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ENVIRALLOY FL-50/EA-50

HIGH INTEGRITY CONTAINER

(NON-PROPRIETARY)

Revision 0 (A)

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'Criteria for High Integrity Containers
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By

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United States Nuclear Regulatory Commission
Office of Nuclear Material Safety and Safeguards
Washington, D.C. 20555

STAFF EVALUATION REPORT

related to the Topical Report covering
the FL-50/EA-50 High Integrity Container
manufactured by Nuclear Packaging, Inc.

Docket No. WM-45

Prepared by: Engineering Branch
Division of Waste Management

October 1985

ABSTRACT

This Staff Evaluation Report has been prepared by the Office of Nuclear Material Safety and Safeguards of the U.S. Nuclear Regulatory Commission for the Topical Report filed by Nuclear Packaging, Inc. covering its FL-50/EA-50 High Integrity Container. The container is proposed for use as a means of containing low-level radioactive waste and meeting the structural stability requirements for waste in 10 CFR Part 61. The staff concludes that the FL-50/EA-50 high integrity container meets the structural stability requirements of Part 61 and may be used for the disposal of low-level radioactive waste that requires disposal in a stable form. Limiting conditions for use of the container may be specified by the regulating authority for a particular disposal site.

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1.0 BACKGROUND

1.1 Regulations

By Federal Register Notice dated December 27, 1982 (47 FR 57446), the United States Nuclear Regulatory Commission (NRC) amended its regulations to provide specific requirements for licensing of facilities for the land disposal of low-level radioactive waste. The majority of these requirements are now contained in Part 61 to Title 10 of the Code of Federal Regulations (10 CFR 61) entitled "Licensing Requirements for Land Disposal of Radioactive Waste" (Ref. 1). Minor modifications, mostly of a procedural nature, have been made to other parts of the Commission's regulations, such as 10 CFR 20 ("Standards for Protection Against Radiation"). These regulations are the culmination of a set of prescribed procedures for low-level radioactive waste disposal that were proposed in the Federal Register on July 24, 1981.

The effective date for the implementation of 10 CFR 20.311, which requires waste generators to meet the waste classification and waste form requirements in 10 CFR 61, was December 27, 1983. As set forth in 10 CFR 61.55, Class B and Class C waste must meet structural stability requirements that are established under 10 CFR 61.56(b). In May 1983, the NRC provided additional guidance by means of a Technical Position on Waste Form (Ref. 2) that indicated that structural stability could be provided by processing (i.e., solidification of) the waste form itself (as with large activated steel components) or by emplacing the waste in a container or structure that provides stability (that is, a high integrity container (HIC)).

1.2 Topical Report Submittals

By letter, dated November 3, 1983 (Ref. 3) Nuclear Packaging, Inc. (NuPac) requested consideration by the State of Washington for approval of a Ferralium 255 (F255) Liner System (the NuPac FL-50[1] high integrity container) for use in the disposal of Class B and C filters from Arkansas Nuclear One to Hanford, Washington at the U.S. Ecology low-level radioactive waste disposal site. At the time, Arkansas Power and Light (AP&L) was contracting with NuPac for the supply of carbon steel liners for packaging these filters for burial at Hanford. With the imminent implementation (on December 27, 1983) of the requirements for HICs as specified in 10 CFR 61, as well as site specific requirements dictated by the State of Washington, NuPac requested an early review of the request for approval of their FL-50/EA-50 HIC, as described in the topical report.

The State of Washington, in turn, requested assistance (Ref. 4) in the review

[1] During the course of this technical review, NuPac renamed the FL-50 HIC as the Enviralloy 50 (EA-50) HIC. From this point on in this Topical Report Evaluation the HIC is referred to as the FL-50/EA-50 HIC.

of the topical report through NRC's Office of State Programs. A preliminary technical review, involving primarily members of (a) the Engineering Section of NRC's Waste Management Engineering Branch, Division of Waste Management, (b) Brookhaven National Laboratory, (c) the Waste Technology Section of NRC's Waste Management Branch, Office of Research, and (d) the Transportation and Certification Branch of NRC's Division of Fuel Cycle and Material Safety, resulted in the generation of several comments (Ref. 5) on the AP&L related FL-50/EA-50 report. These comments focussed principally on the need for further information on the corrosion behavior of the Ferralium 255 alloy, because corrosion was believed to be a controlling factor in the performance of a metallic HIC.

At about the same time that the corrosion comments were being transmitted to the State of Washington for consideration, NuPac submitted (Refs. 6 and 7) a second topical report on the FL-50/EA-50 HIC. Whereas the first report had dealt with a specific application of the HIC for AP&L filter cartridge waste to be sent to Hanford, the second topical was intended to be generic, to apply to a broad spectrum of waste streams, and to allow for disposal at Barnwell, South Carolina as well as Hanford, Washington. Inasmuch as the generic report encompassed and bounded the information contained within the AP&L-related document, the review effort was consolidated, and further review activity focussed on the generic topical. A request for further information (Ref. 8) that incorporated relevant information on soil analyses by an NRC contractor (Ref. 9) and which consolidated questions on the generic report was transmitted to NuPac in October 1984.

1.3 FL-50/EA-50 HIC Description

The NuPac FL-50/EA-50 high integrity container is a simple right angle cylinder with a flat top and bottom manufactured entirely of Ferralium 255. The HIC is approximately 47 inches in diameter by 51 inches tall. The top, bottom, and sides of the container are fabricated from 3/8 inch thick material. The top head has a 24 inch diameter gasketed opening for loading. Closure of this opening is accomplished with a 3/8 inch Ferralium Alloy 255 plate held in place by eight wedge shaped retainer blocks. Four internal L-shaped vertical supports, welded to the inside surfaces of the top and bottom plates, are provided as stiffeners for the top and bottom plates. A seal is provided between the lid and top of the HIC by a silicone rubber gasket (an optional lead gasket is available for highly permeable wastes such as tritium gas). A vent system is located in the lid and allows relief of internal pressure that could result from gas generation caused by biodegradation or radiolytic decay, while preventing significant groundwater movement into or out of the container. The vented lid is not to be used with wastes that contain highly mobile or transient gases such as tritium.

Lifting of the container is accomplished using a cable sling that is provided. The sling consists of a single 3/8 inch steel cable that is attached to two lifting eyes on the container with anchor shackles.

2.0 SUMMARY OF TOPICAL REPORT

The generic topical report on the NuPac FL-50/EA-50 high integrity container is intended to demonstrate that the HIC meets (a) all the applicable stability requirements and criteria of 10 CFR 61 (using guidance provided in the May 1983 Technical Position on Waste Form), (b) 10 CFR 71 sections dealing with Type A Packaging (as the Part 71 requirements apply to HICs), (c) 49 CFR 173 Type A Packaging related areas, and (d) special testing and design conditions requested by the Agreement States.

The FL-50/EA-50 HIC was designed to be certified as a DOT Type A container that would pass all U.S. DOT and U.S. NRC transportation requirements for a Type A container. The HIC is intended to contain the following types of wastes from light water reactors: (1) dewatered bead resins, powdered resins and diatomaceous earth; (2) compressible solid waste; (3) non-compressible solid waste; (4) filter elements and cartridges; (5) solidified resins, sludges, and liquid wastes.

The material from which the FL-50/EA-50 HIC is fabricated is Ferralium 255 (F255), which is a patented ferritic-austentic, duplex stainless steel that reputedly combines high mechanical strength, hardness and ductility with excellent corrosion properties. As acknowledged in the report, "the most critical area associated with long term isolation is considered to be corrosion resistence." A major portion of the report therefore, addresses, the predicted external corrosion behavior of the F255 HIC under expected disposal site environments and an analysis of the internal corrosion of the HIC, taking dewatered bead resin as the expected worst case.

The rest of the report, as submitted, focussed on structural analyses (including results of finite-element calculations using the ANSYS computer code), analyses of closures and seals, analyses of internal gas generation and associated gasketing requirements, analyses of radiation and ultra-violet stability, prototype testing, Type A package testing, heat transfer, inspection, and quality assurance. Much of the information addressing these subjects is contained in several appendices. The final approved report will contain this technical evaluation along with additional information submitted in response to NRC review comments and questions. The additional information will be included in the revised report as a second volume.

3.0 SUMMARY OF REGULATORY EVALUATION

3.1 Major Areas of Review

The basic objective of this staff technical evaluation of the topical report was to confirm that the NuPac FL-50/EA-50 HIC meets the structural stability requirements of 10 CFR 61. The NRC's Technical Position on Waste Form (May 1983), which addresses various details including certain transportation and testing requirements that are presented in 10 CFR 71 and 49 CFR 173, provides guidance on how to satisfy Part 61. Major areas of review that are addressed in the Technical Position and which received particular attention in this review included the following:

1. Corrosion
2. Structural Analyses
3. Prototype Testing
4. Gas Generation and Internal Pressurization
5. Radiation and Ultra-violet Stability
6. Type A Packaging Requirements
7. Quality Assurance and Inspection
8. Remaining Technical Position and Other Considerations

3.2 Corrosion

3.2.1 Background

Because of its reputed high resistance to stress corrosion cracking, crevice corrosion, and chloride-induced pitting, when compared with austenitic stainless steels such as Types 304 and 316, Ferralium 255 is used in marine applications, the oil and gas (and petrochemical) industries, for pollution control equipment, and other applications where the combination of corrosion resistance and high strength are especially needed. There is little field experience, however, with F255 in long-term underground applications. Nor is there much information available in the open literature regarding the corrosion of F255 weldments and the potential for long-range pitting corrosion (for welded, as well as base, material). Concern existed regarding the potential effects of localized corrosion on the structural integrity of the FL-50/EA-50 container and the corrosion effects of various waste stream products, including sulfonated resins, organic liquids, and chlorides; though these matters were addressed indirectly in the report through an analysis that was intended to be bounding, that analysis did not provide adequate assurance that every possible corrosive chemical was accounted for.

Certain administrative procedures were to be implemented to identify and preclude incorporation of undesirable chemicals, but the procedural details were not provided. Substantive information on these matters was needed before it could be confirmed that the NuPac FL-50/EA-50 HIC meets the 300-year structural stability requirement. Accordingly, NuPac was asked (Ref. 8) for considerably more information concerning (a) the metallurgical aspects of F255 corrosion, as well as (b) waste stream or other environmentally-related effects. The following discussion of F255 corrosion addresses the review in the context of these two groups of concerns.

3.2.2 Corrosion-related Metallurgical Factors

3.2.2.1 Corrosion Performance of F255 Welds

In addressing the corrosion behavior of welded F255, NuPac (Ref. 10) cited (a) certain metallurgical characteristics of the alloy that rendered it less susceptible than other stainless steels to intergranular and pitting attack and

(b) welding procedures that would be followed to lessen the likelihood of corrosion problems with weldments. With regard to advantageous metallurgical characteristics, NuPac pointed out that the reason that austenitic stainless steels are susceptible to heat-affected-zone (HAZ) stress/corrosion cracking (SCC) is that chromium-rich carbides are formed at the grain boundaries during welding.

Low-carbon versions of the austenitic stainless steels (e.g., 316L) have been developed to lessen the HAZ problem in those alloys. Ferralium 255, however, has a typical carbon content of only 0.02%, which is even lower than the carbon content (0.03% max.) used in the low carbon version of austenitic steels such as 316L. According to NuPac, microstructural examinations of HAZs in Ferralium have failed to reveal "sensitization" (i.e., grain boundary carbide formation) as encountered in 316 SS weldments.

It was also asserted by NuPac that the Electro Slag Remelting process, which is used to produce the Ferralium F255 alloy, greatly reduces or eliminates the types of non-metallic inclusions that act as preferential sites for localized attack in acid chloride solutions. Therefore, superior performance under conditions conducive to localized corrosion would be expected. This would be true for weldments as well as parent material.

To provide assurance that the intrinsic corrosion-resistant nature of as-manufactured F255 would be preserved in welded metal, NuPac affirmed that all welding procedures utilized in the FL-50/EA-50 HIC fabrication would be developed and qualified in strict accordance with ASME Section IX requirements. Specific details regarding welding specifications, required tests, and inspections were provided in the response (Ref. 10) to NRC staff comments. Typical drawing, planning, and procurement documentation was also provided.

During the course of the review of the topical report it became apparent that there was some conflicting information in the literature regarding the recommended welding parameters (e.g., heat input and rate of cooling) for F255. As explained in NuPac's response (Ref. 10) to the staff's questions, the apparent inconsistency stemmed from differences in the wrought versus cast versions of F255. Recent work on welding parameters for F255 has been documented (Refs. 11, 12, 13) by Cabot, and NuPac will follow Cabot's recommendations in welding F255 HICs.

Intercomparative data[2] on the Ferralium 255 duplex stainless steel and 316 austenitic stainless steel were also used as supporting evidence for the

[2] Austenitic stainless steels are a class of corrosion resistant alloys for which there is a considerable body of test data and substantial experience (some of which involves underground applications). Hence, an intercomparison of the FL255 alloy (which is relatively new) with an established older alloy such as 316 stainless steel provides a measure of the relative merit of the newer material.

expected satisfactory service performance of F255 weldments. In laboratory tests involving the use of (a) potentio-dynamic polarization curves to determine pitting potential in various environments and (b) chloride pitting and crevice corrosion tests, it was shown that while there were instances where the performance of F255 and 316L SS was similar, there was no case where the performance of F255 was inferior to 316L. In 5% NaCl, 316L SS welded samples pitted in the weld, whereas no pitting was observed in F255 in the welded or unwelded state. Hence, the test results showed that F255 weldments generally were superior to 316L SS weldments. This demonstrates that F255 welds should provide even greater assurance of structural integrity and a higher safety margin regarding the required HIC design life of 300 years than would 316L stainless steel.

The performance of austenitic stainless steels in soil environments is discussed in Section 3.2.2.3 of this evaluation report. Based upon the totality of evidence regarding the performance of F255 weldments and NuPac's procedures for assuring satisfactory performance, the staff concludes that there is reasonable assurance that welding of NuPac FL-50/EA-50 F255 HICs will not impair the uniform or stress/corrosion cracking resistance of the HICs.

3.2.2.2 Pitting Corrosion Repassivation

As noted earlier, F255 corrosion test results reported in the open literature suggested that uniform and pitting corrosion rates would both be low. F255 microstructural considerations, discussed in the previous section, also suggested that F255 was quite resistant to pitting corrosion, even in the welded state. There was a concern, however, about the potential for non-passivation of corrosion pits, should corrosion pits ever be initiated. NuPac was, therefore, asked to perform cyclic voltammetry tests on F255 to assure that pitting corrosion, if initiated, would not progress to premature loss of structural integrity of the HIC.

The cyclic polarization tests, which were performed (using simulated solutions) on base metal as well as weldments of both the F255 and 316L SS, showed that there was a lack of hysteresis in all the polarization curves obtained with F255. This result, coupled with the lack of any visible pitting, confirmed the expected high resistance to pitting in F255. In contrast, significant visible pitting and significant hysteresis of welded 316L SS occurred, thereby demonstrating both the superior pitting corrosion resistance of F255 as well as the efficacy of the cyclic voltammetry test.

3.2.2.3 Field Experience with Comparative Alloys

Due to the relatively short time (less than 20 years) that duplex stainless steels such as F255 have been in existence, there is limited field experience with such alloys in soil environments. Some experience does exist, however, with other more common corrosion resistant alloys such as the 300-series austenitic stainless steels. NuPac was, therefore, asked to document such field experience (in a variety of soils with the comparative alloys) that would demonstrate reasonably satisfactory performance of the comparative alloys in those applications. That experience would serve as indirect evidence that the F255 alloy would serve adequately in the proposed application inasmuch as the F255 exhibits superior corrosion resistance to the austenitic alloys in laboratory tests.

In response, NuPac pointed out that stainless steels have not generally been used in underground applications because of cost considerations and the availability of other less expensive corrosion prevention techniques. Where stainless steel pipelines have been installed, there have been mixed results, primarily because pipelines cross a variety of soils with varying resistivities that result in the creation of "long-line currents" that, in the absence of cathodic protection, will cause corrosion. Pipelines installed a few feet below the surface of the ground also are subject to corrosion associated with bacterial decay of organic material.

While pipeline experience with austenitic stainless steels has not been totally satisfactory, NuPac contends that such experience may not be completely applicable to HIC burial because HIC's are buried deeper than normal pipelines and are more isolated electrically. On the other hand, where stainless steels have been used in small amounts for fasteners, hose clamps, couplings, and the like in underground applications, the results reportedly (Ref. 10) have been excellent.

Tests performed with 300-series stainless steels in soil environments have generally been good, although in some samples taken from the more acidic and harsher soils, some pitting corrosion has been noted. These studies indicate that the common stainless steels, while they show substantial resistance to corrosion in long-term burial applications, also have some weaknesses such as pitting. For a given thickness of metal, they thus appear to have less margin to meet the 300-year service life required for HICs.

Inasmuch as F255 has been demonstrated to have significantly higher pitting resistance than the common 300-series stainless steels, particularly when considering attack by chloride, (and taking into consideration the expected chloride concentrations, moisture content, and pH levels at the Barnwell and Hanford sites), the staff concludes that the F255 FL-50/EA-50 HICs will perform better than the 300-series stainless steels would be expected to at those sites.

3.2.2.4 Crevice Corrosion

Hypothetically, there is a potential for crevice corrosion in the area of the HIC between the container and the lid/gasket. As noted (Ref. 10) by NuPac, however, crevice corrosion testing performed with 10% ferric chloride and other solutions has shown that the temperature required for crevice corrosion is much higher than the temperatures that would be encountered at low level radioactive waste burial locations. The burial site chemical environment would, of course, be much less severe than the conditions imposed in laboratory corrosion testing. The staff, therefore, concludes that there is reasonable assurance that crevice corrosion will not be a significant problem with the NuPac FL-50/EA-50 HIC.

3.2.2.5 Effects of Localized Corrosion on Structural Integrity

In the analysis of the structural adequacy of the FL-50/EA-50 HIC (discussed in more detail in Section 4 of this staff evaluation), a wastage allowance approach is applied to account for uniform corrosion of the container. That is, it is assumed that a portion of the total 3/8 inch thickness of the F255 SS is corroded away by uniform corrosion, and the stresses developed in the HIC due to burial loads are then compared to the allowable stresses. For reasons discussed elsewhere in this Staff Evaluation, staff considers it unlikely that uniform corrosion would result in this magnitude of HIC wall thickness loss; rather, it appears more likely for the F255 container to be attacked by localized corrosion. NuPac was, therefore, asked to provide a structural analysis that would address the potential effects of localized corrosion on structural integrity.

To calculate the minimum weld thickness (the welded areas would be most susceptible to localized corrosion) required to prevent structural instability, the highest stressed element was identified, and an estimate of the allowable pitting damage was obtained by calculating the maximum allowable uniform weld reduction. That value (based on a 80,000 psi y.s. for F255) is greater than the wastage allowance for uniform corrosion of the HIC wall. The reduction in weld thickness would reduce the welds' moment carrying capability, but if a weld were pitted, the remaining non-pitted portion of the weld would still not be reduced in thickness (neglecting uniform corrosion) and would thus maintain a moment carrying capability. It would, therefore, require a gross amount of pitting to achieve a condition of structural instability.

Thus, in view of the inherent superior localized corrosion resistance of F255, and taking into account the environmental conditions expected at the Hanford and Barnwell burial sites, staff concludes there is reasonable assurance that localized external corrosion will not threaten the structural integrity of the HIC over its 300 year design life. More information on environmental factors is presented in the following subsection of this staff evaluation.

