirements of Chapter 7 of Ref. 2.2.

4.1.6 Verify that the N-55 as assembled weighs at least 750 lbs.

4.1.7 Photograph the assembled N-55 from all sides.

4.1.8 Transport the N-55 to the NuPac Drop Test Pad.

4.1.9 Complete Items 1 through 5 on the first NPQ 038 form.

4.2 30-foot Drop Test onto Package Top Corner

4.2.1 Using choker techniques, carefully invert the N-55 packaging so that the top surface of the package is on thg ground (upside down).

4.2.2 Attach a length of string to the package at a point on the top corner (which is now near the ground) of the package. The free end of the string shall be tied to a small flat washer, so that the washer hangs 30 feet below the lowest point on the package when the package is lifted in the orientation described in 4.2.3 below. The purpose of the string is to indicate when the package has been lifted to the proper height above the ground prior to release of the package.

4.2.3 Using choke-style techniques, rig the package to a shackle in the quick release mechanism, and attach the quick-release to the crane hook. The package should be rigged such that the string on the upper half of the N-55 (now inverted) is at the lowest point on the package when the package is hanging from the rigging. Also, the package should be rigged such that the axis of the package is 33 to 38 degrees from vertical. Finally, the package should be rigged so that the impact will strike the package approximately 120 degrees around the axis of the package from one of the package latches.

4.2.4 Raise and position the package 30 feet above the pad, using the string and washer to indicate the height and target positioning.

4.2.5 Photograph the package such that the drop orientation can be clearly seen. Set up video camera equipment in a position to clearly view the impact as it occurs. Begin videotaping.

4.2.6 Clear the drop area for at least 40 feet around the impact point.

4.2.7 Complete Items 6 through 12 of first Form NPQ 038.

4.2.8 Release the package.

4.2.9 Photograph and videotape the package from several relevant directions, with a special emphasis on the impact zone.

4.2.10 Complete Items 13 through 15 on the first NPQ 038 form, and the Exterior Damage section of the first NPQ 038A form (on the reverse of NPQ 038).

4.3 30-Foot Drop Test onto Package Bottom Corner

4.3.1 Using choker rigging techniques, carefully place the package in its upright position.

4.3.2 As far as practical, return the package to its condition prior to the first drop. Replace any parts which may have separated from the package, and close any latches which may have opened. Carefully note all items which were altered as a result of this step.

4.3.3 Attach a length of string to the package at a point on the bottom corner of the package. The free end of the string shall be tied to a small flat washer, so that the washer hangs 30 feet below the lowest point on the package when the package is lifted in the orientation described in 4.3.4 below. The purpose of the string is to indicate when the package has been lifted to the proper height above the ground prior to release of the package.

4.3.4 Using choke-style techniques, rig the package to a shackle in the quick release mechanism, and attach the quick-release to the crane hook. The package should be rigged such that the string on the bottom of the N-55 is at the lowest point on the package when the package is hanging from the rigging. Also, the package should be rigged such that the axis of the package is 33 to 38 degrees from vertical, and the package should strike the surface approximately 120^{o} around the package axis from the site of the first drop, and approximately 120^{o} around the axis from the package latch referenced for orienting the first drop.

4.3.5 Raise and position the package 30 feet above the pad, using the string and washer to indicate the height and target positioning.

4.3.6 Photograph the package such that the drop orientation can be clearly seen. Set up video camera equipment in a position to clearly view the impact as it occurs. Begin videotaping.

4.3.7 Clear the drop area for at least 40 feet around the impact point.

4.3.8 Complete Items 6 through 12 of the second NPQ 038 Form. Mark Items 1 through 5 as N/A.

4.3.9 Release the package.

4.3.10 Photograph and videotape the package from several relevant directions, with a special emphasis on the impact zone.

4.3.11 Complete Items 13 through 15 on the second NPQ 038 form, and the Exterior Damage section of the second NPQ 038A Form (on the reverse of NPQ 038).

4.4 30 Foot Drop onto the Package Side

4.4.1 Using appropriate means, carefully place the package on its side, such that the lowest point on the package is a point approximately 120 degrees around the axis of the package from the locations of the first two drops.

4.4.2 As far as practical, return the package to its condition prior to the first drop. Replace any parts which may have separated from the package, and close any latches which may have opened. Carefully note all items which were altered as a result of this step.

4.4.3 Attach a length of string to the center of the package at the lowest point of the package. The free end of the string shall be tied to a small flat washer, so that the washer hangs 30 feet below the lowest point on the package when the package is lifted in the orientation described in 4.4.4 below. The purpose of the string is to indicate when the package has been lifted to the proper height above the ground prior to release of the package.

4.4.4 Using basket-style techniques, rig the package (such that the package axis is horizontal and the lowest point of the package is approximately 120° around the axis from the locations of the first two drops) to a shackle in the quick release mechanism, and attach the quick-release to the crane hook. The package should be rigged such that the string on the bottom of the N-55 is at the lowest point on the package when the package is hanging from the rigging. The package should hang horizontally from the rigging, and should directly strike one of the latches holding the package halves together.

4.4.5 Raise and position the package 30 feet above the pad, using the string and washer to indicate the height and target positioning.

4.4.6 Photograph the package such that the drop orientation can be clearly seen. Set up video camera equipment in a position to clearly view the impact as it occurs. Begin videotaping.

4.4.7 Clear the drop area for at least 40 feet around the impact point.

4.4.8 Complete Items 6 through 12 of the third Form NPQ 038. Mark Items 1 through 5 as N/A.

4.4.9 Release the package.

4.4.10 Photograph and videotape the package from several relevant directions, with a special emphasis on the impact zone.

4.4.11 Complete Items 13 through 15 on the third Form NPQ 038, and the Exterior Damage section of the third Form NPQ 038A (on the reverse of NPQ 038).

4.5 40-Inch Drop onto a Six-Inch Diameter Mild Steel Post

4.5.1 As far as practical, return the package to its worst condition following any one of the previous three drops. This may require opening a latch or latches which opened as a result of previous drops but were closed in preparation for other drops. If the worst damage following any of the three previous drops occurred following the horizontal drop, no changes to the package configuration are required by this step. The worst case damage shall be determined in relation to the expected package performance during this 40 inch drop onto a six-inch diameter mild steel post in the configuration described in Step 4.5.3 below.

4.5.2 Attach a length of string to the latch at the center of the package at the lowest point on the circumfergnce. The free end of the string shall be tigd to a small flat washer, so that the washer hangs 40 inches below the lowest point on the package when the package is lifted in the orientation described in 4.5.3 below. The purpose of the string is to indicate when the package has been lifted to the proper height above the ground prior to release of the package.

4.5.3 Using basket-style techniques, rig the package to a shackle in the quick release mechanism, and attach the quick-release to the crane hook. The package should be rigged such that the string on the bottom of the N-55 is at the lowest point on the package when the package is hanging from the rigging. The package should be positioned over the six-inch diameter steel post in the center of the drop pad, such that the post will strike the package at the latch previously struck during the horizontal 30 foot drop, and such that the impact point is approximately vertically aligned with the package center of gravity.

4.5.4 Raise and position the package 40 inches above the post, using the string and washer to indicate the height and target positioning.

4.5.5 Photograph the package such that the drop orientation can be clearly seen. Set up video camera equipment in a position to clearly view the impact as it occurs. Begin videotaping.

4.5.6 Clear the drop area for at least 40 feet around the impact point.

4.5.7 Complete Items 6 through 12 of the fourth Form NPQ 038. Mark Items 1 through 5 as N/A.

4.5.8 Release the package.

4.5.9 Photograph and videotape the package from several relevant directions, with a special emphasis on the impact zone.

4.5.10 Complete Items 13 through 15 on the fourth Form NPQ 038, and the Exterior Damage section of the fourth Form NPQ 038A (on the reverse of NPQ 038).

4.5.11 Transport the N-55 to an appropriate disassembly location.

4.6 Disassembly Procedure

4.6.1 Disassemble the N-55 in the upright position such that the 55-gallon drum can be viewed in place in the lower half of the N-55. Photograph the interior of the package, both around the drum and the interior of the upper half of the package. Note any sign of possible leakage.

4.4.2 Perform a leak test on the 55-gallon drum cover per the requirements of Ref. 2.6.

4.4.3 Complete Items 16 through 18 on the fourth Form NPQ 038 and the Interior Damage Section on the fourth Form NPQ 038A.

3.0 THERMAL EVALUATION

This section identifies and describes the principal thermal engineering design aspects of the N-55 Packaging important to safety and compliance with the performance requirements of 10 CFR 71.

3.1 Discussion

The N-55 Packaging is designed with a totally passive thermal system. The principal physical characteristics of this thermal system consist of a fully enclosing overpack surrounding a DOT Specification 17H or 17C, 55 gallon drum. The overpack is fabricated of 20 gauge (0.0359 inch thick) galvanized sheet steel outer shell, a 0.125 inch thick fiberglass inner shell, and approximately three pound per cubic foot closed-cell polyurethane foam in between. The payload consists of a 55 gallon drum with three forms of contents as described in Section 1.2.3.

Three heat transfer analyses were run for each of the three classifications of payload utilizing the computer thermal network analyzer program THAN:

(1) A normal condition steady-state analysis at an ambient temperature of 100°F with insulation,

(2) An accident condition steady-state analysis at an ambient temperature of 100°F without insulation, and

(3)An accident condition transient analysis at an ambient temperature of 1,475°F for thirty minutes followed by exposure to 100°F ambient air with sufficient time for temperatures throughout the package to maximize.

As discussed in Section 1.2.3, the N-55 packaging is analyzed for 3.0 thermal watts. Maximum temperatures at various locations within the N-55 Packaging are presented in Table 3.1-1. Details of the thermal analyses are presented in Sections 3.4 and 3.5.

TABLE 3.1-1
Maximum Temperature (°F)

Analysis Type	Outer Shell	Inner Shell	55 gal drum	Payload
Normal Condition Steady-state	153.8	161.5	161.9	161.9
Accident Condition Steady-state	100.2	108.0	108.5	108.5
Accident condition Transient	1,471.8	135.3	117.4[1]	117.4[1]

1. Rising at a rate less than 0.03°F /hour.

3.2 Summary of Thermal Properties of Materials

The N-55 Packaging is fabricated primarily of galvanized carbon steel, fiberglass, and polyurethane foam. The void space between the 55 gallon drum and the inside surface of the overpack is assumed to be filled with air. The following table documents the thermal properties utilized in the analysis models and the source from which they were obtained:

Property	Carbon Steel[1]	Foam[2]	Fiberglass[3]	(Payload)[4]
Conductivity (BTU/hr-ft-°F)	N/A	0.0142	0.25	N/A
Emissivity[4]	0.8	N/A	0.8	0.8
Density (lb/ft3)	490	3	155	N/A
Specific Heat (BTU/lb-°F)	0.113	0.30	0.28	0.30

1. Holman, Heat Transfer, Table A-2
2. Product brochure for LAST-A-FOAM, General Plastics Manufacturing Company, Tacoma, Washington
3. Materials Selector, 9/75
4. Assumed

At temperatures above 400°F, the polyurethane foam begins to decompose forming a char and gas. Gases are vented from the overpack through two low melting point plastic plugs. The char is a porous material that blocks the radiant heat. For analysis, the foam char may be represented by an equivalent air gap without radiant heat transfer (i.e., air conduction only).

Since the thermal conductivity of air varies significantly with temperature, the following table is used in the thermal analyses for all air gaps:

Air Temperature (°F)	Air Conductivity[1] (BTU/hr-ft-°F)
0	0.0133
32	0.0140
100	0.0154
200	0.0174
300	0.0193
400	0.0212
500	0.0231
600	0.0250
700	0.0268
800	0.0286
900	0.0303
1,000	0.0319
1,500	0.0400
2,000	0.0471

1. Kreith, Principles of Heat Transfer, 3rd Edition, Table A-3

3.3 Technical Specifications of Components

The materials used within the N-55 Packaging which are considered to be temperature sensitive are the neoprene dust seal and the polyurethane foam. The neoprene seal has an allowable temperature range of -40°F to 250°F per Page A3-35 of the Parker O-Ring Handbook, ORD 5700, 1982. The polyurethane foam will char at temperatures above 400°F. Other package materials are carbon steel and fiberglass which have melting points of 2,600°F and 1,350°F, respectively.

3.4 Thermal Evaluation for Normal Conditions of Transport

This section presents the thermal analyses for the N-55 Packaging for normal conditions of transport per the requirements of 10 CFR 71.71(c)(1). A 100°F ambient temperature with the following insulation values was used for heat input to the exterior of the package.

Form and Location of Surface	Total Insulation 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

3.4.1 Thermal Model

3.4.1.1 Analytical Model

Figure 3.4-1 illustrates the thermal model utilized for the normal conditions heat transfer analysis. Due to the simplicity of the package, the outside and inside surfaces of the package are modeled as just one node each. Additionally, the model assumes axial symmetry. Heat transfer mechanisms, for the undamaged overpack, are represented by 16 thermal resistors connecting the 13 nodes in an appropriate manner.

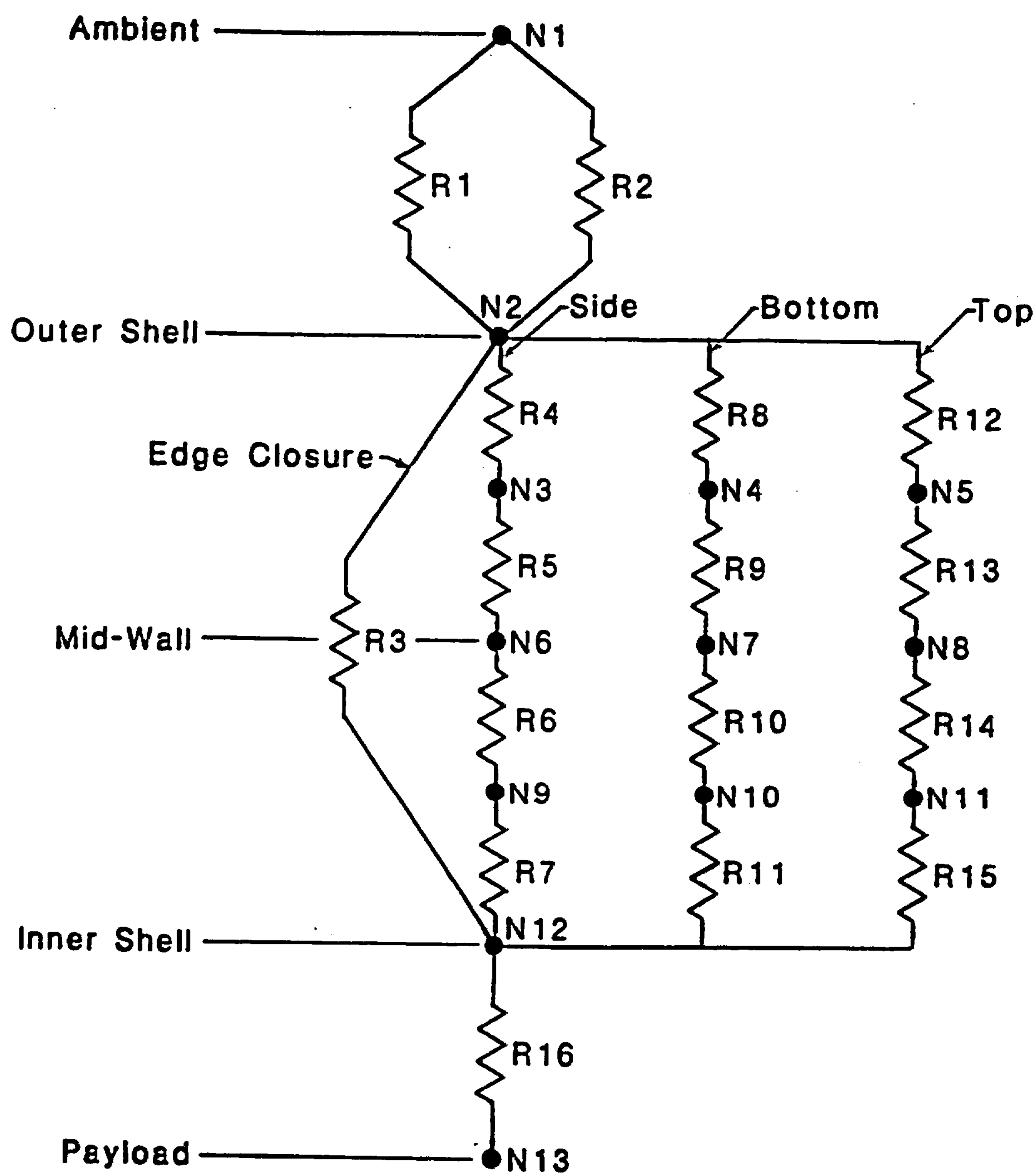
Thermal Capacitance's:

Thermal capacitance's are tabulated following a brief weights analysis to determine overpack mass distribution. Design weights for the overpack and payload are as follows:

Overpack = 180 pounds
Payload = 500 pounds
Total = 680 pounds

Figure 3.4-1

THERMAL MODEL



Although the maximum gross weight is 750 pounds (Section 2.2), the actual estimated weight of 680 pounds will be used in the thermal analyses. The steady state results will remain unchanged and the transient analyses will tend to produce conservatively higher results due to the lower overall thermal mass.

External Steel Shell Weight (Node 2):

$$W = \pi[(32)(48) + (32)^2/2](0.0359)[490/(12)^3]$$
$$= 65.4 \text{ lbs}$$

Top Foam Weight (Nodes 5, 8, and 11):

$$W = (\pi/4)[(32)^2(7.5)][3/(12)^3]$$
$$= 10.5 \text{ lbs}$$

Bottom Foam Weight (Nodes 4, 7, and 10):

$$W = (\pi/4)[(31.375)^2(6)][3/(12)^3]$$
$$= 8.1 \text{ lbs}$$

Side Foam Weight (Nodes 3, 6, and 9):

$$W=(\pi/4)\{[(32)^2-(25)^2](14)+[(31.375)^2-(24)^2](21.5)\}[3/(12)^3]$$
$$= 19.6 \text{ lbs}$$

Inner Fiberglass Shell (Node 12):

$$W=\pi[(24)(35.5)+(24)^2/2+(2)(5.5)(28)](0.125)[155/(12)^3\}$$
$$= 51.2 \text{ lbs}$$

The total calculated weight is:

$$W = 65.4 + 10.5 + 8.1 + 19.6 + 51.2$$
$$= 154.8 \text{ lbs}$$

Ratio the calculated total weight to the assumed total weight as follows:

Component	Nodes	Calculated Weight		Δ Weight		Final Weight
Outer Shell	2	65.4		10.7		76.1
Foam - Top	5,8,11	10.5		1.7		12.2
Bottom	4,7,10	8.1		1.3		9.4
Sides	3,6,9	19.6		3.2		22.8
Inner Shell	12	51.2		8.3		59.5
		154.8	+	25.2	=	180.0

The capacitance for each node in the overpack is summarized in the following table:

Node	Material	Weight (lb)	Specific Heat (BTU/lb-°F)	Capacitance (BTU/°F)
2	Steel	76.1	0.113	8.599
3	Foam	7.6	0.30	2.280
4	Foam	3.1	0.30	0.940
5	Foam	4.1	0.30	1.220
6	Foam	7.6	0.30	2.280
7	Foam	3.1	0.30	0.940
8	Foam	4.1	0.30	1.220
9	Foam	7.6	0.30	2.280
10	Foam	3.1	0.30	0.940
11	Foam	4.1	0.30	1.220
12	Fiberglass	59.5	0.28	16.66

Assume a composite specific heat of 0.30 BTU/lb-°F, and a weight of 500 pounds. The thermal capacitance of Node 13, the payload, is (500)(0.30) = 150.0 BTU/°F.

Radiation Heat Transfer (R_1 and R_{16}):

The general form for radiation resistor coefficient coupling of nodes 'i' to 'j' is taken from Equation 5-56 of Kreith:

$$k_{ij} = \sigma F_{ij} A_i$$

Where:

$\sigma = 0.1714(10)^{-8}$ BTU/hr-ft2-°R^4 (Stefan-Boltzman constant)

$F_{ij} = \varepsilon_i$ ($A_i << A_j$, all external surfaces)

$F_{ij} = 1/[(1/N_i - 1) + 1 + (A_i/A_j)(1/\varepsilon_j - 1)]$
(concentric cylinders)

Resistor R_1:

Resistor R_1 provides the radiant portion of thermal coupling to the external environment from the package outer surface. For this geometry:

$A_i = \pi[(32)(48) + 2(16)2]/(12)2 = 44.68$ ft^2

$A_j = \infty$ (ambient)

$\varepsilon_i = 0.8$ (per 10 CFR 71)
$\varepsilon_j = 0.9$ (per 10 CFR 71)

Then,

$R1 = [0.1714(10)\text{-}8](0.8)(44.68) = 6.1266(10)^{-8}$ BTU/hr-°R^4

Resistor R_{16}:

Resistor R_{16} provides the primary radiant heat transfer between the inner shell of the overpack and the outer surface of the 55 gallon drum. The basic dimensions of the 55 gallon drum are assumed to be 22 inches diameter and 35 inches long.

$A_i = \pi[(22)(35) + 2(22/2)^2]/(12)^2 = 22.078$ ft^2

$A_j = \pi[(24)(35.5) + 2(24/2)^2]/(12)^2 = 24.871\ ft^2$

$\varepsilon_i = \varepsilon_j = 0.8$

Then,

$$R_{16} = [0.1714(10)^{-8}](22.078)/[(1/0.8 - 1) + 1 + (22.078/24.871)(1/0.8 - 1)]$$
$$= 2.5709(10)^{-8}\ BTU/hr\text{-}^\circ R^4$$

Convective Heat Transfer (R_2):

Resistor R_2 provides convective coupling between the outer surface of the overpack and the ambient. Assuming laminar flow of air, the film coefficients for convective heat transfer may be determined by utilizing equations from McAdams, Heat Transmission, 3rd Edition:

For a horizontal plate with the heated surface facing upward (Equation 7-8d):

$h_{cH} = 0.27(\Delta T/L)0.25\ BTU/hr\text{-}ft^2\text{-}^\circ F$

For a vertical cylinder (Equation 7-5b):

$h_{cV} = 0.29(\Delta T/L)0.25\ BTU/hr\text{-}ft^2\text{-}^\circ F$

Assuming convective heat transfer over all but the bottom surface:

$A_H = \pi(32/2)^2/(12)^2 = 5.585\ ft^2$

$A_V = \pi(32)(48)/(12)^2 = 33.510\ ft^2$

Then, the composite film coefficient may be found as:

$$h_c = \{[(5.585)(0.27)/(32/12)^{0.25}] + [(33.510)(0.29)/(48/12)^{0.25}]\}/(5.585 + 33.510)$$
$$= (0.20595)\Delta T^{0.25}$$

The above form is utilized directly for input into the computer code THAN.