3.2.3 Environmentally-Related Corrosion Factors

3.2.3.1 General

The discussion presented in Section 3.2.2 of this Staff Evaluation centers primarily on metallurgical factors that govern the corrosion resistance of the Ferralium HIC. In Section 3.2.3 the focus is on environmental factors (internal as well as external) that were considered in assessing the 300 year corrosion performance of the HIC.

As noted earlier, a wastage allowance (i.e., thickness of material allocated for corrosion) approach was used in the FL-50/EA-50 HIC design; that is, a portion of the total 3/8 inch wall thickness is allocated for uniform corrosion. In assuring that the allowable uniform corrosion rate would not be exceeded, NuPac considered the possible external environments of the burial trench as well as the internal environment that would be provided by various waste streams.

With regard to the external environment, NuPac asserted that data on soils and their corrosive characteristics (Ref. 9) indicate that the soils in the current disposal sites are not necessarily more corrosive than other soils where austentic stainless steels have been tested and demonstrated to be highly resistant to both pitting and general attack (Ref. 14). While the possibility exists that the burial trench groundwater could, in fact, be considerably more agressive than would be encountered in native virgin soils (due to contamination from chloride or organic compound-bearing chemicals), NuPac contended that the expected soil contamination levels are well below those that would affect the F255 alloy.

Based upon comparison of the burial site soil analyses with corrosion test results and field experience with various stainless alloys, the staff would not expect the external (soil) environment to pose a threat to the structural integrity of the FL-50/EA-50 HIC. (See the following subsections for details.)

With regard to waste stream effects on the internal environment of the HIC, the situation is considerably more complicated because it is a function of many factors, including the type of waste, temperature, oxygen concentration, the history of the waste stream, and the waste stream itself. It was acknowledged by NuPac that some detrimental environments could exist. The analyses and adminstrative procedures that were developed to address the potential environmental parameters are summarized in the following subsection, 3.2.3.2.

3.2.3.2 <u>Review Areas Concerning Environmentally Related Corrosion Factors</u>

In the topical report, the analyses of environmentally related corrosion factors focussed primarily on two major areas: (a) soil characteristics (e.g., pH, chloride concentration, water content, organics) and (b) a "worst case" analysis of bead resin corrosion effects. A series of questions concerning these subject areas were raised by the staff. The subject matter and the responses to the Staff's questions are too lengthy and complex to cover in detail here, but the following points summarize the situation.

(1) Several pH ranges are addressed in the topical report. They deal with the pH range for soils (4.0 to 11.0), the pH range for ion exchange resins (taken as 0 to 14), the minimum pH for trench sump liquid (assumed to be 2.4) and a limiting pH of 3 on liquid bearing waste containing more than 2% free halogens. The latter is used to establish a so-called "corrosion criterion" as follows: "The liquid portion of the waste must have a pH greater than 3. If not, then the waste stream must have less than 2% by weight of ionic halogens."

    This criterion was developed by considering (a) the maximum acceptable (uniform and pitting) corrosion rate compatible with preserving structural integrity; (b) the corrosion rates associated with possible waste streams and (c) practical limitations imposed on the container by the potential waste forms.

(2) The practical application of the corrosion limitations placed on the container is provided in a section of the report that contains the responses to Staff questions that deal with a proposed container operating procedure. It is intended by NuPac that the procedure should be followed by all users of the FL-50/EA-50 HIC. Included with the operating procedure is a chemical compatibility flow diagram and check off procedure. Waste streams that would contain liquids with pH less than 3 or halides (chloride or fluoride) greater than 2% by weight would have to be neutralized, diluted or excluded from the container.

Other provisions are made for the use of a vent (to accomodate potential gas generation due to biodegradation) and short-term temperature excursions (to allow filling of the HIC with materials at greater than ambient temperature).

Users of the FL-50/EA-50 HIC will be required to certify that they have complied with all the operating procedures and that the HICs do not contain proscribed chemicals. A copy of the Operating Procedure required for FL-50/EA-50 HIC users is provided as an appendix to this evaluation report.

(3) Regarding the chemical compatibility of ion exchange resins with the HIC, a theoreotical "worst case" analysis was presented in Appendix Q of the as-submitted report. Rather than rely solely on that analysis, the NRC staff asked NuPac to (a) propose the waste streams that the FL-50/EA-50 HIC would see the products of, (b) examine the applicable test data, and (c) show by analysis that the environment that the HIC will be subjected to would not be unacceptable. In response, NuPac presented an analysis that centered around data concerning the titration of ion exchange resins and the pH of contacting water. It was shown, that even with very low pHs (simulating radiation damage effects), corrosion rates were well within the uniform corrosion limit for the HIC.

A revised Appendix Q was submitted as a theoretical backup analysis for an extreme analytical case. The results of the Appendix Q revision indicated that dewatered resins could simulate 10-20% sulfuric acid, which while it was considered excessive for 316 stainless steel, would not result in violation of the uniform corrosion limit for F255.

(4) In addition to the above points, NuPac also addressed (a) the potential need for organic solvents exclusion and pre-treatment, (b) the potential for growth of micro-organisms, (c) effects of sulfur compounds, (d) trench and organic liquid chemical corrosion resistance, (e) chloride content of soils, and (f) effects of radiation on pH. In all cases, the Ferralium container was shown, on the basis of analyses coupled with applicable

data, not to be significantly affected by the postulated plausible environmental condition.

The staff concludes, on the basis of the analyses and data presented in the FL-50/EA-50 report and responses to Staff questions that there is reasonable assurance that the FL-50/EA-50 HIC, if used within the bounds prescribed by the proposed operating procedures, will not suffer a loss of structural integrity over its 300 year design life due to corrosion effects.

Verification of acceptable performance can be provided by means of periodic surveillance of archival specimens (see Section 3.9 of this Staff Evaluation Report). It should be noted that users of the FL-50/EA-50 HIC will have to comply with all state requirements and criteria for a particular LLW burial facility. For example, South Carolina requires waste forms to be within a pH range of 4 to 11. That requirement will thus apply to any FL-50/EA-50 HICs that are buried at Barnwell, regardless of the pH <3 "corrosion criterion" proposed by NuPac.

3.3 Structural Analyses

Burial depths at the Hanford, Washington site do not exceed 45 feet, which corresponds to an external pressure of 37.5 psi on the container, while the 25 feet maximum burial depth at Barnwell, South Carolina corresponds to a container external pressure of 20.8 psi. In the original design of the FL-50/EA-50 HIC, the side walls were 1/4 inch Ferralium, and the HIC had only two internal supports. Reanalyses by NuPac, however, led to two major design changes that were related to the structural analyses of other members of NuPac's Enviralloy HIC family: (1) an increase in the HIC wall thickness to 3/8 inch, and (2) the use of four internal supports. These changes were intended to improve the structural design margin for the HICs.

In examining the February 1985 responses to NRC Staff questions, however, it was discovered that there were some areas that required further clarification and elaboration. These included, in addition to some aspects of the structural analysis, they included some aspects of the special vent design, proposed short term temperature limits for the loaded Enviralloy (F255) HICs, and the need for a clearer commitment to provide surveillance specimens. These concerns were transmitted to NuPac both orally and in writing (Ref. 15), and resulted in substantial revisions to the topical report and in responses to questions that were resubmitted (Ref. 16) in May 1985.

3.3.1 Burial Loads

One of the areas in the HIC structural analysis that required further attention was the effects of burial loads. Basically, the Staff concluded that it had not been adequately demonstrated that the HIC could withstand the predicted burial loads. Specifically, additional information was required (Ref. 15) concerning (a) the calculation of a critical buckling stress, (b) applied loads resulting from placement of the HIC in a non- vertical position in the burial trench, (c) the determination of an allowable stress intensity value, and (d) various details of the structural analysis of the internal vertical angle supports. In a telecopied response (Ref. 16(a)), which was later followed with a formal submittal (Ref. 16(b)), NuPac satisfactorily addressed the staff's concerns.

In brief, it was demonstrated that (1) the HIC did not have a stability problem due to buckling (2) there was significant margin for loading due to side burials of the HICs and (3) the stability of the internal vertical supports was adequate. While the staff did not accept NuPac's approach for deriving an allowable stress intensity for the primary membrane plus bending stress, the difference of opinion was moot inasmuch as none of the burial stresses in the container, whether in the as fabricated or "corroded" (minus the wastage allowance) state, exceeded the published yield stress of 80,000 psi for Ferralium 255.

It should be noted that NuPac analyzed the FL-50/EA-50 HIC for displacement and stresses utilizing a general purpose finite element code called ANSYS (Revision 3, Update 67L). ANSYS is a widely used and accepted finite-element analysis tool that has undergone extensive benchmarking to demonstrate its reliability for structural analysis. The assumptions used in applying the ANSYS model to analyze the behavior of the FL-50/EA-50 HIC under various loadings are described in the structural analysis section of the topical report. A discussion of the elements used and the output generated by the code are provided in various appendices of the topical report. The staff concludes, on the basis of the information provided, that there is reasonable assurance that the FL-50/EA-50 HIC is adequately designed for all conceivable burial loads.

3.3.2 Drop Test Load Analyses

In addition to the analyses of burial loads, NuPac attempted to estimate the loads that would be incurred on various components of the HIC during the drop testing of HIC prototypes. Those calculations, presented in Section 3 of the topical report, addressed such things as the load on the lid during flat-ended and corner drop tests. Several questions were raised by the staff concerning these analyses. Most of the questions dealt with the need for clarification of portions of the report text. A couple of the questions concerned the values used for the maximum payload and gross weight of the container.

In response, NuPac stated that the drop analyses were performed to provide an approximation of the conditions that would be imposed on the HIC during the drop tests and that the actual qualification of the container was based on the drop test results (see Section 3.4). Clarification of the report text was provided where needed, and certain typographical errors were corrected. With regard to the container gross weight, NuPac stated that the maximum gross weight of the FL-50/EA-50 HIC is 4200 pounds and that the user will be required to limit the HIC contents such that this gross weight is not exceeded. The 4200 pound limit meets shipping container licensing requirements.

3.3.3. Thermal Stresses

The HIC will be subjected to some thermal loads due to solar heating during transportation. Differential thermal expansion between the container and the lifting straps, for example, could occur, and a "worst case" or bounding value was calculated. A quantitative analysis of the resultant stresses in the straps or surface of the HIC, requested by the staff, showed that there was a significant safety factor, based on the difference between the maximum thermal stress and the yield stress of the material.

With regard to burial thermal loads, the relatively low burial temperature envelope at Barnwell and Hanford (68°F±18°F) would not be expected to be a factor. Mechanical strength properties of F255 decline gradually with increasing temperature (e.g., strength properties at 200°F and 400°F are reportedly 8.6% and 12.6% less, respectively, than room temperature values). Therefore, any increase in temperature of the HIC that might ensue due to soil insulating effects or the near proximity of other heat-generating wastes would not be expected to significantly affect the HIC. Likewise, temporary storage above ground in a storage facility would not be expected to be a significant factor.

3.4 Prototype Testing

3.4.1 Drop Tests

The HIC should be capable of meeting the requirements for a Type A package as specified in 49 CFR 173 and 10 CFR 71, as applicable to metallic containers (Ref. 2). With regard to drop test requirements, the applicable criteria are provided in 10 CFR 71.71. For the FL-50/EA-50 HIC, which will have a gross weight under 4250 pounds, free drop tests (with the HIC loaded to the maximum gross weight) onto an unyielding surface, from a variety of orientations (i.e., flat and corner drops) were performed. Except for a dent about 1/4 inch deep in the side wall (of a HIC with the original 1/4 inch wall) after a corner drop test, no visible damage ensued. Importantly, there was no loss of contents from the container due to cracks or rupture of the seal.

Similar results were obtained from a full series of drop tests performed from 25 feet onto compacted sand. In this series of tests, the container included a lead gasket. The lead gasket maintained a positive seal. The only visible damage that ensued from the 25 foot drop tests consisted of a denting (about 5/8 inch maximum) of the impacted side betwee the two end plates following a side drop. There was no loss of contents resulting from any of the 25 foot drop tests, nor did a magnetic particle test performed on the closure welds indicate any loss of structural integrity. Angles welded to the lid that serve as handles were broken at the welds after the 25 foot top down drop test, but these are non-structural components of the container and their failure did not affect container integrity.

After one drop test, which was an early test conducted on a container with a gross weight of only 3000 pounds, a crack was detected in one of the welds.

That crack was determined to be due to a weld defect, however, and was not the result of a design deficiency. NuPac has provided assurance that future inspection procedures, to be used on production containers, will preclude the presence of similar weld defects. The staff concludes, on the basis of the submitted information, that the FL-50/EA-50 HIC has satisfied the criteria for free drop tests for high integrity containers specified by NRC staff and the States.

3.4.2 Type A Package Criteria

A high integrity container for low-level radioactive waste should be capable of meeting the "normal conditions of transport" criteria for Type A packages in 49 CFR 173 and 10 CFR 71, as applicable to metallic containers (Ref. 2). Criteria used are those contained in Section 71.71(c), 10 CFR Part 71. Of the Type A package test criteria, the results of drop tests are addressed in Section 3.4.1, above. Other tests, or analyses performed in lieu of tests, are addressed in the following sections.

Penetration Test

A penetration test was performed using the criteria in 10 CFR 71.71(c)(10). In this test a vertical steel cylinder 1-1/4 inch in diameter, weighing 13 pounds, and with a hemispherical end, was dropped from a height of 40 inches onto an exposed surface of the container with no measurable effect.

Water Spray Test

Since the FL-50/EA-50 HIC is fabricated from a duplex alloy steel, the water spray test (which simulates exposure to rainfall) described in 10 CFR 71.71 (c)(6) was not performed. The staff concurs with NuPac's position that metallic stainless steel packages will undergo no measurable physical change when exposed to the equivalent of two inches of rainfall for one hour.

Vibration Testing

The test criterion for vibration normally incident to transport is contained in 10 CFR 71.71(c)(5). Inasmuch as the FL-50/EA-50 HIC is a welded metallic structure with which closure is accomplished by 8 retaining blocks that lock positively into the structure of the container, there is no credible physical way for shock and vibration normally incident to transportation to affect the integrity of the HIC. Also, inasmuch as the F255 alloy exhibits low temperature toughness characteristics similar to the commonly used ASTM A516 fine grain practice steels, vibration effects would not be expected to be a problem even at low temperatures that might be encountered during winter transport. Consequently, staff concurs in NuPac's decision not to conduct vibration testing.

Compression Testing

Criteria for compression tests are addressed in 10 CFR 71.71(c)(9). The compressive load to be applied to the HICs during these tests must be either the equivalent of five times the weight of the package or 1.85 psi multiplied by the vertically projected area of the packages, whichever is greater. As noted in Section 3.3.1 of this staff evaluation, however, the FL-50/EA-50 HIC is designed to withstand burial loads of at least 37.5 psi (corresponding to the 45 foot burial depth at Hanford). This corresponds to a projected load that is more than three times the 21,000 pound load that is obtained by multiplying the 4200 pound gross weight of the container by a factor of five. Therefore, the compression test was not conducted on the FL-50/EA-50 HIC. The staff agrees with NuPac's contention that the test is not warranted for this particular HIC.

Pressure Testing

The criterion for a "reduced external pressure" test, corresponding to an external pressure of 3.5 psia, is contained in 10 CFR 71.71(c)(3). This corresponds to a pressure differential of 11.2 psi (that is, 14.7 psia internal pressure at sea level atmosphere at time of lid closure, minus 3.5 psia). The FL-50/EA-50 HIC was pressure tested with a silicone rubber gasket, using water as the pressurization medium. Leakage past the gasket occurred at 75 psig. A separate test with a lead gasket, following a drop test, resulted in a positive seal until 20 psig pressure was achieved. The FL-50/EA-50 HIC thus was demonstrated to meet the reduced external pressure requirements. No increased external pressure tests were conducted, inasmuch as the HIC, as discussed in Section 3.3.1 of this report, was shown by analysis to be able to withstand the 37.5 psi burial loads with margin.

3.5 Gas Generation and Internal Pressurization

One of the design changes made to the FL-50/EA-50 HIC involves the incorporation of a passive vent system (to be used for non-tritium wastes) to allow relief of pressure generated by gases resulting from possible biodegradation or radiolytic decay. The concern about internal gas generation originated from experience with a few polyethelene containers that exhibited symptoms of excessive gas generation (for example, had become stuck in their transportation casks due to the swelling resulting from generation and internal pressurization). This had resulted in a request (Ref. 17) by the State of South Carolina Department of Health and Environmental Control for consideration of a passive ventilation system as a design feature that would alleviate the problem.

After due deliberation, The NRC Staff concluded that the installation of vents, in all HICs, not just polyethylene ones, would be a prudent way to address the potential symptoms of the problem with gas generation. The approach thus provides a means to minimize the effects of gas generation (e.g., over-pressurization of the HIC) on handling, personnel safety, and long-term integrity of the container. The use of vents is intended to be an interim measure, which would address the symptoms and preclude any serious effects of gas generation, while allowing a long-term solution to be arrived at via a study that would identify the specific cause of the gas generation.

Accordingly, the passive vent system that NuPac currently proposes to use in the FL-50/EA-50 HIC would be basically comprised of a permeable plug of polymeric material placed in the lid of the container in a manner that will minimize any effects on the structure of the container and the possibility of damage from exterior objects. The vent material was chosen on the basis of its radiation resistance, lack of influence on corrosion, chemical resistance and hydrophobic nature. The vent will permit the relief of internal pressure by allowing the passage of gas while still minimizing the ingress of water as recommended by the Technical Position on Waste Form (Ref. 2). Samples of the polymeric material have been tested (Ref. 16(b)) for both air and water flow at various pressures, and have demonstrated satisfactory performance. The staff concludes that there is reasonable assurance that the passive vent system coupled with the back-up capability provided by the silicone rubber gasket, will provide an adequate means to allow for the release of pressure due to gas generation resulting from biodegradation or radiolytic decay.

It should be noted that the passive vent system, though it has been designated "optional" by NuPac, is in fact mandatory because it is the current primary pressure-relieving system for all the FL-50/EA-50 HICs except those that will be used for tritium containing wastes. In the latter case the HIC will have a lead gasket with no passive vent. This lead gasket/no vent design provides reasonable assurance of the containment of the tritium gas.

3.6 Radiation and Ultra-Violet Stability

The radiation stability of proposed container materials as well as radiation degradation effects of the waste itself, should be considered in the design of the HIC. No significant changes in material design properties should result following exposure to a total accumulated dose of 10^8 Rads. (Ref. 2)

For the FL-50/EA-50 HIC, the basic material of construction, Ferralium 255, would not be expected to be affected by radiation from low-level wastes. This is so because radiation damage, in the form of swelling and embrittlement, is caused in metals by neutron radiation, but these HICs will not contain detectable levels of neutron radiation producing materials.

The only components not made out of the F255 alloy are the gasket and the vent. Neither one of these items affect the structural integrity or stability of the container. However, because the topical report contained information indicating that the silicone rubber gasket material had a 20% compression set after exposure to 1×10^7 Rads, further information was requested regarding the testing and capabilities of the gasket.

In response (Ref, 10), NuPac noted that information in the open literature (Ref. 18) indicated that a compression capability of about 10% was obtained in testing to radiation exposures of 10^8 Rads. Although this might not be considered sufficient for applications where the gasket might be subjected to impact loading (as might be encountered during transportation), we agree with NuPac's assertion that under burial conditions there is no mechanism for the gasket material to move. The staff concludes that there is reasonable assurance that the silicone rubber gasket will perform as an effective barrier. The optional lead gasket is not affected by gamma radiation at the 10^8 Rad level and is thus also acceptable from a radiation stability standpoint.

Another component of the HIC outer wall that is not constructed of metal is the passive vent. The vent is basically comprised of a permeable plug of polymeric material, which reportedly (Ref. 19) has good resistance to gamma radiation in excess of 10^8 rads. Inasmuch as the vent does not carry any significant load, any reduction in mechanical properties that might occur as a result of radiation will not affect the performance of the HIC.

In regard to the effect of radiation on the contents of HICs, NuPac indicated (Ref. 10) that only the demineralization resin media have the potential to be affected by radiation in such a manner that they may affect the container. The resin media may undergo radiolysis to produce gas within the container. The slow build-up of gas could be a potential problem (with regard to over pressurization effects) only if there were no provision for pressure relief. Inasmuch as the passive vent will permit the alleviation of the pressure, however, the radiolysis of wastes is not expected to result in over pressurization of the HIC. The potential effect of ultra-violet (UV) radiation on the silicone rubber gasket should also be insignificant, in view of the fact that most of the gasket is shielded from such radiation by the metallic lid and top of the HIC during transportation; after the HIC is buried, it will not, of course, be subject to ultra-violet rays. UV radiation effects on the vent material due to exposure during storage would be limited by covering the vent with UV opaque material (see the Operating Procedure, Section 5.5).

The staff concludes that there is reasonable assurance that the effects of radiation have been adequately considered in the design of the FL-50/EA-50 HIC.

3.7 Quality Assurance and Inspection

High integrity container should be fabricated, tested, inspected, prepared for use, filled, stored, handled, transported and disposed of in accordance with a quality assurance program (Ref. 2). Because the assurance of proper procedures for container fabrication, testing, transportation, storage and use is critical in several areas, the NRC Staff issued (Ref. 8) several questions and comments concerning this subject. NuPac's responses (Ref. 10) can be separated into two general areas: (1) those matters having to do with fabrication, testing and inspection (i.e., operations performed by the vendor or which are directly under the control of the vendor), and (2) items to be addressed by the user.

With regard to the first category of operations, NuPac presented a substantial amount of information, including documentation on required inspections, referenced procedures, and specifications and procurement. All the FL-50/EA-50 HICs will be fabricated and inspected in accordance with NuPac "QA Level 1" criteria. According to NuPac, the Level 1 inspection activity fully meets the requirements of (1) ANSI N 45.2, (2) 10 CFR 50, Appendix B, and (3) 10 CFR 71, Subpart H. This level designation is established after Quality Engineering review of the contract, regulatory, design and fabrication requirements. Specifically required tests, inspections, material controls and data review requirements are then delineated in the inspection planning, drawings, referenced procedures and specifications and related procurement documents. NuPac's program for inspection to assure compliance with material and construction specifications is delineated in a QA manual.

With regard to user QA requirements, the Operating Procedure (Appendix of this report) prescribes procedures to be adhered to by users of the FL-50/EA-50 HIC to assure compliance with handling and material restrictions. HIC users will be required to certify that all required procedures and restrictions have been satisfied. The staff concludes that there is reasonable assurance that quality assurance requirements have been adequately addressed for the FL-50/EA-50 HIC.

3.8 Miscellaneous Requirements

The preceding sections of this Staff Evaluation Report address the technical areas that received the most attention during the course of the review of the FL-50/EA-50 HIC topical report. These items received the most attention because they were deemed to be the most critical with regard to influencing the structural integrity of the HIC. The subjects discussed in the following paragraphs of this subsection, though not trivial, were simpler in scope and in most cases easier to resolve than those addressed earlier.

3.8.1 Free Liquid

The FL-50/EA-50 HIC is designed for containing waste with less than 1% free liquid by volume. Because various types of waste are to be immobilized within these HICs, a variety of dewatering procedures could be used. NuPac has submitted a topical report, No. TP-02, "Dewatering System," dated August 6, 1984 that contains information on the dewatering for these containers.

With regard to the potential effects of dewatering internals on the HIC, NuPac has stated (Ref. 10) that all internal protrusions will be made of a plastic material. All metallic parts of a dewatering system would be restrained from contacting the sides of the HIC by either non-metallic portions of the dewatering structure or by the waste form. Therefore, the dewatering internals should not pose a problem with regard to (a) forming a corrosion couple with the Ferralium 255 HIC or (b) possibly penetrating the HIC during a drop event.

3.8.2 Creep

Design mechanical tests for polymeric material should be conservatively extrapolated from creep test data (Ref. 2). However, inasmuch as the FL-50/EA-50 HICs are to be fabricated from a high strength stainless steel (Ferralium alloy 255), creep of the stainless steel will be negligible under any conceivable condition that the HICs might have to endure. With regard to complicating effects of prolonged waste dewatering times, and a list of the most common fatty acids were submitted as an attachment to the response (Ref [illegible]) to Staff questions. The Operating Procedure, to be followed by HIC users, addresses the practical application of limiting organics, the length of dewatering, and other appropriate related concerns.

While staff does not believe that NuPac's contention about the role of fatty acids in the biodegradation process is particularly persuasive, because there is contrary evidence available from experience with operating reactor wastes, the fact is that (a) Ferralium 255 is very resistant to corrosion, (b) operating procedures (Appendix A) will preclude the loading of the most potentially troublesome waste materials, and (c) the passive vent will allow for relief of any internal pressure generated by biodegradation of wastes containing deleterious chemicals such as fatty acids.

Considering these factors, the staff concludes that there is reasonable assurance that (a) biodegradation of the HIC material (Ferralium 255) is so extremely unlikely that biodegradation testing of the alloy in accordance with ASTM or other standardized tests is unnecessary, and (b) significant biodegradation of wastes, leading to a loss of structural integrity of the HIC (resulting from, for example, corrosion of the F255 alloy or extensive gas generation that would not be alleviated by the passive vent) is also unlikely.

3.8.4 Top Surface Water Retention

The HIC should be designed to avoid the collection or retention of water on its top surfaces to minimize the accumulation of trench liquids that could result in corrosive or degrading effects. NuPac has designed the HIC so that the retaining ring at the center of the upper head is slotted such that any water entering the area can drain back out. All areas at the top head are designed to be self draining. The staff concludes that there is reasonable assurance that there will not be a corrosion problem with the FL-50/EA-50 HIC due to collection or retention of water on the top surface.

3.8.5 Cold Weather Testing

The test "criteria" for evaluating the container under normal conditions of transport includes determination of the effect of ambient cold temperatures as low as -40°F on the HIC design. Concerns about cold weather testing were expressed by the State of South Carolina (Ref. 20), and a multi-part question (No. 16) regarding the impact resistance of Ferralium 255 at low temperatures was generated by the NRC staff (Ref. 8).

In response, NuPac submitted (Refs. 10 and 16b) charpy impact data on welded Ferralium at temperatures as low as -100°F. While the impact strength of F255 weld metal decreases substantially with temperature, the charpy impact values for weldments, at 0°F for example, varied from greater than 10 ft. lbs. to approximately 20 ft. lbs. Even at -40°F, weld metal charpy impact values were equal to or greater than 8 ft. lbs. (Ferralium 255 base metal exhibits much creep of the gasket, there is metal-to-metal contact between the lid and the body of the HIC when the HIC is closed; therefore, the effects of gasket creep on HIC integrity are expected to be insignificant. The vent also is designed such that the creep load will be relatively low, and any effects of creep would not impact the service of the vent or integrity of the HIC. Hence, creep effects were not considered quantitatively in the review of the design of the FL-50/EA-50 HIC.

3.8.3 Biodegradation

The biodegradation properties of the proposed HIC materials, wastes, and disposal media should be considered in the HIC design (Ref. 2). Certain standardized tests are called for in the NRC Staff Technical Position on Waste Form (Ref. 2).

In the initial version (Ref. 6 and 7) of the FL-50/EA-50 generic topical report, biodegradation is addressed (see Section 2.0, Qualification of Container Material). As noted therein, biodegradation of a metal can be defined as the deterioration of the metal by corrosion processes that occur directly or indirectly as a result of the activity of living organisms. Subsequent discussion then addressed various aspects involving the presence of aerobic versus anaerobic bacteria. For clarification, the NRC Staff requested (Ref. 8) additional information concerning (a) the effects of potential sulfur-bearing compounds in the waste, (b) the magnitude of potential gas generation, and (c) the potential effects of aerobic bacteria in anoxic environments. NuPac's response (Ref. 10), which was quite comprehensive, basically can (along with the information in the original report) be summarized as follows:

(1) Any gas generation that might occur within the container would be relieved by the special vent, or if the vent were plugged by some unforeseen process, by the lid gasket (which under test was detected to leak at about 20 to 75 psig for the lead and silicone rubber gaskets, respectively).

(2) Given the limited amount of oxygen and light within the interior of a HIC, the only possible sustained growth of micro-organisms is through microbes that metabolize fatty acids as a carbon source. The most common fatty acids are rarely used at commercial power plants, and if they were used, they would, in most cases, be in low concentrations.

(3) If sulfate, sulfite, or other sulfur-bearing compounds were present in the waste that is placed in the HIC, and/or should the growth of either aerobic or anaerobic bateria occur, the end products would be low concentrations of sufuric acid and hydrogen sulfide. As described in the report, however, Ferralium 255 has been shown to be very resistant to corrosive attack by such chemicals. Therefore, the effect of their potential presence on the performance of the FL-50/EA-50 HIC is expected to be insignificant.

(4) An explanation of specific microbe metabolism methods, possible

higher toughness values than the welded material at low temperatures). Allowing for (a) the inherent difficulty in performing drop tests on fully-loaded FL-50/EA-50 HICs at temperatures as low as -40°F and (b) the fact that the charpy impact tests on weld material demonstrate significant toughness at low temperatures, the staff conclude that there is reasonable assurance that cold weather will not present an undue hazard with the FL-50/EA-50 HIC and that further testing at low temperatures is not required.

3.9 Surveillance

Generally, demonstration of the adequacy of any HIC design would involve three things: (1) laboratory testing, (2) analytical predictions, and (3) field experience. Because field experience with F255 in soil is sparse, there is some uncertainty regarding the possibility for synergistic effects or environmental degradation phenomena whose magnitude it may not be possible to predict or whose nature it may not even be possible to identify at this time. Final confirmation of the adequacy of a new HIC design such as NuPac's FL-50/EA-50 can, however, be provided over time through inspections of surveillance specimens buried at each licensed disposal site.

NRC is considering a plan for establishment of surveillance protocols involving "archival trench" burials of HIC specimens (and "mini - samples" of HIC materials) at LLW burial sites. NuPac was requested (Ref. 8) to agree in principle to providing F255 surveillance specimens for use in a long-term surveillance program, with the understanding that the details of the program can be established on a schedule independent of and possibly subsequent to, the approval of the FL-50/EA-50 HIC design.

In response (Ref. 16b), NuPac expressed a positive interest in supporting a surveillance program, centering around an "archival trench" concept in which surveillance specimens (for example, corrosion coupons or an actual HIC) could be placed for subsequent periodic retrieval and inspection under an established protocol. Until the specific details of such a program have been established, it is not practicable to mandate particular requirements or to expect vendors, burial site operators, state agencies, etc., to make circumstantial commitments. However, it should be noted that verification of the adequacy of a HIC design and materials of fabrication can only be provided directly through actual surveillance, which would involve periodic inspections over several years.

4.0 REGULATORY POSITION

NRC staff has completed its review of the topical report that is intended to serve as the referential document that describes the design of the NuPac FL-50/EA-50 high integrity container (HIC) for low-level radioactive waste and provides the basis for determining the adequacy of the HIC design. In its evaluation staff primarily focussed on (1) applicable sections of 10 CFR 61, 10 CFR 71, and 49 CFR 173 and (2) additional requirements proposed by state agencies. Based on its evaluation of the information provided in (a) the topical report (original submittal plus revisions), (b) written responses by

NuPac to NRC Staff questions and comments, and (c) meetings and telephone discussions with NuPac representatives and consultants, the staff conclude that there is reasonable assurance that, considering the proposed use of the NuPac FL-50/EA-50 HIC, the HIC meets the structural stability requirements of Part 61 and is consistent with the guidance presented in the NRC staff Technical Position of Waste Form.

This approval of the FL-50/EA-50 HIC and Topical Report is predicated on completion and issuance of the final Topical Report (proprietary and non-proprietary versions) according to review agreements and the following conditions:

(1) That the FL-50/EA-50 HIC shall be used in accordance with the Operating Procedure restrictions outlined in the Appendix to this Technical Evaluation and all additional restrictions and requirements specified by the burial site operators and governing state agencies.

(2) Users of the FL-50/EA-50 HIC shall certify that all restrictions and required procedures have been adhered to and that the HICs do not contain proscribed chemicals or waste materials.

Based on responses (Ref. 16) to questions, staff understands that NuPac will provide appropriate material specimens for a surveillance program where corrosion samples are to be buried in an archival trench at each LLW burial site and retrieved and inspected at periodic intervals.

5.0 REFERENCES:

1. 10 CFR 61, Licensing Requirements for Land Disposal of Radioactive Waste, U.S. Government Printing Office, January 1, 1985.

2. Technical Position on Waste Form, Rev. 0, U.S. Nuclear Regulatory Commission, May 1983.

3. Larry J. Hanson (NuPac), letter to Nancy Kirner (WA), File No. 58436.JCR, November 3, 1983.

4. T.R. Strong (Department of Social and Health Services, WA), letter to Donald A. Nussbaumer (NRC), January 5, 1984.

5. Leo B. Higginbotham (NRC), Memorandum for Donald A. Nussbaumer, "Technical Assistance to Washington State on the NuPac HIC," February 16, 1984.

6. John D. Simchuk (NuPac), letter to Michael Tokar (NRC), Subject: Affidavit to Withhold from Public Disclosure NuPac Proprietary Information on the Model FL50 High Integrity Container," File: FL50-G, February 13, 1984.

7. John D. Simchuk (NuPac), letter to Michael Tokar (NRC), Subject: NuPac Model FL-50 High Integrity Container dated 1/30/84, File: FL50-793, March 1, 1984.

8. Michael Tokar (NRC), letter to Richard T. Haelsig (NuPac), "Request for Additional Information on NuPac's Generic FL50 HIC Report," October 25, 1984.

9. P.L. Piciulo, C.E. Shea, and R.E. Barletta, "Analyses of Soils at Low-Level Radioactive Waste Disposal Sites," Draft Report, Brookhaven National Laboratory, BNL-NUREG-31388, May 1982.

10. Charles J. Temus (NuPac), letter to Michael Tokar (NRC), Subject: "NuPac FL-50/EA-50/EA-50, Response to NRC Questions, dated 2/85," File:680-15, March 1, 1985.

11. FERRALIUM Alloy 255, Cabot Bulletin H-2005.

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14. W. F. Gerhold, E. Escalante, and B. T. Sanderson, "The Corrosion Behavior of Selected Stainless Steels in Soil Environments," NBS Publication NBSIR 81-2228, February 1981.

15. M. Tokar (NRC), Telecommunications with C. J. Temus and S. D. Goetch (NuPac), April/May 1985.

16(a). C. J. Temus (NuPac), Telecopy to Dan Huang (NRC), "NRC Structural Findings," April 24, 1985.

16(b). C. J. Temus (NuPac), letter to M. Tokar (NRC), May 16, 1985, with Revised Responses to NRC Staff Comments.

17. Heyward G. Shealey (SC), letter to Stephen Goetsch (NuPac), September 27, 1984.

18. Robert Barbarin, "Selecting Elastomer Seals for Nuclear Service," Parker Hannifir Corporation/Seal Group.

19. R. EG. Jaeger, Compendium on Radiation Shielding, Springer-Verlag, 1975.

20. Virgil R. Autry (SC), letter to Donald A. Nussbaumer (NRC), September 17, 1984.

NUCLEAR PACKAGING

OPERATING PROCEDURE

FOR

ENVIRALLOY DISPOSAL CONTAINERS

WITH SERIES A (WEDGE) CLOSURE

OM-32

Rev. 1

AUGUST 29, 1985

Gary L. Clark	29 August 1985
Prepared By	Date
Engineering	9/5/85
	Date
D.E. Hill	9/5/85
Quality Assurance	Date
	9-5-85
Manufacturing/Production	Date
NA	—
Other	Date
	9.5.85
Document Control/Release	Date

ADDENDUM TO FL-50/EA-50 HIGH
INTEGRITY CONTAINER STAFF EVALUATION REPORT

June 1987

During the final review of the October 1985 Staff Evaluation Report concern was expressed by staff of the Transportation and Certification Branch of NRC's Division of Fuel Cycle and Material Safety that the use of Service Level C criteria of ASME Section III, Subsection NE was not appropriate. The staff proposed the more conservative Service Level A criteria as more appropriate considering the length of time and corresponding uncertainties associated with the performance period. The NRC concerns are summarized in a letter to NuPac (Ref. 21) and an internal memorandum (Ref. 22). A series of discussions between NuPac and NRC staff occurred between December 1985 and February 1986, resulting in submittal by NuPac of several proposed design criteria. Resolution was reached when NuPac indicated that Service Level A criteria would be utilized.

On October 29, 1986, NuPac documented the strutural revision by submitting a revised proprietary topical report for the FL-50/EA-50 High Integrity Container (Ref. 23). The more conservative requirements of Service Level A resulted in minor HIC redesign, mainly evident as an increased thickness to the lid. During January 1987, a non-proprietary version of the report was delivered to the NRC. The revised reports presented the analysis and redesign resulting from the criteria of Service Level A as well as changes reflecting NuPac responses to previous NRC comments.

Based on the review of the revised Topical Report the staff concludes that in addition to the requirements and recommendations of Part 61 and the Technical Position on Waste Form, the conditions for issuance of a final proprietary Topical Report discussed in the October 1985 Staff Evaluation Report have been satisfied. Issuance of a final non-proprietary Topical Report should incorporate the October 1985 Staff Evaluation Report and this Addendum.

ADDENDUM REFERENCES:

21. Thomas L. Jungling (NRC), letter to Charles J. Temus (NuPac), "Proposed HIC Structural Criteria," January 30, 1986.

22. Thomas L. Jungling (NRC), memorandum for Timothy C, Johnson (NRC), "Review of NuPac's Proposed HIC Structural Criteria," January 30, 1986.

23. Charles J. Temus (NuPac), letter to Thomas L. Jungling (NRC), Reference: "Enviralloy FL-50/EA-50 Topical Report," File: XX-7, October 29, 1986.

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ABSTRACT

The Nuclear Packaging Enviralloy FL-50/EA-50 High Integrity Container (HIC) has been designed to meet or exceed the criteria defined in 10 CFR Part 61 and the U.S. NRC Branch Technical Position Paper on Waste Form (BTP). The additional requirements of the States of Washington and South Carolina have also been addressed by the FL-50/EA-50 container.

At the heart of this design is the use of Enviralloy or Ferralium[R] Alloy 255 (UNS Designation S32550), a ferritic-austenitic duplex stainless steel. This material combines high mechanical strength, ductility, and hardness with high corrosion and erosion resistance. The use of this duplex material, together with design innovation and computerized stress analysis, has culminated in the development of a container with high strength, low weight, extreme durability, and superior corrosion resistance.

The corrosion resistance of Enviralloy to waste stream and burial trench environments is superior to that of the full austenitic Types 304 and 316 stainless steels. It has excellent resistance to sulfuric, phosphoric, nitric, and many other acids and salts as well as acetic, formic, and other organic acids and compounds. The material is particularly suitable for corrodant concentrations and temperatures where pitting and localized corrosion are common causes of failure with most conventional stainless steels in the presence of chlorides and other impurities.

The container design has been adequately demonstrated to satisfy all structural, chemical, radiation, lifting, biodegradation, and transportation requirements of the BTP and the appropriate states. This demonstration was accomplished through extensive research, conservative analysis, and prototypic testing of a full-sized container to provide adequate assurance for the 300-yr design life requirement.