Conductive Heat Transfer (R_4 - R_{15}):

The basic heat transfer mode between the inner and outer shells of the overpack is via conduction through the 3 lb/ft^3 polyurethane foam. From Section 3.2, the foam conductivity utilized is 0.0142 BTU/hr-ft^2-°F. It is assumed that the foam chars at a temperature of 400°F. At this temperature, each foam conduction resistor will be replaced by an air conduction resistor of equivalent geometry.

Radial conduction through a cylinder is given as:

$$R_{ij} = \ln(r_i/r_j)/2\pi kL$$

Axial conduction through a flat plate is given as:

$$R_{ij} = t/kA$$

Where:

r_i = outer radius, ft

r_j = inner radius, ft

k = foam conductivity, BTU/hr-ft^2-°F

L = cylinder length, ft

t = plate thickness, ft

A = plate area, ft^2

Overpack Sides (R_4 - R_7):

Heat transfer through the overpack sides is via radial foam conduction. The effective cylinder length is given as 35.5 inches (2.958 ft). The table below summarizes the resistor values for resistors R_4 - R_7:

Resistor Number	Nodes Outer	Nodes Inner	Radius r_i	Radius r_j	Resistor Value (°F-hr/BTU)
4	2	3	16.00	15.13	0.21357
5	3	6	15.13	14.25	0.22631
6	6	9	14.25	13.38	0.24065
7	9	12	13.38	12.50	0.25694

Overpack Bottom (R_8 - R_{11}):

Heat transfer through the overpack bottom is via axial foam conduction. The effective plate thickness is given as 6.0/4 inches (0.1250 ft). The resistor value for resistors R_8 - R_{11} is calculated as:

$$R_8 = R_9 = R_{10} = R_{11} = 0.1250/(0.0142)[\pi(24/2)^2/(12)^2]$$
$$= 2.8020 \text{ °F-hr/BTU}$$

Overpack Top (R_{12} - R_{15}):
Heat transfer through the overpack top is via axial foam conduction. The effective plate thickness is given as 7.5/4 inches (0.1563 ft). The resistor value for resistors R_{12} - R_{15} is calculated as:

$$R_{12} = R_{13} = R_{14} = R_{15} = 0.1563/(0.0142)[\pi(25/2)^2/(12)^2]$$
$$= 3.2279 \text{ °F-hr/BTU}$$

Edge Closure (R_3):

The edge closure is of 0.125 inch thick molded fiberglass for both the top and bottom halves of the overpack. The mean conduction path length is approximately 5.5 inches. For purposes of this analysis, assume axial heat conduction as the mode of heat transfer.

$R_3 = t/kA = (5.5/12)/(0.25)\{2(0.125)\pi[(24 + 32)/2]/(12)^2\}$
$= 12.005$ °F-hr/BTU

External Heat Loading:

The insulation onto the top of the overpack is given as 800 g cal/cm² (2,950 BTU/ft²) per 12 hours:

$q_{top} = (2,950)[\pi(32/2)^2/(12)^2] = 16,476$ BTU/12 hours

Likewise, the insulation onto the curved side of the overpack is given as 400 g cal/cm² (1,475 BTU/ft²) per 12 hours:

$q_{side} = (1,475)[(32)(48)/(12)^2] = 15,733$ BTU/12 hours

Therefore, the total external heat load per hour is:

$q_e = (q_{top} + q_{side})/12 = (16,476 + 15,733)/12$
$= 2,684$ BTU/hr

Internal Heat Loading:

$q_i = (3.0 \text{ watts})(3.412 \text{ BTU/hr-watt}) = 10.23$ BTU/hr

3.4.1.2 Test Model

Not applicable as no thermal testing for normal conditions of transport is performed for the N-55 Packaging.

3.4.2 Maximum Temperatures

The maximum normal conditions of transport steady-state nodal temperatures, as directly output by THAN, are presented below:

```
            OUTPUT VARIABLES BY CLASS

 STEADY STATE PROBLEM

                TOTAL NUMBER OF NEWTON ITERATIONS =                 7
                NUMBER OF TEMPERATURE DEPENDENT INTERPOLATIONS =    3
                NO. OF NEWTON ITERATIONS FOR FINAL UPDATE =         1
 CLASS 2 - TEMPERATURE, T
```

ID	DEGREES F	ID	DEGREES F	ID	DEGREES F	ID	DEGREES F
1	100.0000000	2	153.7563123	3	155.5263446	4	155.6987108
5	155.6987108	6	157.4019639	7	157.6411093	8	157.6411093
9	159.3964306	10	159.5835077	11	159.5835077	12	161.5259062
13	161.9404477						

3.4.3 Minimum Temperatures

The minimum temperature distribution for the N-55 Packaging will occur with no internal decay heat, no insulation, and an ambient air temperature of -40°F per 10 CFR 71.71(c)(2). Since the steady-state analysis of this condition represents a trivial case, no computerized thermal calculations were performed. Instead, it is assumed that all N-55 components will reach the -40o F temperature as required above. As presented in Section 2.6.2, this temperature will have negligible effects upon the N-55 Packaging.

3.4.4 Maximum Internal Pressures

Since the overpack is not a containment vessel, pressure calculations for this boundary need not be performed. The internal pressure within the 55 gallon drum may be found utilizing the ideal gas law from thermodynamics. Conservatively assume a static loading temperature of -40°F, and a steady state payload temperature of 161.9°F which totals a 201.9°F change in temperature. Assuming air, the change in internal pressure may be found to be:

$$P_1V_1/T_1 = P_2V_2/T_2$$

Assuming a constant volume, the equation reduces to:

$$P_1/P_2 = T_1/T_2$$
$$P_2 = (14.7 \text{ psia})[(201.9 + 459.69)/(-40 + 459.69)]$$
$$= 23.2 \text{ psia} = 8.5 \text{ psig}$$

3.4.5 Maximum Thermal Stresses

Since the pressure due to the rise in temperature within the drum is small (the Specification 17H drum is pressure tested to 15 psig per 49 CFR 178.118), stresses due to thermal effects may be considered negligible.

3.4.6 Evaluation of Package Performance for Normal Conditions of Transport

It can be readily seen by the calculations presented above that the N-55 Packaging will meet all the thermal requirements of the normal conditions of transport.

3.5 Hypothetical Accident Thermal Evaluation

This section presents the thermal analyses of the N-55 Packaging for the hypothetical accident fire condition specified in 10 CFR 71.73(c)(3). The initial temperature distribution in the package prior to the fire is taken as that corresponding to the 100°F steady state condition of Section 3.4, without insulation, in accordance with 10 CFR 71.73(b). To determine the effect of the fire, the package is exposed to a 1,475°F fire for a period of thirty minutes at which time the thermal boundary is returned to a 100°F ambient air condition as specified in 10 CFR 71.73(c)(3). The transient analysis is continued for a time sufficient to determine the maximum values for all temperatures within the package. Those nodes not achieving a maximum temperature within a period of ten hours following the end of the fire have been so noted.

3.5.1 Thermal Model

3.5.1.1 Analytical Model

The analytical model used to evaluate the hypothetical accident condition was nearly identical to that described in Section 3.4.1.1. Minor model modifications were incorporated to account for accident condition damage as discussed in Section 2.7. The application of this damage to the thermal model is covered in Section 3.5.2.

3.5.1.2 Test Model

Not applicable as no thermal testing for accident conditions is performed for the N-55 Packaging.

3.5.2 Package Conditions and Environment

For conservatism, the effects of three (3) successive impacts on the overpack will be collectively imposed upon the thermal model and utilized for the hypothetical fire transient analysis. Each impact effect is represented as a single 'damage' resistor in parallel with the other elements of the thermal model, connecting between Nodes 2 and 12, as shown in Figure 3.5-1.

Top and Bottom Corner Impact Damage (R_{18} and R_{19}):

Consider the following illustration to determine the effects of overpack damage upon the thermal analyses:

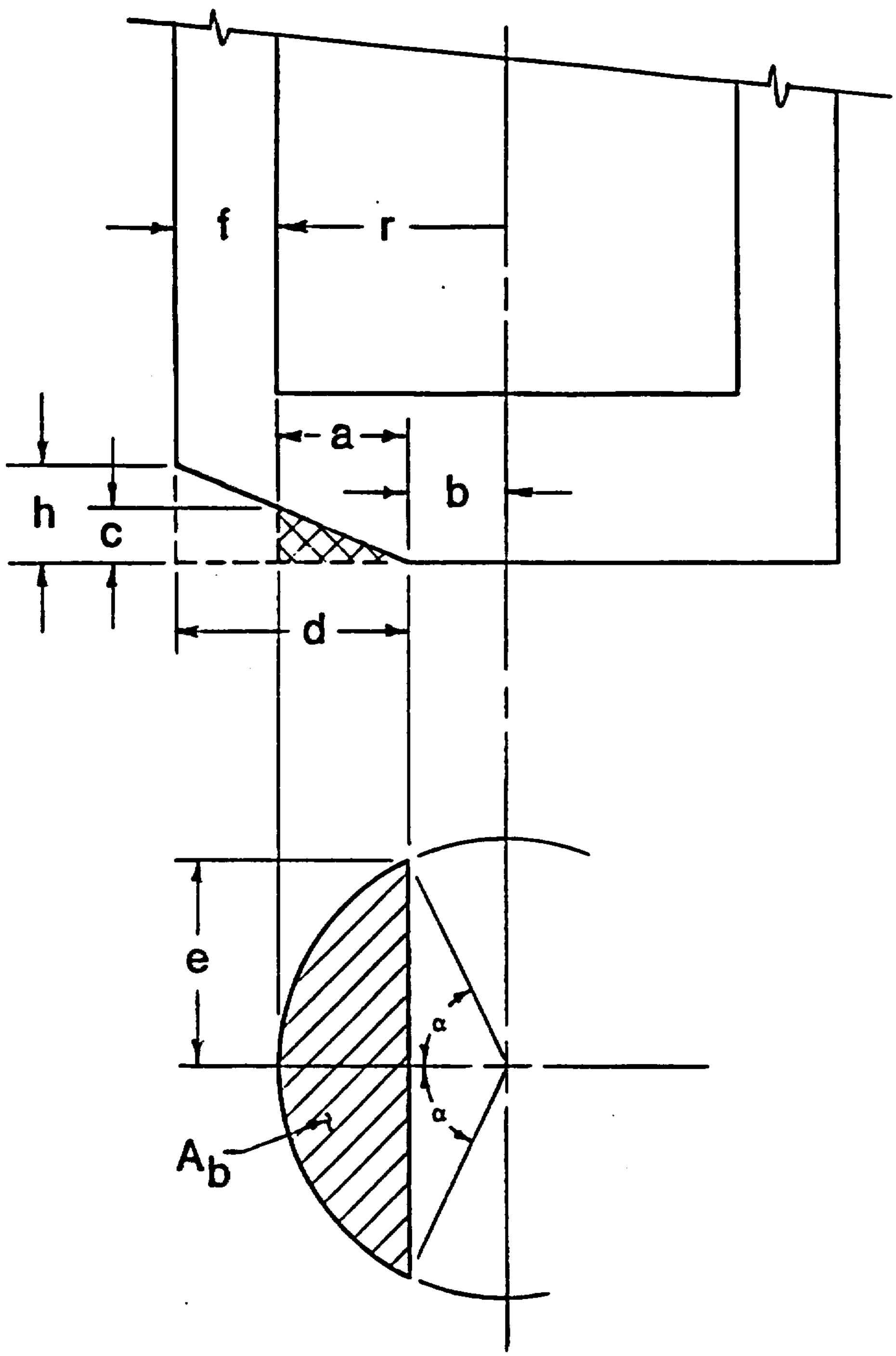
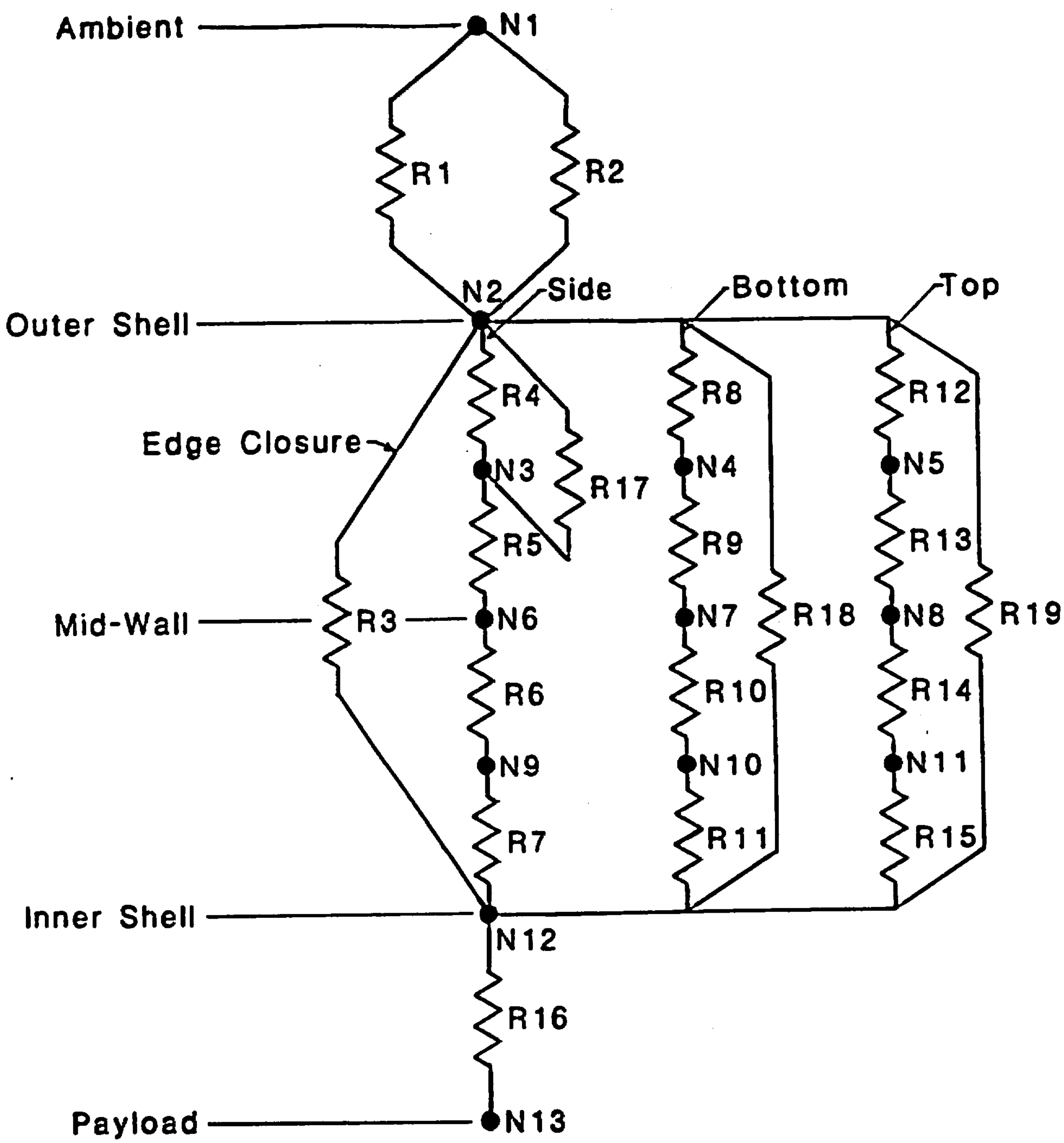