This report contains the non-proprietary information of the FL-50/EA-50 Proprietary Topical Report.

1.0 INTRODUCTION

Nuclear Packaging, Inc. has developed a right cylindrical high integrity container (HIC) to meet the nuclear industries needs for long-lived stable disposable containers fitting the various transportation casks commonly used. The container is compatible with the many different waste streams and the burial environments. The Enviralloy FL-50/EA-50 high integrity container has been shown to meet the criteria of 10 CFR 61 for stable radioactive waste disposal packages.

The FL-50/EA-50 container is based on a common material which can accommodate the varied waste streams produced by the nuclear industry. The Enviralloy material is a duplex stainless steel manufactured by Cabot Corporation as Ferralium Alloy 255. This duplex stainless steel possesses superior corrosion resistance and high mechanical strength compared to austenitic steel. The duplex stainless contains both austenitic and ferritic phases in the matrix. The duplex microstructure imparts unique corrosion resistance and strength properties to this alloy. This alloy is superior to austenitic steels in pitting, crevice corrosion, and chloride stress corrosion cracking, typically the corrosion 'weak links' in austenitic materials. These properties are further aided by not only the high alloy composition of the chromium, nickel and molybdenum, but also close control of the austenitic and ferritic phases.

The high corrosion resistance of the material allows it to be used with the various waste streams of the industry and the soil environments of both the Hanford, Washington and Barnwell, South Carolina sites.

The Enviralloy FL-50/EA-50 HIC has been designed to contain the following dewatered waste forms regardless of the source:

a) Demineralization bead, powdered, and zeolite resins.

b) Filtration material such as sand, activated charcoal, and diatomaceous earth.

c) Compressible solid wastes.

d) Non-compressible solid waste.

e) Filter elements and cartridges.

f) Both solidified and dewatered resins, sludges.

g) Absorbed liquid wastes.

h) Any radioactive waste meeting class B or C limits and the chemical compatibility requirements of Section 5.0

Regardless of waste form, Enviralloy is highly resistant to corrosion for a wide assortment of chemical compositions. The corrosion resistance of Enviralloy is described in Section 5.0.

The high strength properties of the material allows for an efficient container maximizing transport cask cavity space utilization while simultaneously supporting imposed burial loads.

The Enviralloy FL-50/EA-50 container has a 24-inch opening which allows the container to handle a variety of waste forms. Section 2.0 describes this container in detail.

Sections 3.0 through 16.0 demonstrate the Enviralloy FL-50/EA-50's capabilities to meet the criteria of 10 CFR 61 for high integrity containers. The demonstration of compliance with the criteria as set forth by USNRC's Final Waste Classification and Waste Form Technical Position Papers, dated May 11, 1983, clearly shows the versatility and acceptability of the Enviralloy FL-50/EA-50 container to serve as a stable, durable high integrity container.

2.0 THE ENVIRALLOY FL-50/EA-50 HIGH INTEGRITY CONTAINER

For a container to qualify as a disposal package for radioactive material, it must meet many different requirements. It must have a minimum weight impact on the cask payload. It must allow for maximum utilization of space within the cask cavity. It must be unaffected by either the waste or the burial environment. It must be easy to handle and adapt easily to remote operations. It must be of a material that can be easily manufactured to fit various existing cask designs. The container must also be able to meet the requirements of 10 CFR 61 for structural stability over a 300 year life.

To meet these requirements, Nuclear Packaging, Inc. (NuPac) has developed a container design using Enviralloy, or Ferralium Alloy 255. Ferralium Alloy 255 is a patented alloy manufactured by Cabot Corporation under license from Bonar Langley Alloys, Limited, U.K. This alloy is a duplex stainless steel that is highly corrosion resistant and has high strength values. This alloy allows for easy fabrication of a light, high strength container. The high strength of the material allows efficient and simple designs to meet the structural stability criteria of US 10 CFR 61.

2.1 Design Criteria and Controlling Requirements

The NRC staff position paper entitled Final Waste Classification and Waste Form Technical Position Papers dated May 11, 1983, presents a set of criteria that aid in ensuring that structural stability per 10 CFR 61 is achieved . Sections 3.0 through 16.0 of this report describe how each of these criteria is met by the NuPac Enviralloy FL-50/EA-50 High Integrity Container (HIC). For reference, the criteria are listed below:

a. The maximum allowable free liquid in a high integrity container should be less than one percent of the waste volume as measured using the method described in ANS 55.1. A process control program should be developed and qualified to ensure that the free liquid requirements in 10 CFR Part 61 will be met upon delivery of the wet solid material to the disposal facility. This process control program qualification should consider the effects of transportation on the amount of drainable liquid which might be present (Section 3.0).

b. High integrity containers should have as a design goal a minimum life of 300 years. The high integrity container should be designed to maintain its structural integrity over this period (Section 4.0).

c. The high integrity container design should consider the corrosive and chemical effects of both the waste contents and the disposal trench environment. Corrosion and chemical tests should be performed to confirm the suitability of the proposed container materials to meet the design life goal (Section 5.0).

d. The high integrity container should be designed to have sufficient mechanical strength to withstand horizontal and vertical loads on the container equivalent to the depth of proposed burial, assuming a cover material density of 120 lbs/ft^3. The high integrity container should also be designed to withstand the routine loads and effects from the waste contents, waste preparation, transportation, handling and disposal site operations, such as trench compaction procedures. This mechanical design strength should be justified by conservative design analysis (Section 6.0).

e. For polymeric material, design mechanical strengths should be conservatively extrapolated from creep test data (Section 7.0).

f. The design should consider the thermal loads from processing, storage, transportation and burial. Proposed container materials should be tested in accordance with ASTM B553 in the manner described in Section C2(g) of the NRC technical position. No significant changes in material design properties should result from this thermal cycling (Section 8.0).

g. The high integrity container design should consider the radiation stability of the proposed container materials as well as the radiation degradation effects of the wastes (Section 9.0).

Radiation degradation testing should be performed on proposed container materials using a gamma irradiator or equivalent. No significant changes in material design properties should result following exposure to a total accumulated dose of 10^8 rads. If it is proposed to design the high integrity container to greater accumulated doses, testing should be performed to confirm the adequacy of the proposed materials. Test specimens should be prepared using the proposed fabrication techniques.

Polymeric high integrity container designs should also consider the effects of ultra-violet radiation. Testing should be performed on proposed materials to show that no significant changes in material design properties occur following expected ultra-violet radiation exposure.

h. The high integrity container design should consider the biodegradation properties of the proposed materials and any biodegradation of wastes and disposal media. Biodegradation testing should be performed on proposed container materials in accordance with ASTM G21 and ASTM G22. No indication of culture growth should be visible. The extraction procedure described in Section C2 (d) of the NRC technical position may be performed where indications of visible culture growth can be attributable to contamination, additives, or biodegradable components on the specimen surface that to do not affect the overall integrity of the substrate. It is also acceptable to determine biodegradation rates using the Bathta-Pramer Method described in Section C2 (d). The rate of biodegradation should produce less than a 10 percent loss of the total carbon in the container material after 300 years. Test specimens should be prepared using the proposed material fabrication techniques (Section 10.0).

i. The high integrity container should be capable of meeting the requirements for a Type A package as specified in 49 CFR 173.398(b). The free drop test may be performed in accordance with 10 CFR 71, Appendix A, Section 6 (Section 11.0).

j. The high integrity container and the associated lifting devices should be designed to withstand the forces applied during lifting operations. As a minimum, the container should be designed to withstand a 3g vertical lifting load (Section 12.0).

k. The high integrity container should be designed to avoid the collection or retention of water on its top surfaces in order to minimize accumulation of trench liquids which could result in corrosive or degrading chemical effects (Section 13.0).

l. High integrity container closures should be designed to provide a positive seal for the design life of the container. The closure should also be designed to allow inspections of the contents to be conducted without damaging the integrity of the container. Passive vent designs may be utilized if needed to relieve internal pressure. Passive vent systems should be designed to minimize the entry of moisture and the passage of waste materials from the container (Section 14.0).

m. Prototype testing should be performed on high integrity container designs to demonstrate the container's ability to withstand the proposed conditions of waste preparation, handling, transportation and disposal (Section 15.0).

n. High integrity containers should be fabricated, tested, inspected, prepared for use, filled, stored, handled, transported and disposed of in accordance with a quality assurance program. The quality assurance program should also address how wastes which are detrimental to high integrity container materials will be precluded from being placed into the container. Special emphasis should be placed on fabrication process control for those high integrity containers which utilize fabrication techniques such as polymer molding processes (Section 16.0).

2.2 Container Description

To meet the various criteria listed above, Nuclear Packaging, Inc. (NuPac) has developed the Enviralloy FL-50/EA-50 container. The container is a right cylindrical configuration and is designed for both the burial loads at the Hanford, Washington burial site as well as the Barnwell, South Carolina burial site.

The Nuclear Packaging, Inc. (NuPac) Enviralloy FL-50/EA-50 HIC has been designed to maximize the internal cavity volume of the shipping cask by completely filling the cask cavity less necessary clearance space. For this reason, the FL-50/EA-50 HIC has been designated with the same nomenclature as the corresponding NuPac cask (NuPac 50 Series cask is used for transporting the FL-50/EA-50 HIC).

The FL-50/EA-50 HIC features an optional internal dewatering system. This dewatering system has been described and approved under a separate topical report. Refer to Table 2.2-1 for dimensional details of the container.

Table 2.2-1

ENVIRALLOY FL-50/EA-50 HIC Dimensional Data

External Container Dimen.		Weight (lbs)		Volume (Cu. Ft.)	
Dia (in)	Height (in)	Tare	Net	Internal	External
46-1/2	50-3/4	1475	2725	44.9	49.9

Tare Weight: Empty Container Weight

Net Weight: Maximum Payload

The container is designed to a set of specifications that ensure their ability to meet the design criteria.

a. Dimensions will be shown on the drawings (see Appendix A).

b. A corrosion allowance has been incorporated into container design.

c. The container lifting device has been designed to three times maximum gross container weight (see Section 12.0).

d. The closure has been designed to maintain a positive seal under all anticipated conditions of usage, including during impact after a free drop of four feet (see Section 15.0).

e. The container will be fabricated from Ferralium 255^{R} as manufactured by the Cabot Corporation.

f. The design had no identifiable parameters that would reduce the design life below 300 years.

g. The container is designed to maintain a positive Margin of Safety for all handling, transportation and burial loads.

h. The closure is designed for ease of operation to reduce operator exposure.

The FL-50/EA-50 HIC has a 24-inch lid opening at the center of the container top. The lid seal is maintained by eight evenly spaced Ferralium Alloy 255 lid retaining lugs. The body incorporates four vertical supports, which are attached to the top plate directly underneath the locking lug ring. The vertical stiffeners are attached to base plates welded on the bottom plate of the container (see Drawing X-201-015, Appendix A).

After the container has been loaded, the lid is placed over the container opening and the eight wedge shaped retaining blocks are driven into the ring which surrounds the lid. The wedges are designed such that they seat into this ring, forcing the lid to deform the silicone rubber or lead seal and make metal-to-metal contact with the container. This forms a seal between the container and lid as well as securing the retaining blocks against removal during transportation and handling. Should it become necessary, the container contents may be inspected by driving the blocks out and lifting the lid off.

The lifting device for this container consists of two to four lifting eyes, depending on the user's requirements. These lifting eyes are attached to the container top by an all-around fillet weld.

2.3 Material Description

The Enviralloy High Integrity Containers are fabricated from Ferralium^R Alloy 255. Ferralium is a duplex ferritic-austenitic stainless steel which combines high mechanical strength, ductility, and hardness with resistance to corrosion and erosion. The duplex stainless steel structure consists of both austenite and ferrite phases. The duplex stainless steel has superior corrosion resistance and strength as compared to austenitic stainless steels such as Types 304 and 316. Much of the strength and corrosion resistance comes from the relatively high content of chromium, molybdenum and nitrogen as seen in the chemical composition in Table 2.3-1.

The high strength of the material is such that it allows the utilization of thinner sections for a more efficient container than if the container were fabricated from more common austenitic stainless steels. The ASTM A240-82/A479-82 UNS Designation S32550 (Ferralium 255) standards specify the following minimum room temperature values for the material:

Yield Strength, S_y = 80 Ksi (550 MPa)

Ultimate Tensile Strength, S_u = 110 Ksi (760 MPa)

Note that these are minimum values. Nominal strength values for yield and ultimate tensile are much higher, as shown in Table 2.3-2.

Table 2.3-1

Percent[1] Chemical Composition of Ferralium[R] Alloy 255

Fe	Cr	Mo	Ni	Si	Mn	C	N	Cu	Others
BAL	24.0–27.0	2.0–4.0	4.5–6.5	1.0[2]	1.5[2]	0.04[2]	0.10–0.25	1.5–2.5	P-0.04[2] S-0.03[2]

NOTES: 1. The undiluted deposited chemical composition of covered electrodes may vary beyond the limits shown.

2. Maximum amount.

Table 2.3-2

Comparative Typical Tensile Data at Room Temperature

Alloy	Ultimate Tensile Strength Ksi (MPa)	Yield Strength at 0.2% offset, Ksi (MPa)	Elongation in 2 in. (50.8mm) Percent
Ferralium Alloy 255	126 (869)	98 (676)	30
Type 304L Stainless	81 (558)	39 (269)	55
Type 316L Stainless	81 (558)	42 (290)	50
Type 317L Stainless	86 (593)	38 (262)	55

3.0 FREE LIQUID

The Nuclear Packaging Enviralloy FL-50/EA-50 HIC has been designed for containing waste with less than 1% free standing water. Various types of waste may be immobilized within the container, which leads to a variety of dewatering procedures and apparatus used. The specific procedures and actual dewatering equipment can be qualified in a separate document for each basic type of waste form. Some types of dewatering equipment that can be utilized are described in NuPac Topical Report No. TP-02-NP-A.

The different dewatering internals that will be used will not be detrimental to the integrity of the container. Typically, the internals are made from either plastics, carbon steel or stainless steel. The plastics are inert in relation to the Enviralloy. Carbon steel and stainless steel dewatering internals (300 series), when used, are sacrificial to the Enviralloy for galvanic corrosion, as demonstrated by galvanic potential considerations (see Section 5.3.2).

4.0 DESIGN LIFE

The Nuclear Packaging, Inc. Enviralloy FL-50/EA-50 High Integrity Container (HIC) is designed for a minimum life of 300 years. There is no known mechanism which will cause HIC failure, when handled properly, under the internal and external environments of service. All mechanisms that could affect the structural stability of the containers have been examined and accommodated in the design. Since a principle failure mechanism for the HIC is corrosion, Section 5.0 examines the effects of the various environments imposed on the HIC. A major result of this review is the selection of a corrosion thickness assuring a 300 year design life.

5.0 CORROSION BEHAVIOR

The corrosion resistance of Ferralium Alloy 255 under HIC service environments is superior to that of all fully austenitic stainless steels such as 304, 316, and 317L. Unlike the austenitic steels, Ferralium is highly resistant to chloride stress corrosion cracking, crevice corrosion, and pitting in burial environments, including those exhibiting the presence of chlorides and fluorides. The corrosion resistance capabilities have been documented by the use of Ferralium in many environments, as described in Cabot's Booklet No. H-2005.

There are eight basic corrosion mechanisms: 1) uniform corrosion 2) galvanic corrosion, 3) crevice corrosion, 4) pitting, 5) intergranular corrosion, 6) alloy parting, 7) erosion corrosion, and 8) stress corrosion. These eight basic corrosion mechanisms are applicable to both internal and external corrosion conditions.

This section discusses the corrosion resistance of the Enviralloy FL-50/EA-50 HIC for the service life requirements under all corrosion modes and environmental exposures. Subsequent sections discuss both external and internal corrosion environments (Section 5.1), a general discussion of Ferralium Alloy 255 corrosion behavior (Section 5.2), a discussion of specific corrosion modes for the material (Sections 5.3 through 5.11), and finally, a summary classification of chemicals suitable for disposal in the Enviralloy FL-50/EA-50 HIC. The complete corrosion behavior of the material is provided in the Proprietary Report.

5.1 Corrosion Environments

A high integrity container is subjected to both external and internal corrosion agents. External corrosion is attributable to the surrounding burial soils and possible burial trench liquids. Internal corrosion is attributable to waste contents. Each environment will be discussed separately to describe the potential corrosive agents that might affect the FL-50/EA-50 container.

5.1.1 External Environments

Currently, there are two existing commercial shallow land disposal sites where Enviralloy HIC's will be buried: Hanford, Washington and Barnwell, South Carolina. The potential corrosive characteristics of the sites are discussed on the basis of chemical and galvanic corrosiveness as well as potential burial trench liquids.

5.1.1.1 Soil Galvanic Action

The Barnwell site is located in the Coastal Plain geologic province. Waste trenches are excavated in the uppermost stratigraphic layer called the Hawthorn Formation. This soil layer is composed of sandy dense clay beneath a layer of silty coarse sand. The soil's corrosive effects due to galvanic corrosion is considered mild. The soil pH values indicate a slightly acidic soil, as shown in the Proprietary Report.

The Hanford site is situated in the Pasco Basin on the Columbia River Plateau. The burial trenches are located in the uppermost layer known as the Hanford Formation. This layer consists mostly of wind-blown (eolian) sediments. The material is described as unconsolidated sands, silt, and gravels whose deposition is attributed to glacial flood waters. The galvanic corrosion at the site can be defined as very mild. Soil pH values indicate that the soil is considered acidic to neutral.

Both sites fall within the resistivity classification that are considered 'very mild'. Therefore, the galvanic corrosive attack on the Enviralloy HIC's is anticipated to be minimum.

5.1.1.2 Chemicals in Soils

The major chemical component in soils that is specifically aggressive to metals is the chloride ion. Both the Barnwell and Hanford sites have low levels of chloride ions and hence, will not cause any significant aggressive corrosion.

5.1.1.3 Burial Trench Liquids

It is anticipated that there will not be any significant amount of liquids in the burial trenches since all waste (as well as the site) must meet the stability requirements of 10 CFR 61. However, prior to Part 61 regulations, burial trenches at previous burial sites were found to contain ground water which was considerably more aggressive. An example of this occurrence is that the water contained in the Maxxey Flats, Kentucky trenches had fairly high chloride ion concentrations at a low pH level.

The corrosive effects of the external environments that the Enviralloy HIC's will be exposed to are discussed in subsequent sections as they relate to the specific corrosion mode.

5.1.2 Internal Environment

The Enviralloy FL-50/EA-50 container will be loaded with a variety of contents ranging from dry activated waste (DAW), or trash, to demineralizer wastes. In general, the DAW-type materials are chemically passive whereas the demineralizer materials are chemically active by nature. It is these chemically active demineralizer materials (or media) that pose the only significant internal environment worthy to note. Regulated process control techniques assure that the container will be essentially dry (1% maximum free standing water). However, a broad range in pH values is still possible.

The demineralizer systems are designed to handle a variety of demineralizing media. The media utilized must filter the waste stream effectively as well as provide a relatively non-aggressive environment with respect to the container. Some of the media that are anticipated, but not limited to, are as follows:

a) Zeolite

b) Sand

c) Charcoal

d) Organic Ion-Exchange Resins

The zeolite, sand, and activated charcoal are all a balanced media. The zeolite consists of dry hydrous tectosilicate mineral, which captures large cations and loosely holds water molecules. The sand is a clean filter support media. No substantial organics will be present in the sand. The charcoal activation process insures that any free sulfates are driven off. If the charcoal contains any sulfate compounds after drying, they would be in the crystalline structure and as such, would not be chemically leachable. The pH levels of the media and waste stream are well above the critical pH limit of Ferralium Alloy 255 (FR-255). Ferralium has been proven to have very low corrosion rates to the extent of being inactive to substances with a pH value above a certain level.