Figure 3.5-1
Fire Accident Thermal Model



The procedure for determining the 'damage' resistors is as follows:

1) Calculate the end area
2) Calculate the wedge volume
3) Calculate the equivalent thickness reduction, volume/area
4) Calculate the foam conduction resistor for the thinner section

The end area is the area of a circle, or:

$$A = \pi r^2$$

Where:

r = effective end radius for the thermal analysis

The volume of an ungula may be found from the following expression:

$$V = c[(2e^3/3) - bAb]/a$$

Where:

$$a = d - f$$

$$c = ah/d$$

$$b = r - a$$

$$e = [a(2r - a)]^{0.5}$$

$$Ab = r^2[S - (\sin \alpha)(\cos \alpha)]$$

$$\alpha = \cos^{-1}(b/r)$$

If R_t is the resistance of the undamaged section, R_d is the resistance of the damaged section, and Re is the equivalent resistance using the Parallel Resistor Law, then:

$$R_d = 1/[(1/R_t) + (1/R_e)] = (R_t R_e)/(R_t + R_e)$$

Rearranging,

$R_e = (R_t R_d)/(R_t - R_d)$, R_t from Section 3.4.1.1
(11.2080 for bottom, 12.9116 for top)

Where:

$R_d \propto t - \Delta t$

$R_t \propto t$

$\Delta t = V/A$

Then,

$R_d/R_t = \beta = (t - \Delta t)/t$

Substituting,

$R_e = R_t^2/(R_t - R_t\beta) = R_t\beta/(1 - \beta)$

Parameter	Bottom Resistor (R_{18})	Top Resistor (R_{19})
r	12.0	12.5
d	12.0	16.0
h	4.5	8.0
f	3.6875	3.50
a	8.3125	12.50
b	3.6875	0.0
c	3.1172	6.25
e	11.4194	12.50
A	452.39	490.87
α	72.104°	90.00°
A_b	139.108	245.437
V	179.92	651.04
t	6.00	7.50
Δt	0.3977	1.3263
β	0.9337	0.8232
R_e	R_{18} = 157.84	R_{19} = 60.118

Side Impact Damage (R_{17}):

Assume any localized effect of the side latch is negligible and utilize the same techniques as above to determine resistor R_{17}.

The impact zone is assumed to have a length equal to the cylindrical overpack. The width of the impact zone is the length of the circular segment formed. The volume of the circular segment is:

$$V = r^2 l[2\beta - (\sin 2\beta)]/2$$

Where:

$r = 16.0$ in

$l = 48.0$ in

$\beta = \cos\text{-}1[(r - \delta)/r]$

$\delta = 0.75$ in

Then,

$$\beta = \cos\text{-}1[(16.0 - 0.75)/16.0] = 17.61°$$

$$V = (16.0)^2(48.0)\{(2\pi\beta/180)\text{-}[\sin 2(17.61°)]\}/2 = 233.49 \text{ in}^3$$

The total surface area of the overpack cylinder is:

$$A = 2\pi rl = 2\pi(16.0)(48.0) = 4{,}825.5 \text{ in}^2$$

The effective change in thickness, Δt, is:

$$\Delta t = V/A = 233.49/4{,}825.5 = 0.0484 \text{ in}$$

Assuming the damage effects only the first ring of insulating foam (R_4), the total thickness, t, is 0.875 inches. The reduction coefficient, β, is:

$$\beta = (t - \Delta t)/t = (0.875 - 0.0484)/0.875 = 0.9447$$

and,

$R_{17} = R_4[\beta/(1 - \beta)] = 0.21357[0.9447/(1 - 0.9447)]$
$= 3.6485$ BTU/hr-ft^2-°F

3.5.3 Package Temperatures

The maximum nodal temperatures for the hypothetical fire accident, as directly output by THAN, are presented in Table 3.5-1, and Figures 3.5-2 and 3.5-3.

3.5.4 Maximum Internal Pressures

The maximum normal condition payload temperature of 161.9°F represents the highest temperature experienced by the N-55 Packaging. Since the hypothetical fire temperatures are less than the normal condition temperatures, the corresponding internal pressure will be less than the 8.5 psig determined in Section 3.4.4 thereby resulting in a higher margin of safety.

3.5.5 Maximum Thermal Stresses

Since the pressure due to the rise in temperature within the drum is small (the Specification 17H drum is pressure tested to 15 psig per 49 CFR 178.118), stresses due to thermal effects may be considered negligible.

3.5.6 Evaluation of Package Performance for Hypothetical Accident Thermal Conditions

It can be readily seen by the calculations presented above that the N-55 Packaging will meet all the thermal requirements of the hypothetical accident conditions.

TABLE 3.5-1
Classification I, 3 Watt Payload

Time (hr)	Node 1	Node 2	Node 6	Node 12	Node 1:
0.000	1475.000	100.240	103.880	108.010	108.550
0.100	1475.000	1466.855	148.006	109.028	108.556
0.200	1475.000	1469.326	248.475	110.200	108.575
0.300	1475.000	1470.592	354.185	111.668	108.611
0.400	1475.000	1471.308	448.757	113.616	108.668
0.500	1475.000	1471.758	528.989	116.104	108.753
0.600	100.000	267.719	579.687	118.223	108.864
0.700	100.000	197.198	580.150	120.582	108.998
0.800	100.000	170.749	554.319	123.250	109.163
0.900	100.000	156.010	518.060	125.966	109.361
1.000	100.000	146.226	479.653	128.494	109.593
1.100	100.000	139.147	442.790	130.674	109.856
1.200	100.000	133.765	408.860	132.424	110.144
1.300	100.000	129.532	378.208	133.726	110.453
1.400	100.000	126.112	350.739	134.601	110.776
1.500	100.000	123.289	326.199	135.093	111.106
1.600	100.000	120.914	304.292	135.259	111.438
1.700	100.000	118.886	284.731	135.156	111.768
1.800	100.000	117.131	267.249	134.838	112.092
1.900	100.000	115.597	251.611	134.355	112.407
2.000	100.000	114.246	237.608	133.748	112.710
2.200	100.000	111.976	213.795	132.302	113.278
2.400	100.000	110.155	194.589	130.717	113.789
2.600	100.000	108.676	179.047	129.129	114.243
2.800	100.000	107.464	166.429	127.620	114.641
3.000	100.000	106.464	156.159	126.234	114.988
3.200	100.000	105.637	147.779	124.989	115.290
3.400	100.000	104.948	140.926	123.890	115.551
3.600	100.000	104.373	135.311	122.930	115.777
3.800	100.000	103.892	130.703	122.099	115.972
4.000	100.000	103.487	126.915	121.386	116.141
4.200	100.000	103.145	123.796	120.776	116.288
4.400	100.000	102.855	121.225	120.257	116.415
4.600	100.000	102.609	119.102	119.815	116.526
4.800	100.000	102.399	117.348	119.441	116.622
5.000	100.000	102.219	115.896	119.125	116.707
5.200	100.000	102.064	114.693	118.856	116.782
5.400	100.000	101.930	113.695	118.629	116.848
5.600	100.000	101.814	112.866	118.436	116.906
5.800	100.000	101.713	112.176	118.272	116.959
6.000	100.000	101.624	111.601	118.133	117.005
6.200	100.000	101.545	111.122	118.013	117.047
6.400	100.000	101.476	110.720	117.910	117.085
6.600	100.000	101.414	110.384	117.822	117.120
6.800	100.000	101.359	110.102	117.745	117.151
7.000	100.000	101.309	109.864	117.677	117.179
7.500	100.000	101.204	109.418	117.542	117.241
8.000	100.000	101.121	109.119	117.438	117.290
8.500	100.000	101.052	108.913	117.354	117.330
9.000	100.000	100.995	108.765	117.284	117.363
9.500	100.000	100.946	108.656	117.221	117.389
10.000	100.000	100.903	108.571	117.165	117.410