Dewatered bead resin (organic ion exchange resin) represents the worst potential corrosive internal environment. The corrosive effects of bead resins have been analyzed and an estimated corrosion rate has been established. There does not appear to be any significant corrosion possibility due to the resin if the resin is depleted and has a pH value greater than a minimum value for the contacting water. If the pH of the resin is greater than this minimum, the hydrogen affinity has been satisfied.

5.2 General Corrosion Behavior of Ferralium Alloy

The corrosion of Ferralium to waste streams and burial trench environments is superior to that of full austenitic Type 304 and 316 stainless steels. Duplex stainless steels demonstrate superior resistance to soil induced corrosion compared to other highly alloyed stainless steels. The stainless steels with high chromium content, with or without nickel, are consistently more resistant to soil induced corrosion than carbon steel. In several soils, Type 410 and 430 chromium steels demonstrated more rapid pitting than lower chromium content steels. The chromium nickel steels (Types 302, 304, and 309) developed shallow pits, but the molybdenum bearing steels, such as Type 316, did not pit significantly. Average weight losses were low for the 400 series and insignificant for the 300 series steels.

Ferralium Alloy 255 has excellent resistance to sulfuric, phosphoric, nitric, and many other acids and salts as well as acetic, formic, and organic acids and compounds. The alloy is particularly suitable for concentrations and temperatures where pitting and localized corrosion is a common cause of failure for most conventional stainless steels. Corrosion tests have shown that the duplex stainless steel base metal and weld material is superior to the austenitic stainless steels in all cases.

Although the austenitic stainless steels (304, 316, and their low carbon versions) have been successfully and widely used in many environments, they suffer from two main weaknesses: sensitivity to chloride stress corrosion cracking and pitting corrosion. These weaknesses somewhat limit their use due to economic and safety considerations. The development of ferritic stainless steels solved the above weaknesses, but their intrinsic metallurgical characteristics make them more difficult to fabricate and weld. In addition, the ductile-brittle transition temperature is high, allowing a much greater risk of brittle fracture during service in cold temperatures.

A series of alloys with both corrosion resistance and strength (far superior to Type 316L SS) is the duplex stainless steel family, whose structure basically consists of a mixture of austenite and ferrite. Some wrought duplex alloys were used in small quantities in the late 1950's with the next advancement being the introduction of American Castings Institute CD4MCU alloy approximately 25 years ago. The next important advancement was the development of Ferralium Alloy 255.

Ferralium is produced by balancing critical elements (including nitrogen) and has a structure consisting of approximately 50% ferrite and 50% austenite. The austenitic phase is stable and does not transform into martensite upon quenching from annealing temperature. Ferralium has the highest strength and the best localized corrosion resistance among the wrought duplex alloys. The complete corrosion behavior is provided in the Proprietary Report.

5.3 Uniform Corrosion

Uniform corrosion is the most common form of corrosion. It is normally characterized by a chemical or electrochemical reaction which proceeds uniformly over the entire exposed surface or over a large area. The metal becomes thinner and eventually fails.

The corrosion thickness utilized in the design of the FL-50/EA-50 container is based on the known corrosion rates of various materials when in contact with FR-255 and the expected environment that the container will actually experience in its 300 year design life. Both the external environment (soil) and the internal environment (due to the waste stream) were considered in the selection of the corrosion thickness.

Even though all available data indicates Ferralium Alloy 255 will suffer no detrimental corrosion over the design life, a corrosion allowance has been incorporated in all design calculations to assure no compromise of structural integrity.

Internal and external uniform corrosion environments are discussed separately below. The internal environment proves to be the most severe exposure for the material and is used as a basis for derivation of the uniform corrosion allowance. As indicated earlier, the most severe internal environment was found to be attributable to organic ion exchange resins.

5.3.1 External Environment

Actual long-term field experience for Ferralium Alloy 255 and other duplex stainless steels in soil environments is somewhat limited. This lack of information is due to the relatively short time these alloys have been available (approximately 20 years), an ..ne economic considerations for their use in soil applications. In general, these materials have been restricted to applications which have very harsh environments that made other less costly materials totally unacceptable. This condition has also been the case for austenitic stainless steels, in general, ever since they became a commercially available material in the early 1900's. Duplex stainless steels' primary use has been in the process and the maritime industries where other forms of corrosion prevention were unacceptable. Their use in the pulp and paper, chemical, and oil industries, and in various maritime applications demonstrate this fact. Only in recent years have the duplex materials been utilized in services such as drill pipe and other well applications. These uses were only used in subsea applications where the seawater made an extremely harsh environment for the more standard materials.

In general, stainless steels have not been utilized in underground applications because of cost and the availability of other less costly corrosion prevention techniques. An example of the most common underground application is pipelines. Pipelines can and are fairly easily protected by a variety of means, such as protective coatings and cathodic protection, which are more difficult to apply in maritime and dynamic applications. Typically, these processes have been much less expensive than applying high alloy systems, such as stainless steel. In addition, these systems normally have an expected economic life with no restrictions on replacement or abandonment at their end of service. Some stainless steel pipelines have been installed with very mixed service results. Pipelines in general, because of their length, cross a variety of soils with varying resistivities. This condition results in the pipeline carrying various currents.

Recognizing that pipeline data is not totally applicable for comparison to the external environment that the HIC will experience, other applications were examined. Austenitic stainless steels have been used in small amounts as fasteners, hose clamps, couplings, etc. in underground applications. Traditionally, the results have been excellent. In many instances, it has been difficult to discern if the results were due to the alloy or if it was due to the fact that the coupled material was sacrificial to the stainless steel component. Those components that have not been coupled to other conducting material (e.g., stainless steel clamps on plastic pipe) have shown little damage due to corrosion.

In an attempt to answer these and other questions concerning underground corrosion of metals, the U.S. National Bureau of Standards has been testing various metals by burying specimens on a long term basis at various sites around the country. Some of the stainless steel specimens have been exposed up to fourteen years. In one study, six test sites were chosen, with one site located near Toppendish, Washington, forty miles south west of the Hanford Reservation. The soil at this location is similar to the Hanford soil characteristics. At the burial depth, both soils are composed of dry, loose sand with a minimum of organics.

From this location, 300 series stainless steel base metal, which had been sensitized, was analyzed after an exposure of eight years. The specimens were found to have minimal uniform corrosive weight losses and only a few corrosion or pitting sites. The weld samples demonstrated similar absence of corrosion or pitting sites. The study continues to evaluate special alloys with high chromium and nickel content with the addition of molybdenum. The results of the tests indicate that high grade austenitic stainless steels faired well.

For corrosion to initiate, a combination of soil conditions must be present. Generally, the moisture content, galvanic characteristics, and soil acidity must be relatively high for the commencement of corrosion.

One study indicates that the moisture content of the Hanford site is relatively low. Although the Barnwell site has a higher moisture content than Hanford, the backfill material provides adequate drainage. The soil acidity at the Hanford site was stated to be neutral while at the Barnwell site, a slightly acidic environment was noted. As for the resistivities of both burial sites, they were noted to be only mildly corrosive to steels. The amount of chloride ions reported at either site will not be chemically detrimental as compared to the capabilities of Ferralium Alloy 255

These studies indicate that the common austenitic stainless steels do demonstrate adequate resistance to corrosion for long term burial. However, they still demonstrate some weaknesses such as pitting. The common stainless steels also appear marginal when comparing their performance against the unknown of the three hundred year design life.

The external corrosion of Ferralium Alloy 255 due to soil is judged not too significant since Types 304 and 316 stainless steels have been demonstrated to highly resistant to both pitting and general attack in actual soil tests. It is recognized that the soils the test specimens were buried in may not be the most corrosive that the container may be exposed to during its design life. The possibility of a slightly more corrosive environment is not restrictive due to the greater corrosion resistance of Ferralium as compared to the 300 series stainless steels. The known data on soils and their corrosive characteristics indicate that the soils in the current disposal sites are not necessarily more corrosive than the soils where the stainless steels were tested. As noted in Section 5.1.1.3, liquids in the trenches at the Maxxey Flats site had high chloride levels and a low pH value. These chloride levels, however, are still below that which any effects are reported on Ferralium Alloy 255.

The acidity or alkalinity of the soil does not appear to be in the range where it would detrimentally affect the container material. In fact, when reviewing the soil chemistry of the various disposal sites against the chemistry which has been found to be corrosive to the alloy, the soils are a very passive environment. It was determined that there is a very high probability that the soil will not lead to any detectable corrosion of the container.

In order for the chloride content to pose a significant corrosion potential, the concentration must be at a very high level and in a very acidic environment. This chloride level is considerably higher than the maximum reported trench liquid level. Clearly, the chloride level in the soil will not pose a corrosion problem for the Ferralium alloy containers.

Further, Cabot has simulated a worst case trench liquid for a corrosion coupon test. It was intended to simulate the possible mixture of acids from a particular solidification process and ions in the soil. The resultant corrosion rate due to this acid mixture was less than the corrosion criteria established for the alloy.

From the soil corrosion studies performed on the 300 series stainless and duplex stainless steels, it has been demonstrated that the duplex stainless steels are superior. Studies have shown that stainless steels with high chromium and nickel content are very resistant to pitting or crevice corrosion. In soils that are adequately drained (i.e., low in chlorides and have a balance of oxygen), the resistance to aggressive corrosion attack has been reported as outstanding for duplex stainless steels.

For these reasons and to ensure that the design life requirement is satisfied with an adequate margin of safety, Nuclear Packaging selected Ferralium Alloy 255, which provides a greater margin against pitting and uniform corrosion. Additionaly, a corrosion thickness allowance was included in the design.

5.3.2 Internal Environment

The exact corrosion behavior of the internal environment of the container is very difficult to judge. It is a function of the type of waste, the temperature, the oxygen content, the history of the particular waste stream, and the specific waste stream itself. Although they are very diverse, the waste streams have, in general, the common trait of being very dilute. The nuclear industry is based around water as the primary medium and generates the largest portion of its waste in purifying that medium. The chemicals that are normally found in these waste streams are very passive toward metals since whole material control programs are based on protection of the plant. However, it is recognized that some detrimental environments could exist. The various chemicals that could be disposed of in the container and the various mediums (e.g., ion exchange resin) were reviewed against the known corrosive data for Ferralium Alloy 255.

At and below room temperature, none of the chemicals that would normally be found in a radioactive waste stream demonstrated a corrosion rate in excess of the limit utilized in the design. The only chemicals that were found to be aggressive at all to Ferralium at room temperature were those that contained high amounts of chloride or fluoride in highly acidic solutions. Highly acidic solutions by themselves are not a problem. Solutions containing a high percentage of chlorides are not a problem to the material as long as they are not strongly acidic. It is recognized that for some of these solutions weldments may have a slightly higher corrosion rate and susceptibility to pitting than the base metal. However, although the rates are slightly higher, they are still within the acceptable range.

Other chemicals that may be more common to the waste streams were reviewed and found to have corrosion rates compatible with the selected corrosion thickness, even at elevated temperatures such as boiling. Additionally, many combinations of acids were also found to be acceptable at slightly elevated temperatures.

As noted in Section 5.1.2, bead resins represent the greatest corrosion potential for Ferralium. Essentially all (99.9%) of the ion exchange resins that originate from nuclear plants are styrene-based types.

The watery pores of the resin beads (and the functional groups within) are the source of corrosion by the beads. The entrapped water in the beads can actually be considered a chemical solution like an acid, caustic, or other salt solution. In a chemical solution, there is an equilibrium between the following three constituents of the water:

- Positively charged ions (cations) such as hydrogen, sodium, magnesium, etc.

- Negatively charged ions (anions) such as hydroxide, chloride, sulfate, etc.

- The combination of positive and negative charged ions into a neutral molecule, such as sodium chloride, hydrogen sulfate, hydrogen chloride, etc.

Since the solution in the ion exchange beads behaves just like any other chemical solution, the known corrosion rates of various acids and bases can be correlated to the worst expected corrosion case for resins.

Other potentially corrosive materials are anion resins. The highly basic nature of anion resins was also investigated. Corrosion data show no effects of the equivalent amount of caustic. One set of data shows a very small corrosion rate. This case is well above the maximum operating case of anion resin equivalent at ambient temperatures.

The case where the resin is in point contact with the vessel wall was also considered. This condition is important in that ion exchange resins have a high percentage water content with approximately 36 percent void space between the resin beads. Therefore, when the plastic portion of the resin is ignored and there is not any free water around the outside of the resin, then the water portion of the resin can have a larger acid concentration than calculations performed on the gross resin volume. The results of this evaluation demonstrated negligible corrosion rates.

Radiation effects are not considered a significant contribution to the lowering the pH level in relation to the direct contact of dewatered resins with the container. The question of ion exchange resin corrosion on the container can be separated into three progressively more severe and less likely cases. They are: 1) undamaged resins with the most severe corrosion capabilities; 2) utilize the added corrosion potential due to reported reductions in the pH level from radiation damage; and 3) a theoretical calculation that effectively places all of the corrosive sites or acidity of the resin at the container wall.

5.4 Galvanic Corrosion

Galvanic corrosion is a corrosion mechanism where an electrical current is established between two dissimilar metals. Corrosion of the less corrosion-resistant metal is usually increased and attack of the more resistant material is decreased, as compared with the behavior of the two metals when they are not in contact. The less resistant material becomes anodic while the more resistant metal becomes cathodic. Usually, the cathode or cathodic metal corrodes very little or not at all in this type of couple.

The driving force for current and corrosion is the potential developed between the two metals. The potential differences between metals under reversible, or noncorroding, conditions form the basis for predicting corrosion tendencies. These corrosion tendencies have been tabulated into the standard electromotive force (emf) or galvanic series. This tabulation is shown in Table 5.4-1.

By studying this information, it was found that potential galvanic corrosion exists between the carbon steel lifting hardware and the Ferralium lifting lug, Ferralium being cathodic and the carbon steel being anodic. Therefore, the steel lifting hardware and optional false bottom will probably undergo galvanic corrosion over the 300 year design life. The container material, being cathodic, will not sustain any galvanic corrosion.

In reviewing the galvanic cell that would result in a duplex to austenitic stainless steel interface, it was found that the Types 304 and 316 stainless steels will be sacrificial to Ferralium. Therefore, Types 304 and 316 stainless steels are anticipated to undergo a certain degree of corrosion. However, the Ferralium container, being more noble, will not sustain any corrosion and the life of the container will not be reduced due to this corrosion mechanism.

Table 5.4-1

Galvanic Series of Common Alloys*

Anodic ↑	Magnesium	
	Magnesium alloys	
	Zinc	
	Aluminum, 2S	
	Cadmium	
	Aluminum alloy 17S-T	
	Carbon steel	
	Copper steel	
	Cast iron	
	4 to 6% Cr steel	
	12 to 14% Cr steel	
	16 to 18% Cr steel	Active
	23 to 30% Cr steel	
	Ni-resist	
	7% Ni, 17% Cr steel	
	8% Ni, 18% Cr steel	
	14% Ni, 23% Cr steel	Active
	20% Ni, 25% Cr steel	
	12% Ni, 18% Cr, 3% Mo steel	
	Lead-tin solder	
	Lead	
	Tin	
	Nickel	
	60% Ni, 15% Cr	Active
	Inconel	
	80% Ni, 20% Cr	
	Brasses	
	Copper	
	Bronzes	
	Nickel-silver	
	Copper-nickel	
	Monel metal	
	Nickel	
	60% Ni, 15% Cr	Passive
	Inconel	
	80% Ni, 20% Cr	
	12 to 14% Cr steel	
	16 to 18% Cr steel	
	7% Ni, 17% Cr steel	
	8% Ni, 18% Cr steel	Passive
	14% Ni, 23% Cr steel	
	23 to 30% Cr steel	
	20% Ni, 25% Cr steel	
	12% Ni, 18% Cr, 3% Mo steel	
	Silver	
Cathodic ↓	Graphite	

* C. A. Zapffe, *Stainless Steels*, Cleveland: American Society for Metals.

5.5 Crevice Corrosion

Crevice corrosion frequently occurs within crevices and other shielded areas on metal surfaces exposed to corrosives. This type of attack is usually associated with small volumes of stagnant solution caused by holes, gasket surfaces, lap joints, surface deposits, and crevices under bolt and rivet heads.

To function as a corrosion site, a crevice must be wide enough to permit liquid entry, but sufficiently narrow to maintain a stagnant zone. For this reason, crevice corrosion usually occurs at openings a few thousandths of an inch or less in width. It rarely occurs within wide (e.g., 1/8-inch) grooves or slots. Fibrous gaskets, which have a wick action, form a completely stagnant solution in contact with the gasket flange face; this condition forms an almost ideal crevice-corrosion site.

In the Enviralloy container, all metal components are completely welded to eliminate any crevices. The only potential crevice corrosion site that exists in the container design is the lid/gasket interface. However, crevice corrosion is not anticipated to occur at this interface for the following reasons:

1. Since the gasket materials utilized are not fibrous (silicone rubber or lead), no wicking action will occur.

2. There is little or no corrosive liquids anticipated in sufficient quantities from either the burial environment or the waste stream to initiate and maintain the crevice corrosion mechanism should it occur.

Additionally, crevice corrosion tests performed on Ferralium have shown no corrosion by this mechanism. Tests were performed in aggressive solutions at room temperature for 10 days and at 113 ^{o}F for 100 hours. Both of these test demonstrated Ferralium's superior resistance to crevice corrosion compared to austenitic stainless steels.

A loose or intermittent contact between two surfaces (a rough surface-to-surface contact), similar to a soil/metal contact, gives rise to a nonaggressive crevice geometry, which lessen the probability of crevice corrosion. As most experiments are performed using tight fitting plastic washers to promote pitting and crevice corrosion, the studies indicate a worst-case condition.

Another study performed polarization current tests with Ferralium. The tests demonstrate that crevice corrosion was arrested. Based on these test results, it is not anticipated that crevice corrosion will be a major concern in the design life of the container. The complete crevice corrosion evaluation is provided in the proprietary report.

5.6 Pitting

Pitting of a material is defined as the preferential removal of material in a localized area. Because of its extremely localized nature, pitting results in holes in the metal. These holes may be small or large in diameter, but in most cases they are relatively small. Pits are sometimes isolated or so close together that they look like a rough surface. Generally, a pit may be described as a cavity or hole with the surface diameter about the same as or less than the depth.

As in the area of uniform corrosion, Ferralium Alloy 255 is far superior to austenitic stainless steels and lower alloy duplex stainless steels in its resistance to pitting in all predicted environments that the container would experience. It is recognized that the quantity and rate of pitting for a given material in any environment is very difficult to predict. However, the resistance a material demonstrates to pitting in very harsh environments, such as ferric chloride, can be expected to carry over in other less harsh environments that the container will encounter. It is also interesting to note that the pitting temperature, as determined in basic-acidic solutions, was found to be considerably higher for Ferralium than for other stainless steels. This temperature, in excess of 120 ^{o}F, is far above the container burial temperature. Additionally, potentiodynamic tests were performed on the alloy, both on base and welded samples in a theoretical worst case solution. The material readily repassivated in this solution since there was no hysteresis loop formed during the cyclic pitting polarization curve test.

The available test data provides a comparison of corrosion properties that are anticipated to be in the worst environment for material survivability. Several investigators have identified trends in material behavior. A quote from one reference sums up the investigators philosophy: 'Generally, if a material performs well in service, any material performing equally or better in this study is likely to also perform well in the same application'. By this statement, Ferralium will perform better than Type 316 or Type 304 stainless steel, which have been extensively used in burial environments. The basic concern is that the container should structurally survive a minimum of 300 years and provide a confined volume where low level waste can decay to normal background levels. It is anticipated that pitting will not structurally affect the integrity of the container in such a manner as to cause catastrophic weld failures.