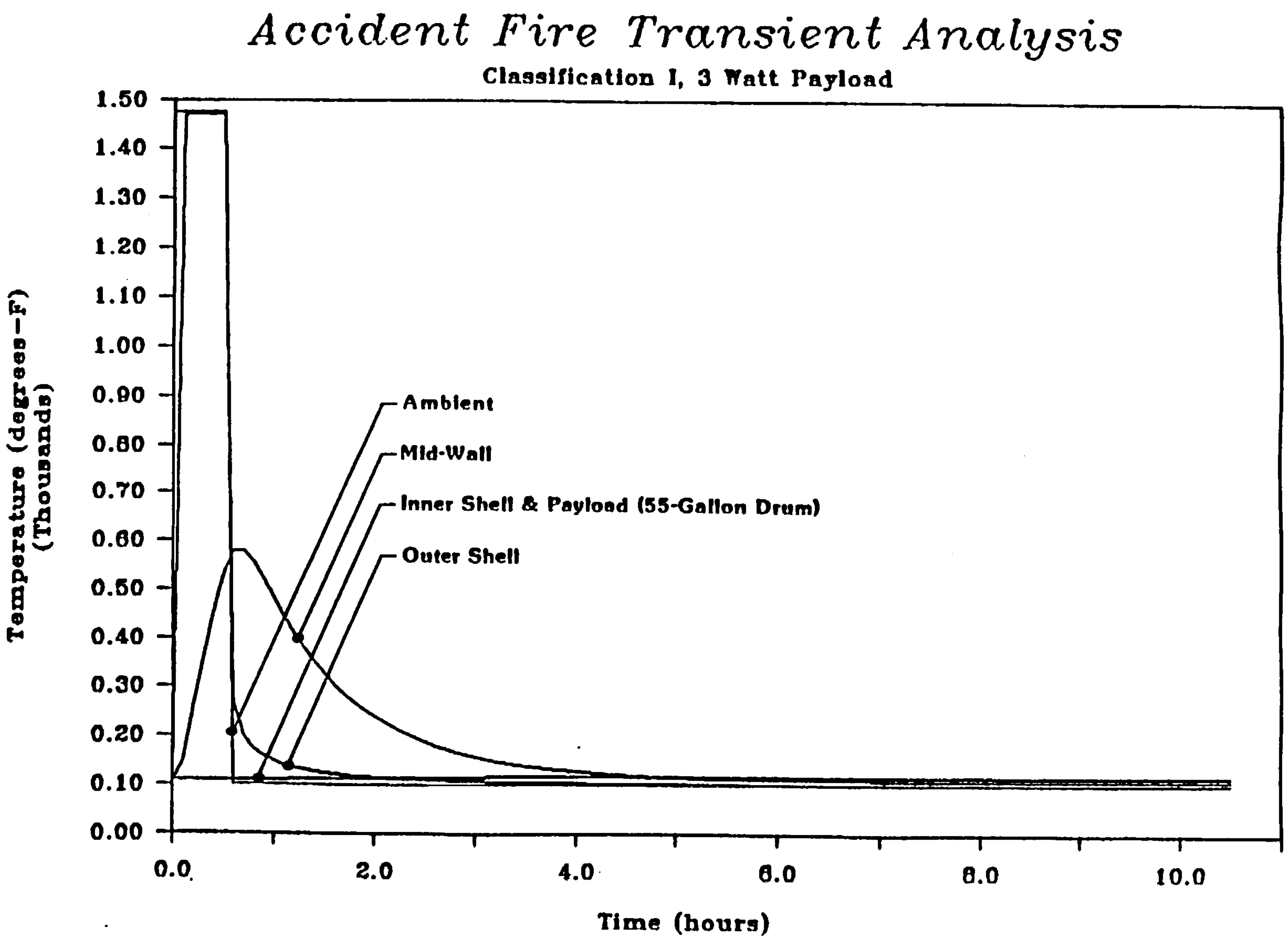
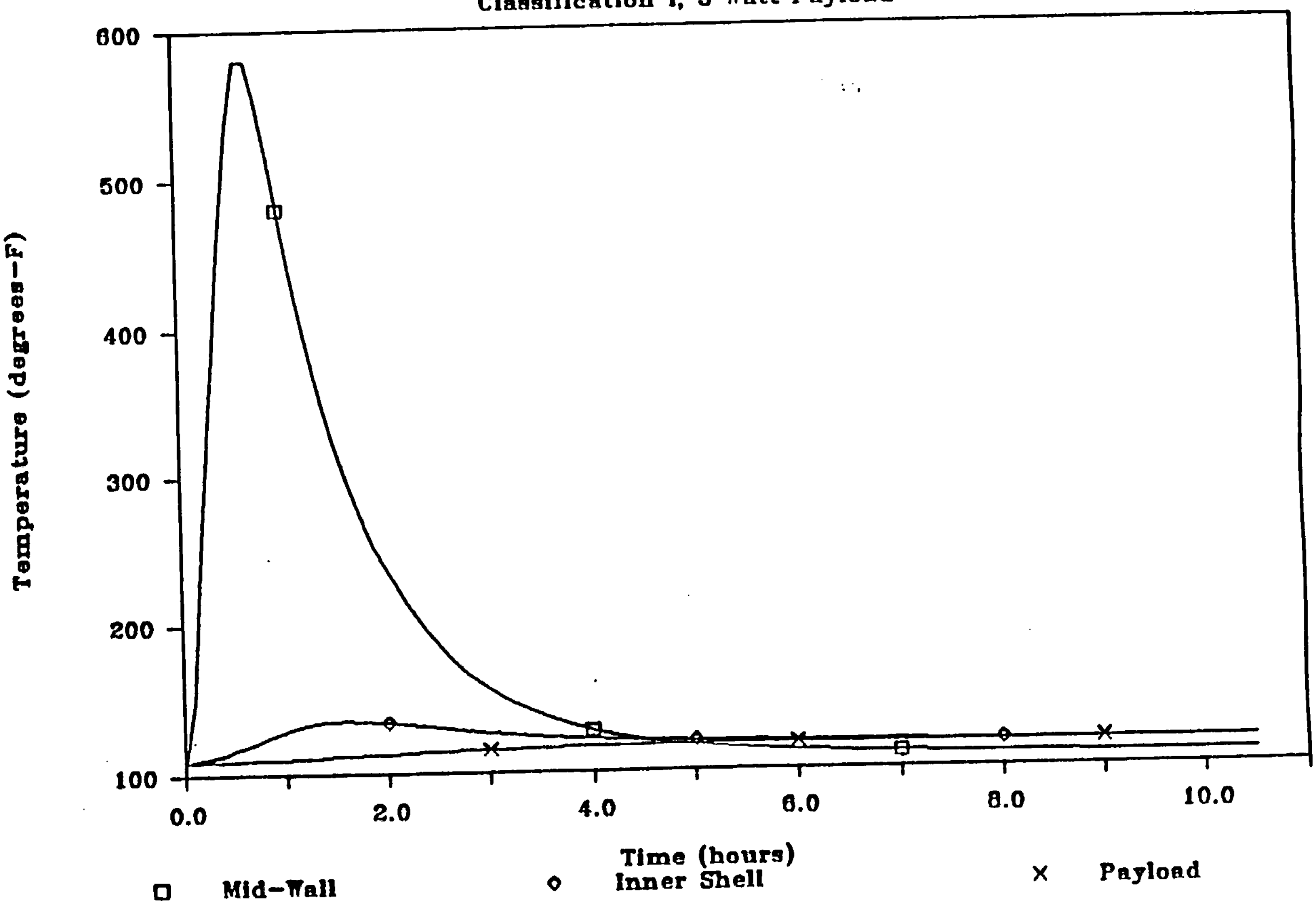