To investigate the corrosion properties of the austenitic and duplex stainless steels, aggressive chemical agents were used to screen materials. Results indicate that Ferralium has fewer initiation points with a shallower attack depth than austenitic stainless steels. It is also interesting to note the time required to initiate pits in Ferralium is approximately a factor of three longer than Types 316 and 304 steels.

The probability of there being a sufficient density of through-pits present to cause structural failure of the container is improbable.

NuPac has thoroughly investigated pitting and various mechanisms (as shown in the Proprietary Report) and found that Ferralium Alloy 255 was highly resistant to this form of corrosion for several reasons: not only because of its composition/material phase, but also its fabrication techniques.

Even though the material gives all indications that pitting would not be a problem, the usage of a corrosion thickness in the design provides additional conservatism. The corrosion thickness allows for additional metal to be placed in the weld areas, which would be preferential pitting areas. By designing without the material being present, the design assures that adequate strength is present to ensure structural stability.

5.7 Intergranular Corrosion

Localized attack at and adjacent to grain boundaries, with relatively little corrosion of the grains, is called intergranular corrosion. The alloy disintegrates (grains fall out) and/or loses its strength.

Intergranular corrosion can be caused by impurities at the grain boundaries, enrichment of one of the alloying elements, or depletion of one of these elements in the grain-boundary areas. Depletion of chromium in the grain-boundary regions results in intergranular corrosion in austenitic stainless steels. This condition results when chromium carbides ($Cr_{23}C_6$) precipitate during certain heat treatments and welding.

Comparative stress corrosion cracking data has been generated in sodium hydroxide and other environments for Ferralium. It is clear from this data that the alloy has superior stress corrosion cracking resistance in many environments tested compared to Type 316L stainless steel.

It is clear that the prerequisites for intergranular corrosion do not exist at either existing burial site or any planned environments. The duplex structure of Ferralium, in conjunction with the added precautions NuPac is utilizing in the fabrication process, will prevent this type of corrosion mechanism from occurring, as described in the Proprietary Report.

5.8 Alloy Parting

Alloy parting (or selective leaching) is the removal of one element from a solid alloy by corrosion processes. The most common example is the selective removal of zinc in brass alloys (dezincification). Similar processes may occur in other alloy systems in which aluminum, iron, cobalt, chromium, and other elements are removed.

The only alloy parting process of potential concern for Ferralium is chromium leaching. However, this corrosion process only occurs at high temperatures (1800 ^{o}F) when stainless steels are exposed to a low-oxygen atmosphere. Since Ferralium is restricted to a maximum temperature of 500 ^{o}F, chromium leaching will not occur.

5.9 Erosion Corrosion

Erosion corrosion is the acceleration or increase in rate of deterioration or attack on a metal because of relative movement between a corrosive fluid and the metal surface. Generally, this movement is quite rapid, and mechanical wear effects or abrasion are involved. Metal is removed from the surface as dissolved ions, or it forms solid corrosion products which are mechanically swept from the metal surface.

Some of the factors pertinent to erosion corrosion are cavitation damage, fretting corrosion, surface films, velocity of environment, and galvanic corrosion. Since none of these factors exist in the HIC environment (internal or external), erosion corrosion will not occur for the Enviralloy container.

5.10 Stress Corrosion

Stress corrosion cracking refers to cracking cause by the simultaneous presence of tensile stress and a specific corrosion medium. One type of stress corrosion cracking is IGSCC, which was previously discussed (refer to Section 5.7). Another type of stress corrosion cracking is transgranular, which advances without apparent preference for grain boundaries.

Factors which affect stress corrosion cracking in stainless steels include temperature, chloride concentrations, stress level, metallurgical factors, and the physical state of the environment (i.e., single-phase aqueous versus alternate wetting and drying conditions).

As noted in Section 5.7, stress corrosion will not occur in the Enviralloy container because of the fabrication methods utilized and the HIC service environment.

5.11 Weldment Corrosion Behavior of Ferralium

In general, weldments exhibit different corrosion qualities than the base metal. These differences are due primarily to the localized heating and cooling of the base metal during and following the welding process. However, with proper controls, the differences are minimized.

Corrosion tests performed have demonstrated that Ferralium Alloy 255 weldments are superior to Type 316L stainless steel weldments, as shown in the Proprietary Report. In the simulated solution, even though 316L performed well, Ferralium should provide a greater assurance and a much higher safety margin for the 300 year design life.

As far as the filler metals of different compositions are concerned, NuPac utilizes the standard Ferralium Alloy 255 filler metal coupled with a standard corrosion test as one of the quality assurance tests.

NuPac has carefully chosen the welding process to provide for sufficient heat input and cooling rate to ensure that weldments will perform similar to the base material (refer to Section 16.0 for further details).

5.12 Waste Classifications for Enviralloy HIC's

There are a variety of ways a waste form could potentially be a corrosion problem. These include various combinations of types of corrosion, the means by which the material comes in contact with the container, and potential thermal effects. All of the combinations can be alleviated by one or a combination of operating methods, design factors, and administrative procedures.

The commonly occurring chemicals at a nuclear facility are most corrosive when mixed with water and at elevated temperatures. Direct chemical contact with the vessel at, or less than, the chemical's usually known concentration occurs when the chemical is disposed on a solid such as a cartridge filter, cloth encapsulated with exposed areas, or on metal parts. If the chemicals have been properly screened, there will be neither a chemical or a temperature problem.

The chemical can be in contact with the vessel at higher than the applied concentration, or pH level, by the concentrating effects of ion exchange resins or inorganic zeolites. Further complicating these higher than applied chemical concentrations are oxidizing effects of organic ion exchange resins. A low concentration of an oxidizing acid could be removed by the resin and concentrated to such an extent that the acid begins to generate heat as it reacts with the resin itself. During that reaction, heat is generated and the rising temperature creates the corrosive condition of the chemical with the vessel wall. This potential problem is of particular concern when the resin has been dewatered, thereby removing the heat sink. Therefore, oxidizing chemicals are noted as such in operating procedures.

After reviewing all available data on both the base material and the weldments of Ferralium Alloy 255 and the basic waste stream and their disposal environment, it was determined that very few waste streams are required to be treated differently or excluded from disposal in the containers. Only those waste streams that present a potential problem to the container would have to be neutralized, diluted, or excluded from the container. This requirement ensures that any potential corrosive waste streams would be eliminated which would exceed the allowable corrosion layer. The pH level less than 3.0 requirement ensures a margin of safety against non-uniformity of the waste stream. These limits are based on the design life of the container and the environment the container will experience during that design life, such as room temperature and below. Brief excursions above the 120 $^{\circ}$F limit are permitted for the container, such as 180 $^{\circ}$F during filling for less than 12 hours, which again limits the total corrosion. Since basic solution environments are very non-corrosive to the alloy, temperatures up to the maximum operating limit of the material (500 $^{\circ}$F) is permitted for less than four hours.

These limits are controlled by the metallurgy of the material and its corrosive resistance. The corrosion analysis performed in this report is based on the container being at room temperature. Actually, in the buried condition, the nominal temperature would be considerably below this temperature. It is recognized that for some environment/waste streams, the corrosion rate of the metal would increase with increased temperature. However, while the corrosion resistance of the material remains high at increased temperatures, this resistance may not be sufficient to ensure survival of the container for its design lifetime. Based on this fact, the temperature limitation of up to 180 $^{\circ}$F for less than 12 hours was imposed. Even if the corrosion rate increased greatly for this period of time, it would have an insignificant effect on the 300 year design life.

The higher temperature limit of less than 500 $^{\circ}$F for environments with a basic pH level is related to the maximum temperature limit imposed on Ferralium Alloy 255. By restricting the temperature excursions to only waste basic streams, the corrosion rate increase effect is reduced to an insignificant level. The normal recommended operating limit of 500 $^{\circ}$F for the alloy is based on the reduction of material impact resistance values when exposed to high temperatures for extended periods of time. As noted by Cabot, the impact values for Ferralium Alloy 255 begin to drop off at 500 $^{\circ}$F when exposed for over 1000 hours. The 500 $^{\circ}$F temperature limit for four hours was chosen to be conservative.

With the conservatism cited above, the corrosion allowance in the vessel and a allowable corrosion rate at temperatures less than 120 ^{o}F, a Ferralium HIC is very conservatively designed to last 300 years, as demonstrated in the Proprietary Report.

6.0 BURIAL STRENGTH

The NuPac Enviralloy FL-50/EA-50 High Integrity Container (HIC) has been designed to meet all strength and structural stability requirements of 10 CFR Part 61 for burial.

6.1 Burial Loads

The maximum burial depth at the Hanford, Washington site will be 55 feet. Conservatively assuming hydrostatic pressure loading from the soil, this depth corresponds to a container external pressure of:

$$P_H = (55\ \text{ft})(120\ \text{lb/ft}^3)/(12\ \text{in/ft})^2$$

$$= 45.83\ \text{psi}$$

The burial depth at the Barnwell, South Carolina site is a maximum of 25 feet, which results in an external hydrostatic pressure of 20.83 psi. For the structural analysis, the Hanford burial pressure will be utilized as a worst-case basis.

6.2 Design Criteria

The allowable component stresses and buckling criteria are derived from Section III of the ASME Boiler and Pressure Vessel Code for Metal Containment structures and Code Case N-284. Additional guidance has been provided by the USNRC. Margins of Safety (M.S.) are calculated based on the following relationship:

$$M.S. = (S_{allowable}/S_{actual}) - 1$$

6.3 Allowable Stresses

The physical properties of Ferralium Alloy 255 are given in Section 2.0. Per the USNRC Staff, the maximum stress intensity should not exceed ASME III Service Level A limits.

In the buried environment, there are two possible configurations of the container: nominal and uniformly corroded. From a stress standpoint, the worst condition is the uniformly corroded container. For either condition, the allowable stress intensities are:

- General Membrane Stress: $P_m \leq S_{mc}$

  $P_m \leq 36.67$ ksi (252 MPa)

- Local Membrane Stress: $P_L \leq 1.5S_{mc}$

  $P_L \leq 55.0$ ksi (378 MPa)

- Local Membrane plus Bending: $(P_L + P_b) \leq 1.5S_{mc}$

  $(P_L + P_b) \leq 55.0$ ksi (378 MPa)

- $S_{mc} = 1/3\ S_{ult} = 36.67$ ksi (252 MPa)

Secondary stresses (thermal and peak stresses) are not evaluated for the buried container since these stress types are only of concern for precluding fatigue failures, which does not exist for HIC's. Note that the HIC is loaded for only one-half of a cycle.

Components subjected to compressive loads shall be evaluated against buckling limits set by the appropriate structural code. For shell and plate elements, ASME Code Case N-284 in conjunction with Subsection NE-3000 will be utilized. For structural steel elements, the American Institute of Steel Construction (AISC) buckling allowables will be utilized.

6.4 Analytic Model

The NuPac Enviralloy FL-50/EA-50 HIC was analyzed for displacements and stresses utilizing the general purpose finite element code ANSYS, Revision 4.2. Five distinct components were evaluated in this analysis: the bottom plate, the side or shell, the top plate, the lid plate, and the internal vertical support angle.

6.5 Structural Analysis Results

Maximum stress intensities were determined for each component of the container. The controlling stress intensity is the combined bending plus local membrane stress intensity. All membrane stress intensities were found to be very low (with subsequent high margins of safety) compared to the combined membrane and bending stress intensities.

The combined local membrane and bending stress intensity ($P_L + P_b$) of each most highly stressed component is compared to the allowable stress intensity as described in Section 6.3. A summary of the maximum stress intensities for the maximum burial pressure in the nominal and uniformly corroded is shown in Table 6.5.1-1. The minimum margin of safety (M. S.) for the highest stressed component is also provided for each case.

Table 6.5.1-1

Container Component Stress Intensities (ksi)

Condition	Bottom	Side	Top	Lid	Minimum
Nominal Thickness*	19.51	15.21	18.45	25.43	+1.16
Corroded Thickness	43.90	34.22	41.52	45.20	+0.22

* Ratioed from corroded thickness analysis.

Note that the requirements of 10 CFR 71.71(c) for maximum compressive load is less than 25% of the burial pressure that the container is designed and analyzed to withstand over a 300 year design life. Therefore, this requirement is satisfied by the finite element analysis.

The adequacy of the end plate welds to the container shell wall were verified with the container in the uniformly corroded burial condition.

The maximum stress intensity at the outer shell-end plate joint was found to be 35.94 ksi. This stress intensity is based on the container in the uniformly corroded condition. The adjusted maximum stress intensity in the weld joint then becomes:

$$S_w = 19.72 \text{ ksi } (136 \text{ MPa})$$

The weld stress margin of safety, based on an allowable of 55.0 ksi, is:

$$M.\ S. = (55/19.72) - 1 = +1.79$$

From the discussion in Section 5.0, it was determined that the weldments will perform as well as the base metal. Therefore, no weld structural problems are anticipated due to these corrosion effects.

The structural stability of the FL-50/EA-50 has been conservatively demonstrated for burial in both the vertical and horizontal or side orientations. In the vertical orientation, the pressure from the soil overburden is reacted through the internal angle supports and the container shell. The horizontal orientation is reacted primarily through the container shell. Each orientation is discussed separately.

Vertical Orientation

The structural stability of the container is maintained by the internal angle supports and the container shell. The stability of the top and bottom plates is assured as long as the stability of the angles is maintained.

The maximum bending moment in the support angle occurs at the end and is induced by the deflection of the top and bottom plates of the container due the applied pressure load (with the corrosion allowance applied). By symmetry, no bending about the radial axis occurs in the vertical support leg. Therefore, all bending is about the tangential axis. The total load that each of the axial members must carry (due to the applied hydrostatic pressure load of 45.83 psi) is as follows:

$$\text{Total Force on Container End} = pA = (45.83)\ \pi\ (46.5)^2/4$$

$$= 77{,}830 \text{ lbs.}$$

Total Force on Angles = 59,328 lbs.

The stability of the angle supports is based on AISC criteria.

The margin of safety for axial compression of the angle supports alone is:

$$M.\ S. = +3.36$$

For combined axial and bending loading, the internal vertical supports satisfy AISC requirements for stability under the 45.83 psi loading.

Therefore, the internal angle supports remain stable in the corroded condition. Since the container experiences constant burial pressure and the supports would be larger in the non-corroded condition, the angle supports are stable under all burial conditions.

The compressive stability of the FL-50/EA-50 shell is conservatively demonstrated by assuming a simple cylinder with a uniform hydrostatic pressure loading.

Horizontal Orientation

The container in the horizontal orientation can be treated as a buried conduit or pipe. For this condition, the structural support from the end plates is not considered.

Analyzing for the critical buckling pressure yields a pressure of 126.82 psi. With the actual hydrostatic burial pressure at 45.83 psi, the margin of safety against buckling in the horizontal, uniformly corroded orientation is:

$$M.\ S. = (126.82/45.83) - 1 = +1.77$$

Based on this analysis, the FL-50/EA-50 container stability has been conservatively demonstrated in the horizontal orientation for both burial sites.

Damaged Container Effects

The effects of damage on the structural integrity of the FL-50/EA-50 container is not expected to alter the preceding analyses. This conclusion is based on the resultant container damage of several drop tests of a single container. As noted in Section 15.0, the maximum deformation that resulted from these tests was 5/8-inch. From these test observations, very little container damage can be expected to occur from any mishandling. However, should a container sustain a large amount of damage during use, a separate evaluation and any necessary repairs will be performed to assure that the structural integrity of the container is maintained.

6.6 Conclusion

It has been demonstrated that the NuPac Enviralloy FL-50/EA-50 High Integrity Container will be structurally sound, with combined stresses not exceeding the criteria of ASME and USNRC, delineated in Section 6.2, on burial to the depth and pressure requirements of Section 6.1. In addition, structural stability is assured with the application of conservative factors of safety and allowances to the HIC geometry during analysis. The complete structural evaluation of the container is provided in the Proprietary Report.

7.0 CREEP EFFECTS

The FL-50/EA-50 HIC is fabricated of high strength ferritic-austenitic steel. Creep effects are negligible for metallic materials except at extreme temperatures above approximately 800°F. All conditions of HIC usage involve temperatures well below these levels. Hence, creep effects are not a consideration in the design of the FL-50/EA-50 HIC.

8.0 THERMAL LOADS

Enviralloy FR 255, like other metallic materials, is relatively insensitive to temperature effects below approximately 800°F. From room temperatures up to this value, mechanical properties experience gradual, gentle changes. In general, as temperatures increase, mechanical strength properties reduce while permissible strain values (elongation) increase. For example, strength properties at 200°F are 8.6% less than room temperature values and 12.6% less at 400°F. This section describes the thermal environment of the HIC under all conditions and demonstrates that temperatures remain well below levels of concern.

8.1 Processing

Loading operations, in general, impose no thermal loads upon the HIC. One advanced dewatering mode imposes modest thermal loads. In this mode (a proprietary NuPac procedure) thermal energy is introduced, in sufficient quantity, to compensate for energy lost to phase change effects. In any case, the maximum temperature is well below the 500 °F operating limit which is required to be observed by the waste generator.

8.2 Storage

Enviralloy HIC's will, in general, be stored within covered radwaste facilities. Occasionally, storage may occur outside, in restricted and controlled areas. Storage temperatures are always expected to remain below 180°F.

8.3 Transportation

Temperature predictions for the transport mode do not differ greatly from the storage estimates given in the preceding section.

The structural effects of the predicted cask temperatures on the FL-50/EA-50 HIC will be minimum. However, to demonstrate this conclusion, a worst case conservative analysis has been performed.

If the stress-free temperature of the container is assumed to be 70°F, then the container shell would experience a maximum temperature change of:

$$207 - 70 = 137^{o}F$$

Assuming a perfect rigidity between the outer shell and the internal supports, a worst case differential thermal expansion between the supports and the shell will result in a plane-stress condition in the support angles. If the shell is assumed to be at the cask temperature and the supports at the stress-free temperature, the resultant strain, ε, will be:

$$\varepsilon = 8.357x10^{-4} \text{ in/in}$$

converting this strain to a maximum axial stress yields:

$$\sigma = 25.49 \text{ ksi}$$

This stress results in a M. S. against yielding of:

$$\text{M. S.} = (80/25.49) - 1 = +2.14$$

It should be noted that this result is extremely conservative. In actual practice, there will be little if any, differential thermal expansion between any component of the container. Additionally, should any differential expansion occur, the flexibility of the top and bottom plates will allow for unrestrained growth. In any case, any thermal expansion stresses in the container are considered secondary and thus, are self-limiting.

8.4 Burial

The burial temperature envelope at Barnwell and Hanford has been specified as $20^{o}C \pm 10^{o}$ ($68^{o}F \pm 18^{o}F$). At this temperature, the Ferralium Alloy 255 material is not affected in any detrimental manner. The sealing gasket material is also unaffected.

9.0 RADIATION AND ULTRA-VIOLET STABILITY

Ferralium Alloy 255, being a duplex stainless steel, is highly resistant to gamma and ultraviolet radiation. No reduction in the life of the container due to exposure to ultraviolet radiation or to a total accumulated radiation dose of 10^8 rads is anticipated.

Gamma radiation is not known to cause degradation of metallic materials. The radiation damage to metals which is normally a concern is due to exposure to neutron radiation (i.e., radiation hardening, swelling and embrittlement). These containers will not contain neutron radiation producing materials of a quantity which is detectable. Therefore, radiation resistance is not a concern for Ferralium Alloy 255 materials.