Accident Fire Transient Analysis
Classification I, 3 Watt Payload
Temperature (degrees-F) (Thousands)
1.50
1.40
1.30
1.20
1.10
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Ambient
Mid-Wall
Inner Shell & Payload (55-Gallon Drum)
Outer Shell
0.0
2.0
4.0
6.0
8.0
10.0
Time (hours)

FIGURE 3.5-2

FIGURE 3.5-3

Accident Fire Transient Analysis

Classification I, 3 Watt Payload



4.0 CONTAINMENT

The containment boundary of the NuPac N-55 packaging consists of a DOT specification 17C or 17H, 55-gallon drum. The design specifications for the 17C and 17H drums are provided in 49 CFR 178.115 and 49 CFR 178.118, respectively.

The contents are limited, per Section 1.2.3, to dry, solid forms of radioactive material. Hence, the DOT Specification 17C and 17H, 55 gallon drums are necessary only to serve as a means of confinement for the non-dispersible radioactive material. Actual leak testing of the 55 gallon drums is not necessary to meet the requirements of 10 CFR 71.

As demonstrated by full scale testing and as discussed in Sections 2.6 and 2.7, the N-55 overpack adequately protects the various containment vessels. The presence of the overpack ensures that containment vessel damage will be limited and that a release of radioactive material will not occur under the specified normal or accident conditions.

5.0 SHIELDING EVALUATION

No shielding is provided by the N-55 Packaging.

6.0 CRITICALITY EVALUATION

A criticality evaluation is not required for the NuPac N-55 packaging.

7.0 OPERATING PROCEDURES

This section generally describes the procedures to be used for loading and unloading the N-55 Packaging.

7.1 Procedures for Loading the Package

1. Unfasten the four toggle clamps which secure the lid to the body of the overpack. Visually inspect the package exterior for significant damage such as cracks, holes and broken welds.
2. Remove the overpack lid by attaching suitable hooks to the lifting lugs on the lid. Care should be taken during this operation so as not to damage the lid to body interface seal while setting the lid down.
3. Inspect the inside of the base and lid to assure there are no loose articles within the packaging. Visually inspect the package interior for significant damage such as cracks, holes and broken welds.
4. Verify that sufficient life remains in the overpack weather seal (neoprene gasket). If the weather seal is beyond 12 months of age (1 year), replace per the requirement of Section 8.2.
5. Place a loaded 55 gallon drum into the base of the overpack. For less than full loads, sufficient dunnage, shoring and/or bracing shall be utilized between the contents and the drum to minimize the effects of normal and accident conditions. In particular, protrusions associated with the contents such as lifting eyes, etc., shall be positioned such that they will not contact the drum walls or shoring shall be provided to prevent puncture of the drum walls by the protrusions under normal conditions of transport or hypothetical accident conditions.
6. Replace the lid and secure it to the body by fastening the four toggle clamps. This shall be done by adjusting the 'T' bar on the clamps such that the clamps may be closed with minimum force. Reopen the clamps, and rotate the 'T' bar on all four clamps four full 360o turns clockwise. Then close the clamps.
7. Inspect the package for proper labeling necessary to meet federal regulations. Correct any labeling deficiencies.

8. Install an approved security seal.
9. Radiation monitor the package per the requirements of 10 CFR 71.47. Verify surface contamination levels are below the limits specified in 10 CFR 71.87.
10. Using suitable material handling equipment, transfer the packaging to the transport vehicle.
11. When in position on the transport vehicle, the lift lugs shall be rendered inoperable for use as tiedown devices. This can be achieved by replacing each lift shackle with a bolt, washer and nut, by running a cable (or equivalent band) snugly around the package and through all 4 shackles such that the shackles are snug up against the body of the N-55 package, or by any equivalent means.
12. After all packages are on the transport vehicle, secure them to the vehicle using appropriate tie down devices.

7.2 Procedures for Unloading the Package

1. Receipt of the NuPac N-55 packaging should be in accordance with the instructions set forth in 10 CFR 20.205.
2. Remove the tiedown devices and render the lift lugs operable.
3. Move the unopened package to the appropriate unloading area. Place it in a suitable unloading attitude.
4. Perform an external inspection of the unopened package. Record any significant or potentially significant observations.
5. Remove the security seal.
6. Repeat Steps 1 and 2 in Section 7.1, above, for removing the overpack lid.
7. Remove the inner 55 gallon drum.

7.3 Preparation of an Empty Package for Transport

Previously used, empty packages are handled per the requirements of 49 CFR 173.427.

8.0 ACCEPTANCE TESTS AND MAINTENANCE PROGRAM

8.1 Acceptance Tests

The N-55 Packaging shall be inspected and released for use by a responsible employee prior to loading. The following items will be included in such inspections:

1. The entire package, both inside and out, shall be visually inspected and assured that it has not been significantly damaged (no cracks, punctures, holes, nor broken welds) per the requirement of 10 CFR 71.85(a).
2. Toggle clamps and gaskets must be present and free of defects.
3. The exterior nameplate must be in place and legible, bearing the packaging identification number, model number, gross weight, and certificate of compliance number per the requirement of 10 CFR 71.85(c).
4. Follow all company operating procedures and complete all necessary records for the handling and operation of the N-55 Packaging.

NOTE: The requirement of 10 CFR 71.85(b) for pressure testing the containment system to a level 50% higher than the normal operating pressure is unnecessary. From Section 2.6.1, 150% of the 8.5 psig normal operating pressure is still below the 15 psig test pressure of a DOT Specification 17C or 17H, 55 gallon drum.

8.2 Maintenance Program

A good sound industrial maintenance program should be followed to assure the integrity of the N-55 packaging. Components such as gaskets, toggle clamps, and components necessary for the safe and easy operation of the packaging should be given regular inspection and repaired or replaced as necessary.

9.0 QUALITY ASSURANCE

The NuPac N-55 Packaging has been designed and will be fabricated under a quality assurance program with approval No. 0192, by the US Nuclear Regulatory Commission. VECTRA Technologies, Inc. administers this program which satisfies the eighteen (18) criterion of 10CFR71, Subpart 11, in its entirety.