The Enviralloy FL-50/EA-50 container easily meets the requirements of remaining stable when exposed to 10^8 rads. The actual curie loads carried in this container will nominally produce a much lower dose rate. The total radioactive material per container is controlled by USNRC and USDOE requirements for allowable radiation levels when transported in their respective licensed casks.

The only materials that are not Ferralium are the gasket materials and the vent. Neither one of these items affect the structural integrity or stability of the container.

The gasket is designed to provide a seal during transportation and provide a positive closure or barrier to the migration of groundwater into and out of the container. Both of the optional gaskets proposed for the container provide such a barrier. The lead gasket is totally unaffected by gamma radiation in excess of 10^8 rads total accumulative level. The silicon rubber gasket will suffer some degradation when exposed to an accumulation of radiation. However, information presented in literature has verified that at an exposure dose of 10^8 rads, 10% compression capability will still remain. Since there is no mechanism for the gasket material to move from its location when in the buried state, the gasket will continue to perform as an effective barrier, and therefore, the degradation in resilience that may have occurred will have been non-significant. This conclusion is demonstrated by an analogy to metal gaskets which take a more than 90% compression set upon initial installation and yet provide a very effective seal.

The other component of the container that is not made from Ferralium is the vent. The vent is made from a permeable polymeric material which has very good radiation resistance in excess of 10^8 rads. The material does not carry any load when used as a vent in the container. Therefore, any reduction in strength or elongation that may occur due to radiation will not affect the performance of the container.

10.0 BIODEGRADATION

Biodegradation is not a problem for the Enviralloy FL-50/EA-50 container. Biodegradation, or biological corrosion, is the deterioration of a metal occurring directly or indirectly as a result of the activity of living organisms. These organisms include bacteria and micro forms such as mold or fungus.

Microorganisms are classified according to their ability to grow in the presence or absence of oxygen. Aerobic organisms grow only in nutrient mediums containing free dissolved oxygen. Anaerobic organisms grow in mediums without free dissolved oxygen. One type of anerobic organism grows by reducing sulfate to sulfide according to the following chemical equation:

$$SO_4^{2} + 4H_2 \longrightarrow S^{-2} + 4H_2O$$

The source of hydrogen for this reaction could be cellulose, sugars or other organic products.

Should the growth of either organism occur, the end-product of the chemical reactions (i.e., low concentrations of sulfuric acid, ferric hydroxide, thiosulfiate, sulfate, sulfur or hydrogen sulfide) would not corrode Ferralium. The generation of hydrogen sulfide gas within the container is not possible since the organisms would require sulfur compounds to produce it, and there will not be measurable quantities present in the container. The generation of any gas, however, will be relieved through the vent (Refer to Section 14.0).

A more thorough discussion of the corrosion resistance of Ferralium Alloy 255 and the growth of microorganism growth can be found in Section 5.0 and the Proprietary Report.

11.0 TYPE A CRITERIA

Type A criteria requires that packages be capable of withstanding 'Normal Conditions of Transport', per 49 CFR 173.412, with qualification test criteria given in 49 CFR 173.465, without 'loss or dispersal of contents'. Application of these criteria to HIC's is intended to insure a robust, tough container suitable for field use. The HIC is intended to be transported within a licensed transportation container.

By test and analysis, this report demonstrates compliance with each element of these criteria. Subsections of this section describe applicable demonstrations. The order of presentation parallels the requirements as listed in 49 CFR 173.465.

11.1 Water Spray Test

Since the Enviralloy FL-50/EA-50 HIC is fabricated entirely from a duplex alloy steel, the water spray/soak test (49 CFR 173.465(b)) is not applicable. More specifically, metallic packages, of stainless steel or duplex alloy steel, undergo no physical change when exposed to moisture.

11.2 Free Drop Test

The NuPac Enviralloy FL-50/EA-50 HIC is evaluated against the following Type A criteria (49 CFR 173.465(c)). All drop tests are performed on unyielding surfaces.

Package Weight (W) (lbs)	Drop Height (feet)
$W \leq 11{,}000$	4
$11{,}000 < W \leq 22{,}000$	3
$22{,}000 < W \leq 33{,}000$	2
$33{,}000 < W$	1

The FL-50/EA-50 HIC has been thoroughly tested to the 4 foot drop requirement in a variety of critical attitudes or orientations. In addition, the container has been tested to the special 25 foot drop (soil impact) requirements of the States of Washington and South Carolina. Under all test conditions, the FL-50/EA-50 sustained little damage or plastic deformation. Essentially all changes were 'cosmetic'; neither structural nor mechanical. This testing is described in Section 15.0.

11.3 Compression Test

The compression test consists of applying an opposing pressure to two faces of the package equal to five times gross container weight for a period of 24 hours (49 CFR 173.465(d)). The NuPac Enviralloy FL-50/EA-50 HIC has been designed for burial pressures of 45.83 psi, applied for a period of 300 years. This pressure is 3.7 times greater than the compression test requirement (see Section 6.0, Burial Strength, for an evaluation of these far greater burial pressures). Thus, the compression test requirements are satisfied with an abundant margin of conservatism.

11.4 Penetration Test

The six kilogram (13 lb.) steel cylinder penetration test (49 CFR 173.465(e)) has no effect on the FL-50/EA-50 container. The only indication of impact with the container is a small scuff mark. This behavior has been demonstrated by test (refer to Section 15.0).

11.5 Reduced Pressure Design Requirements

The reduced external pressure design requirements of 49 CFR 173.412(i) corresponds to an internal pressure of 11.2 psig. Conformance of the Enviralloy FL-50/EA-50 HIC with these requirements is demonstrated by the following more severe exposures:

(1) External burial pressures as described in Section 6.0, Burial Strength, total 45.83 psi; 4.09 times greater from a stress view point than this reduced pressure requirements. External pressures are more critical because they potentially can introduce compressive buckling or crippling stresses. Internal pressure differentials, such as the reduced pressure condition, induce less critical tensile stresses. This fact was confirmed by performing a 11.2 psi analysis of the ANSYS Model.

(2) The HIC has been tested to the 11.2 psig requirement without any leakage. The pressure was then increased until leakage occurred. At 75 psig, leakage commenced due to seal deformation. No other observable damage was noted (refer to Section 15.0 for details).

Note that this reduced pressure requirement also corresponds to 10 CFR 71.71(c)(3).

12.0 LIFTING DEVICES

The Enviralloy FL-50/EA-50 High Integrity Container employs either a two or three point lifting fixture geometry. The two point geometry will be the basis for a worst-case analysis.

The lifting lugs are fabricated from Ferralium plate. The attachment of the lug to the container is achieved with an all-around fillet weld. The overall lug configuration is shown in Figure 12-1.

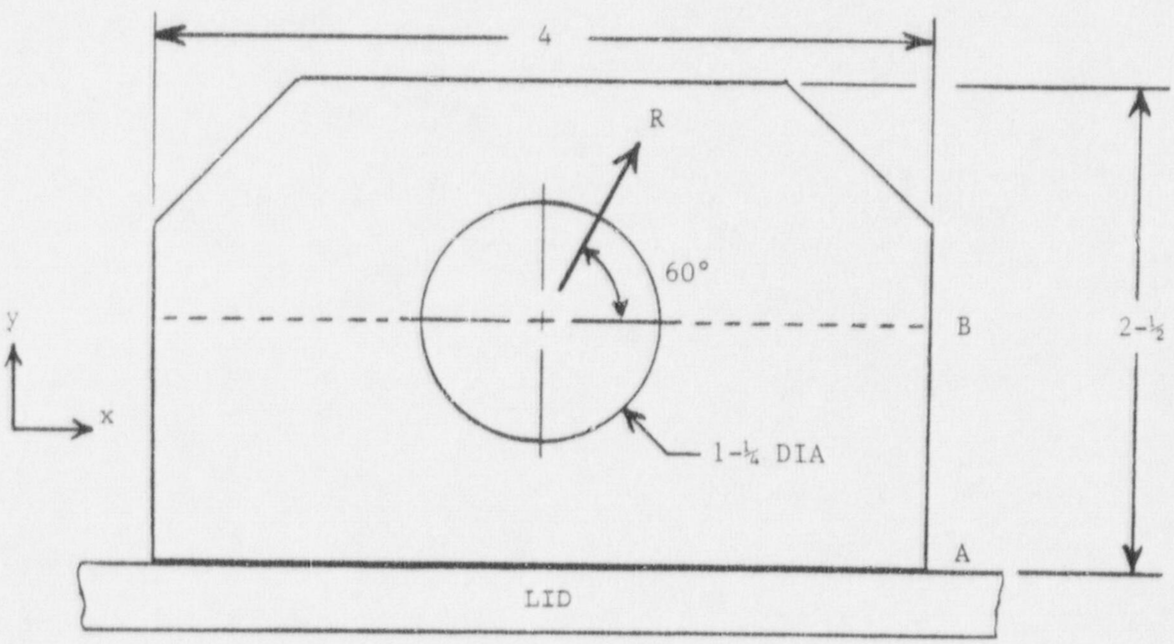


Figure 12-1 Standard Lifting Lug Configuration

Critical lug stresses during lifting include shear tearout, direct tensile, bending, and weld stresses. Bearing stresses are not considered critical since localized yielding will redistribute the load and hence, will be self limiting.

Per the NRC staff Branch Technical Position for High Integrity Containers, lifting devices must be capable of withstanding a 3g vertical load. This requirement means that each lifting lug must withstand a vertical load (F_y) of 6300 lbs. The resultant total lug load for a lift angle of 60^o will then be:

$$R = 7275 \text{ lbs.}$$

This resultant load also produced a horizontal load of:

$$F_x = 3638 \text{ lbs}$$

At the attachment point to the container (point A), the maximum lug stresses will occur due to bending, direct tension, and shear loading. The maximum bending moment will be produced by the horizontal force component acting at a distance equal to the hole offset plus a portion of shackle pin diameter. Therefore, the maximum bending moment is:

$$M_{max} = 5532 \text{ in.-lbs.}$$

The maximum tensile stress is due to the bending stress plus the direct tensile stress.

$$\sigma_{max} = 9.73 \text{ ksi}$$

The resultant lug shear stress will be

$$\tau_x = 2.43 \text{ ksi}$$

The resultant margin of safety (M.S.) for these stresses against yield (with shear yielding equal to 0.6 S_y) will be:

$$\text{Tensile M.S.} = +7.22$$

$$\text{Shear M.S.} = +18.75$$

The maximum shear tearout stress and resulatant minimum M.S. will be equal to:

$$\tau_{TO} = 10.89 \text{ ksi}$$

$$\text{M.S.} = +3.41$$

The maximum weld stress will be due to primary shear stress in both the horizontal and vertical directions plus secondary shear stress due to the bending moment. The maximum shear stress will then be the vectorial sum of these shear stresses.

The primary shear stresses will be

$$\tau_y = 4.46 \text{ ksi}$$

$$\tau_x = 2.58 \text{ ksi}$$

The secondary shear stress in the weld is determined by the torsion formula and is equal to 4.66 ksi.

The resultant shear stress then becomes:

$$\tau = 9.48 \text{ ksi}$$

This stress results in a minimum M.S. of:

$$\text{M.S.} = +4.06$$

All other stresses in the lug will be lower than the stresses calculated above and therefore will have higher M.S.. The shackle and lift cable M.S. can easily be computed.

The lifting sling connector has a work load capacity of 4000 lbs. and an ultimate strength of 24,000 lbs. The M.S. then for the connector is:

$$M.S. = +0.98$$

The aircraft cable has an ultimate strength of 14,400 lbs. Using the assumed load of 7,275 lbs (3 times actual load) and the assumed yield strength for the cable of 8,640 lbs, gives the minimum M.S. as:

$$M.S. = +0.19$$

An optional lifting device that is designed to be utilized with remote lifting equipment could be used as a single lifting device for righting containers, such as in a storage facility. For this condition, the minimum M.S. against yielding due to shear tearout will be:

$$M.S. = +1.20$$

Note that the minimum margin of safety occurs in shear tearout of the lifting lug eye. Since this area will fail prior to any other lug area, there will be no detrimental effects to the integrity of the container.

The optional lifting lug designs have similar large margins of safety as the standard lifting lug. Therefore, the qualification of these lugs is demonstrated by comparison to the standard lug design.

13.0 WATER RETENTION

The Enviralloy FL-50/EA-50 High Integrity Container has been designed to avoid the collection or retention of water on its top surface. The lid retaining ring, or stiffeners, at the center of the upper head, are slotted such that any water entering this area will drain back out. All areas of the top head are designed to be self-draining.

Due to the extreme corrosion resistance of Ferralium Alloy 255 and the use of a corrosion allowance, the retention of water, should it occur, is not deemed to be a problem.

14.0 CLOSURES, SEALS, AND VENTS

The FL-50/EA-50 High Integrity Container has a 24-inch lid opening at the center of the container top. The lid seal is maintained by eight evenly spaced retaining lugs. The wedged-shape retaining lugs are driven into the ring which surrounds the lid, forcing the lid to deform the seal and make metal-to-metal contact. The type of seal used on the container is dependent on the waste form placed within the container. A passive vent is installed in the center of the lid. All closure mechanisms become passive when in the burial environment; i.e., burial loads ensure that the container remains sealed.

The closure capabilities to withstand the transportation and handling loads are described in Section 11.0. Built into the closure design are capabilities that allow easy, rapid closure, which reduces operator exposure. To further reduce the exposure, Nuclear Packaging, Inc. has developed remote closure equipment for this design. Should it become necessary, the container contents may be inspected by driving the retaining lugs out.

For non-tritium waste materials, a silicon rubber gasket is utilized for the container seal. The rubber gasket is designed to allow for any compression set that may occur due to radiation exposure (refer to Section 9.0). The closure is designed so that any thickness reduction in the seal (due to compression set) does not affect the structural stability of the container. The silicone rubber seal has been shown by test to withstand a 60-80 psig pressure differential.

A lead seal is utilized for those containers that contain greater than Class A quantities of tritiated waste material without the passive vent. The lead gasket has been demonstrated by test to hold a gas pressure in excess of 20 psig. By considering the total amount of tritium that the regulations permit to be shipped in a container, the diffusivity of the materials involved (i.e., Ferralium and lead), and the half-life of tritium, it can be shown by calculation that far less than the Class A quantities of tritium will never be released in the burial environment. The lead gasket is also utilized where the accumulative gamma radiation will exceed 108 rads.

The biodegradability of the seal materials is not a significant problem. The silicone rubber and the lead do not contain compounds that support fungus growth per MIL-STD-810B method 508 test. Both of these materials are also resistant to the chemicals generated by bacteria that may survive by feeding on other nutrients.

Passive venting of any generated gases is achieved through a polymeric plug (patent pending). The vent, shown in Figure 14-1, is installed in the lid of the container, minimizing the impact on the structure of the container and the possibility of damage from exterior objects. This vent allows the passage of gases while minimizing the flow of water.

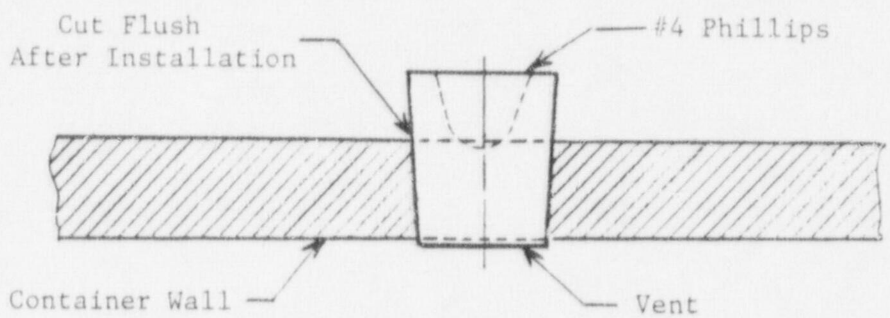


Figure 14-1 Nupac Passive Vent Design.
(Patent Pending)

The polymeric material was chosen for its radiation resistance, chemical resistance, lack of influence on corrosion, and the hydrophobic nature of the material.

This material has good radiation resistance for the 108 rad dose specified for the containers and is reported to maintain 80% of its strength in 109 rads. In addition, another study reports only minor reduction in mechanical properties. The major reduction occurs in the materials ability to tolerate deformation. In the vent design, the material does not have to tolerate any deformation.

The chemical resistance of the material is very good for the environment that the vent will normally see. The material is highly resistant to inorganic materials. The vent will see very few organic materials in concentrations that will cause any problems for the vent. Those organics that are known to cause deterioration of the material do so by being absorbed into the material and cause softening or weakening of the material. In the configuration of the container, the vent material is not required to resist any substantial loading, hence its long term strength is of only minor concern.

It should be noted that should the vent material fail, the structure integrity, as required by 10 CFR 61, of the container will not be impaired. The ingress and egress of water will be increased, but the water would still have to pass in and out of a small single opening.

Samples of this vent have been tested for both air and water flow under prototypic burial conditions at various pressures. The vent demonstrated zero pure water flow at pressure differentials up to a maximum value, as described in the Proprietary Report. At pressures above this maximum pressure, pure water flow was initiated, but at a very low rate.

Vent flow rate tests were also performed with Hanford-type sand and Barnwell-type clay soil to demonstrate vent capabilities in the burial trench. Under these conditions (soil and water), no significant degradation in the gas flow of the went was detected. However, decreased water flow rates were detected with a soil-water mixture.

Because the material is a porous material, no absolute guarantees can be made that water will never pass through the material in the three hundred year design life. However, the vent design will minimize any water flow. Because the existing burial sites are basically dry environments, the magnitude of water pressure the vent must resist is undetermined. Sites such as Hanford are dry with the water table several hundred feet below and the waste actually placed below the level at which ground water penetrates before being evaporated. Wet sites, such as Barnwell, are above the water table and the trenches are capped to prevent the ingress of ground water. These conditions indicate that the containers would never expect to see submergence in water such that the vents would have to resist the water. If for some reason submergence does occur, the vent, as indicated above, will reduce the inflow of water to a rate at which the container would barely fill when submerged to the greatest burial depth for the 300 year design life.

As a backup to the passive vent, the closure utilizing a simple, flat seal design acts as a pressure relief device. Venting via the lid utilizes the same system that is common in all standard pressure relief devices: deflection of a material when loaded under pressure. For the FL-50/EA-50 container, the lid between the retaining lugs is not as stiff as the container lip. The relative amount of stiffness is controlled by the material thickness and the retaining lug spacing. As the pressure increases, the separation between the lid and container increases, thus relaxing the compressive force on the seal.

When the gasket relaxes sufficiently and can no longer maintain a seal, the pressure decreases as the gas leaks out. This reduction in pressure, or burping, allows the lid to reseal. The minute separation that allows pressure reduction also ensures no dispersion of contents from the container. Pressure tests performed on a production container with a corroded thickness lid have demonstrated this lid burping.

All closures, seals, and vents provide for a positive seal for all conditions of use. The components do not impair or compromise the structural stability of the container under any conditions of use.

15.0 PROTOTYPE TESTING

The original version of the FL-50/EA-50 (thinner wall, two internal supports) was tested with a gross weight of 4200 lbs. The performance tests included drop, penetration, and leak tests. The tests were performed in accordance with the requirements of the NRC branch position on high integrity containers and the states of Washington and South Carolina for burial at their respective burial sites.

The container was dropped from both four foot orientations (as required by NRC for a Type A package) and from from twenty-five foot orientations (as required by the states). The four foot drops were performed on an unyielding surface and the twenty-five foot drops on compacted sand. The compacted sand was actually a surface of compacted sand over a roadbed of compacted gravel.

As part of the test program, a load test of each of the lugs was performed. This test was performed to 4200 pounds per lug or 200 percent of their maximum load. This load is in excess of the standard 150 percent load test required for even critical lifting equipment. This test was not an attempt to qualify the lug against the requirement of maintaining the lug stresses to one-third of yield as this was achieved by analysis (see Section 12.0).

The configuration of the container tested included a lead gasket. The lead gasket with its reduced resiliency was qualified with these tests. Previous tests had qualified the silicone rubber gasket. The lead gasket would be more likely to cause a loss of contents than the silicone rubber gasket since it would be unable to follow any dynamic elastic deflection of the lid during the drop event. The lead gasket was also tested for leakage and its ability to maintain a positive seal. The lead gasket did not leak until the pressure was raised to over 20 psig.

The only damage that was sustained was some slight denting of the side wall after the four foot corner drop and after the twenty-five foot side drop. The dent resulting from the corner drop was about 1/4-inch deep. The damage resulting from the twenty-five foot side drop consisted of a denting or flattening of the impacted side between the two end plates. This denting was a marimum of 5/8-inch. There was no loss of contents resulting from any of the drop tests. The lid maintained a positive closure. To ensure that there was no structural damage, a magnetic particle test was performed on all closure welds after the drop tests were complete. No damage to the welds were detected. The angles welded to the lid that serve as handles were broken at the welds from the twenty-five foot top down drop. These angles are nonstructural components of the container and their failure did not affect the integrity of the container. Photographs of the drop tests are shown in Appendix B.

The NuPac proprietary dewatering system that is designed for use in the FL-50/EA-50 container was not installed in the test specimen. However, all internal protrusions are made of a plastic material which is much softer than the Ferralium HIC material. All metallic parts are restrained from impacting the container sides by other dewatering structure or actual dewatered resin. Furthermore, Ferralium is significantly stronger than any material placed within the container, and therefore, penetration of the container by internals during a drop event is precluded.

A penetration test per 49 CFR 173.465 (e) was also performed. The 13 pound, 1-1/4 inch diameter rod did not cause any damage to the FL-50/EA-50 container.

Although the tests were performed at ambient temperatures of approximately 60oF, similar performance would be expected should the container sustain a free drop during cold weather. This conclusion is based on the fact that Ferralium exhibits positive charpy impact valves at temperatures as low as -40oF. In addition, the nil-ductility-transition temperature (NDT) for Ferralium weldments is well below any anticipated service temperatures.

As stated by Cabot, the impact properties of Ferralium are directional in nature. However, as demonstrated by Charpy impact tests and the full-size container drop tests, the overall effect of this difference on the integrity of the container is minimal.

16.0 QUALITY ASSURANCE PROGRAM

The Enviralloy FL-50/EA-50 container, manufactured by Nuclear Packaging, Inc., is controlled by a complete QA System meeting all major QA specifications and requirements utilized in the United States and Canadian Nuclear Industry. These include the following:

- RDT F2.4T
- RDT F2.2
- ANSI N45.2
- ASME Section III, Article NCA 4000
- ANSI/ASME NQA-1
- 10 CFR 71, Subpart H
- 10 CFR 50, Appendix B
- CSA Z299.2
- CAS Z299.3

In addition, the NRC has issued approval No. 0192 to Nuclear Packaging, Inc. attesting that the QA System meets the requirements of 10 CFR 71, Subpart H. This approval will be due for renewal by December 31, 1990. A copy of the NRC approval letter is shown in Appendix C.

The QA System provides procedures and criteria for the preparation, use and control of QA documentation for all design, fabrication and operational activities at NuPac.

The control of container fabrication, storage and use is particularly critical in many areas. The NuPac QA System is designed to respond to all QA requirements for all fabrication activity from special 'one time' projects to high technology production runs. Therefore, it is well suited to control container production, storage and use because fabrication encompasses all facets of manufacturing and QA expertise.

The QA System is utilized to assure adherence to container design, fabrication, storage and use criteria in the following areas:

a. Inspection and certification of materials in accordance with design criteria.

1. Raw materials will be inspected for adherence to chemical, physical and configuration requirements prior to any processing.

2. Samples will be taken from raw materials for alloy checks on a random basis or if the available data is questionable. Based on design and performance criteria, these tests will include:

   - Physical Tests: These tests will include yield, ultimate and elongation tests.

   - Chemical Tests: Tests will be conducted to determine that chemical composition adheres to specification.

3. Random tests described in item a.2 and/or review and approval of supplier provided tests data for each lot of raw materials will be utilized to assure close adherence to design acceptance criteria.

b. Process control for welding to comply with structural design criteria.

1. All welding procedures, welding personnel and equipment will be developed and qualified in accordance with Section IX of the ASME Code as follows:
   A welding specification is developed as specified in QW-201.1 of Section IX. Special consideration is given to essential and non-essential variables which affect corrosion performance so that pitting in the heat affected zone can be prevented. The specification is prepared in the format specified by QW-482 of Section IX.

After review and approval of the welding specification by Engineering and Quality Assurance, a Welding Procedure is prepared in accordance with QW-201.2 of Section IX. The procedure format shown in QW-483 of Section IX is utilized. Test coupons are then prepared for Tensile (QW-150), Guided Bend (QW-160), Toughness (QW-170) or Filet Weld Tests (QW-180) as appropriate to the design weld configuration.

All of Section IX required tests are performed to qualify the weld procedure and supporting weld specification design. In addition, coupons welded at the same time are subjected to a 5 day immersion test in a 10% ferric chloride solution to verify the weld and heat affected zones have similar resistance to pitting as does the base material. The ferric chloride test will also detect sigma phase if present in large amounts, which is undesirable for impact strength.

Upon successful completion of the described tests the weld specification and procedure are approved and released for production use.

All welding personnel are then required to be tested and qualified to the approved welding procedure in accordance with QW-301 of Section IX of the ASME code prior to welding on any Enviralloy fabrication. Coupons are also prepared by each welder during his qualification tests for immersion in a 10% ferric chloride solution for 5 days to assure absence of pitting in the welds and heat affected zone.

During fabrication, 100% weld inspections are performed in accordance with written, in-process inspection instructions. These instructions provide specific requirements for visual weld inspection, non-destructive testing and liner assembly pressure tests designed to assure continued adherence to approved welding procedures.

Performance of the required inspection and complete documentation of the inspection results assures that weld pitting or other weld failure does not occur.

c. Inspection and control of fabrication to assure compliance with design specification and acceptance criteria.

1. The physical tests described in Section a.2 will also be utilized as the first inspection hold point to assure material control during fabrication.

2. Additionally, dimensional, configuration and functional checks will be performed at appropriate points during container fabrication.

3. All inspection will be performed in accordance with written inspection planning. All planning will be prepared and approved in strict accordance with NuPac QA systems procedures and criteria.

d. Performance control of Nondestructive Testing required to adhere to design specifications.

1. The same Inspection Planning discussed in c.3 will incorporate requirements, procedures and acceptance criteria for NDT activities during Enviralloy fabrication.

2. NDT will include, but not be limited to:

- Liquid Penetrant to ASME criteria Section III and V of all closure welds to assure weld integrity to design requirements.

- Magnetic Particle to ASME Criteria Section III and V of all closure welds to assure weld integrity to design requirements as alternate to liquid penetrant.

- Visual weld inspection of all welds to ASME Section III and V criteria.

- Soap bubble tests of all production units will be conducted to assure configuration and manufacturing quality and leak tightness.

e. NuPac's entire program for inspection to assure compliance with material and construction specifications is delineated in the NuPac QA manual. This manual describes requirements and procedures necessary to exercise control over design documentation, procurement, material, fabrication, inspection inventory shipment and quality data retention. NuPac Quality System and implementing Quality Procedures are designed and administered to meet the 18 criteria of 10 CFR 71 Subpart H. A complete manual of detailed procedures for each criteria is required to be utilized by NuPac's suppliers.

f. Development, inspection and control of the handling and storage environment to assure continued adherence to design and performance criteria after fabrication and prior to delivery for use.

   1. Damage prevention i.e., denting, gouging, puncture, deforming.

   2. Maintenance of cleanliness.

g. Review and approval of Operating Procedure OM-32 to assure that the containers are utilized in accordance with design criteria.

   1. Areas of concern during QA review will include those discussed in section f.1 usage with appropriate waste streams and proper filling, sealing, lifting, transportation and placement for long term storage.

APPENDIX A

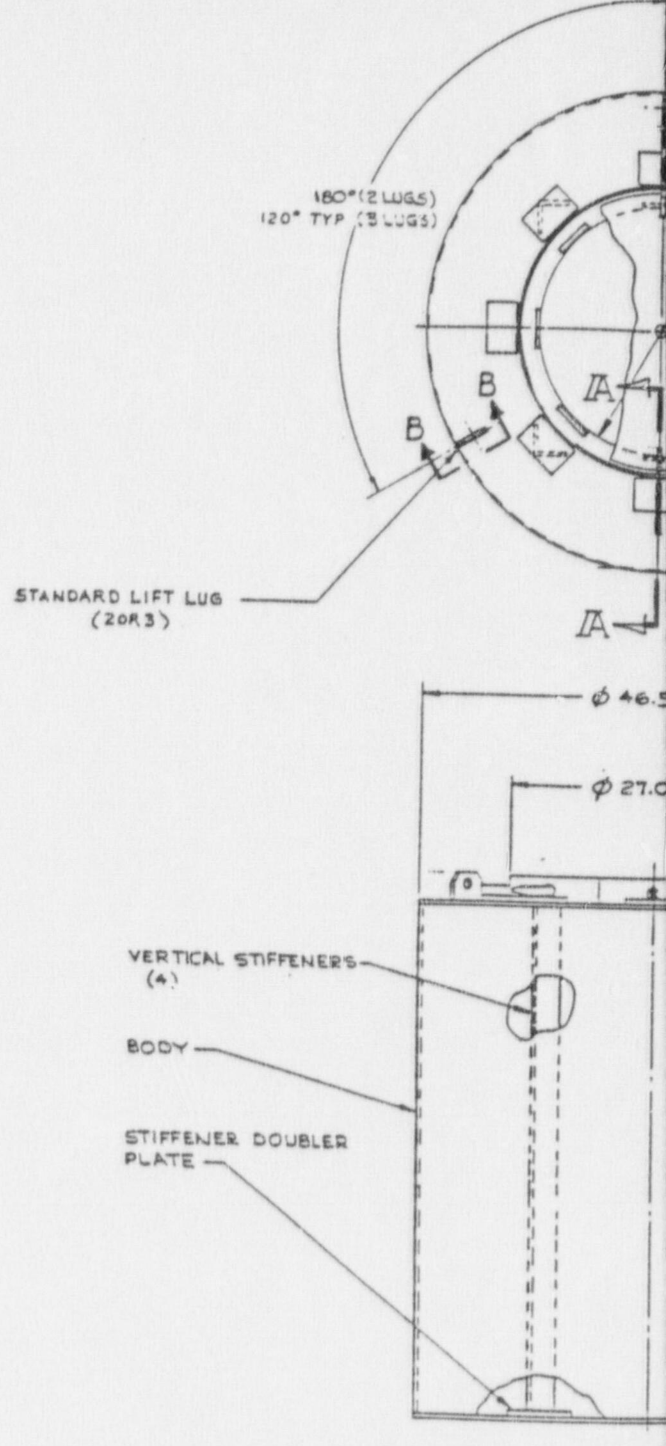
Drawings for Enviralloy FL-50/EA-50 HIC

D

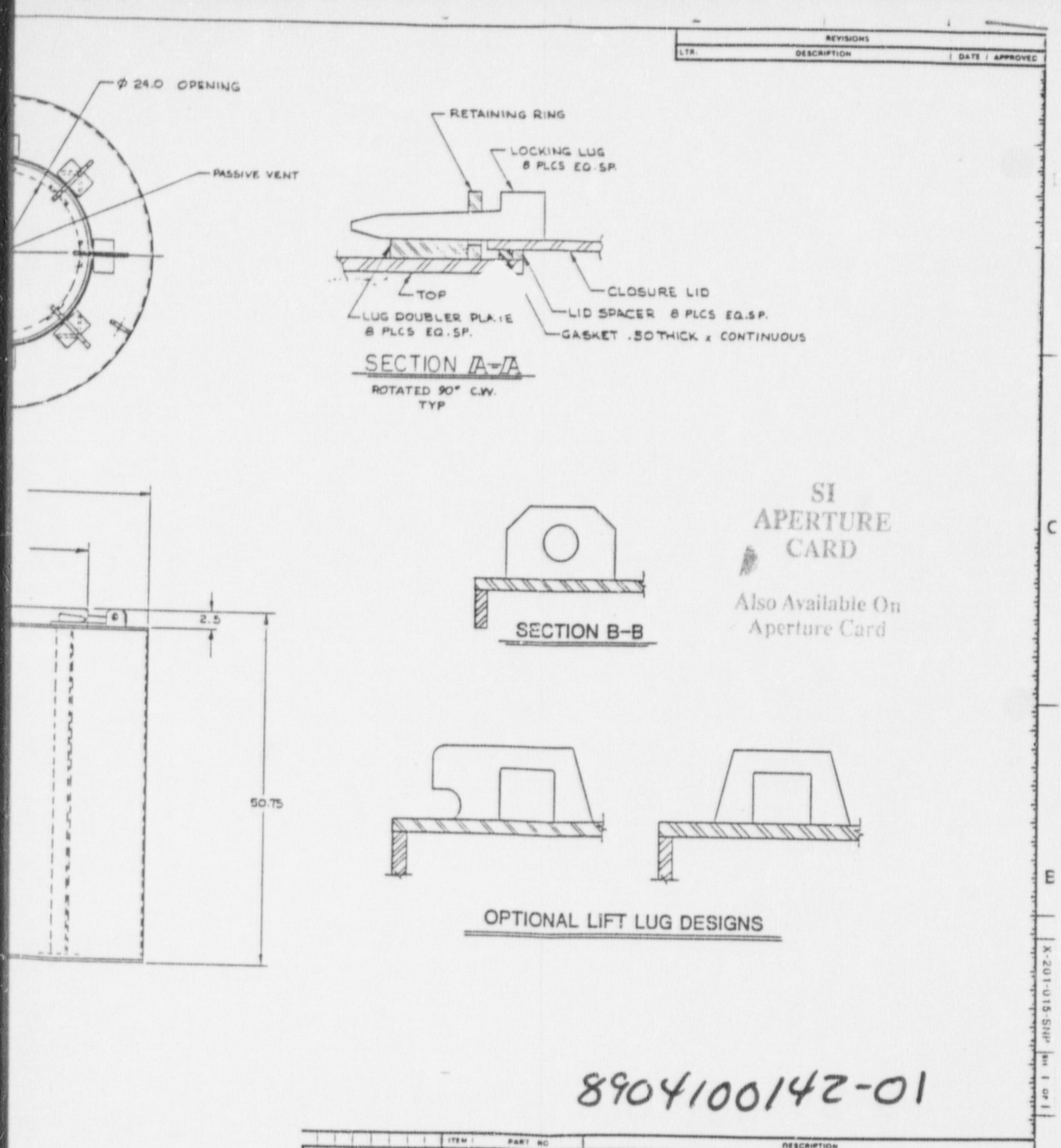
C

B

A


180°(2 LUGS)
120° TYP (3 LUGS)
B
B
A
STANDARD LIFT LUG
(2 OR 3)
A
Ø 46.5
Ø 27.0
VERTICAL STIFFENERS
(4)
BODY
STIFFENER DOUBLER
PLATE

8



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ITEM	PART NO	DESCRIPTION
ASSEMBLY & QUANTITY		LIST OF MATERIAL
REL	12/18/86	NUCLEAR PACKAGING A Pacific Nuclear Company FEDERAL WAY, WA
APPD		
APPD	12/8/86	
APPD	12/8/86	
APPD	12/8/86	HIGH INTEGRITY CONTAINER
APPD	12/4/86	
APPD	12/4/86	NUPAC ENVIRALLOY EA-50
APPD	12/4/86	
QA	12/2/86	
CHECK	12-4-86	
DRAWN NKH SMITH		

IT	QTY	NEXT ASSY

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES
FRACTIONS ± 1 PLACE DECIMALS ±
ANGLES ± 2 PLACE DECIMALS ±
3 PLACE DECIMALS ±

PROPRIETARY DATA: This drawing and the design it covers are the property of NUCLEAR PACKAGING, INCORPORATED. It is transmitted to you in confidence and trust and is to be returned upon request. No persons may not be disclosed in whole or in part to others or used for other than the purposes for which transmitted without prior written permission of NUCLEAR PACKAGING, INCORPORATED.

SCALE: ~	WT. 1475 LBS
REV NONE	SHEET 1 OF 1
DWG SIZE D	DWG NO. X-201-015-SNP

APPENDIX B

Photographs of Drop Tests

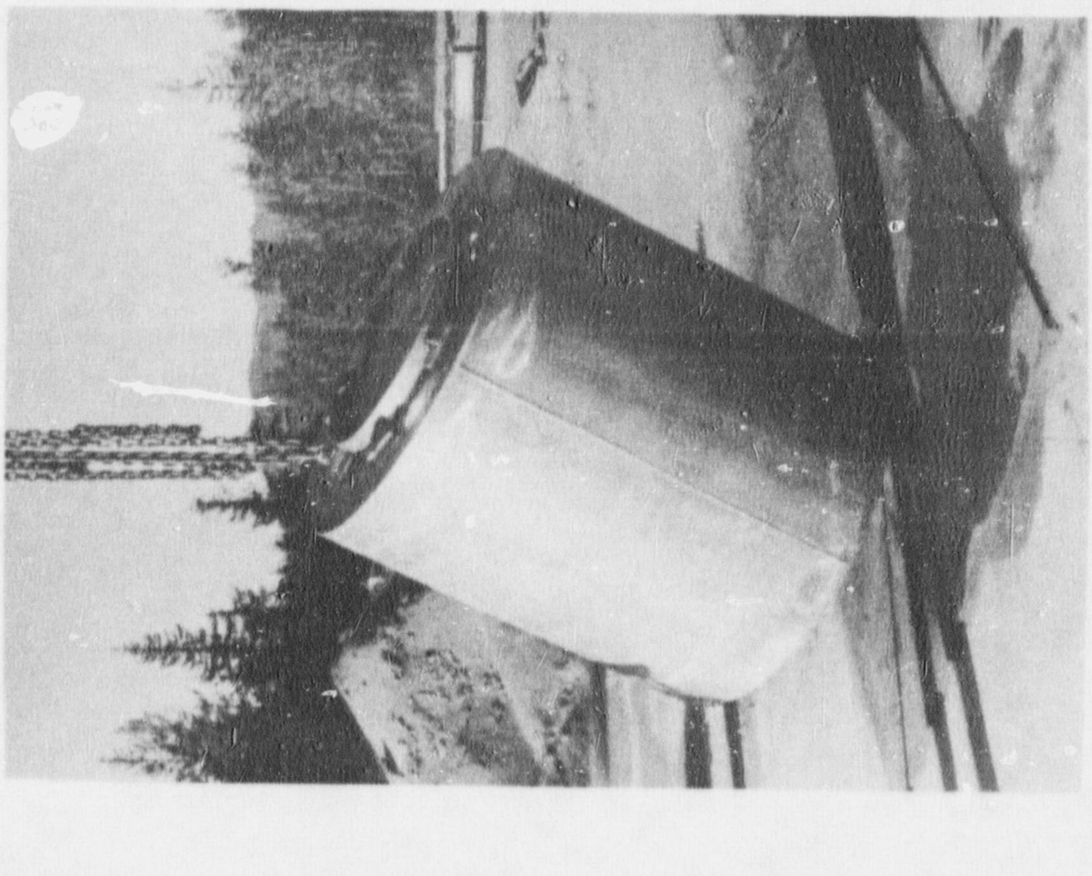

Figure B-1 Lifting Eye Load Test

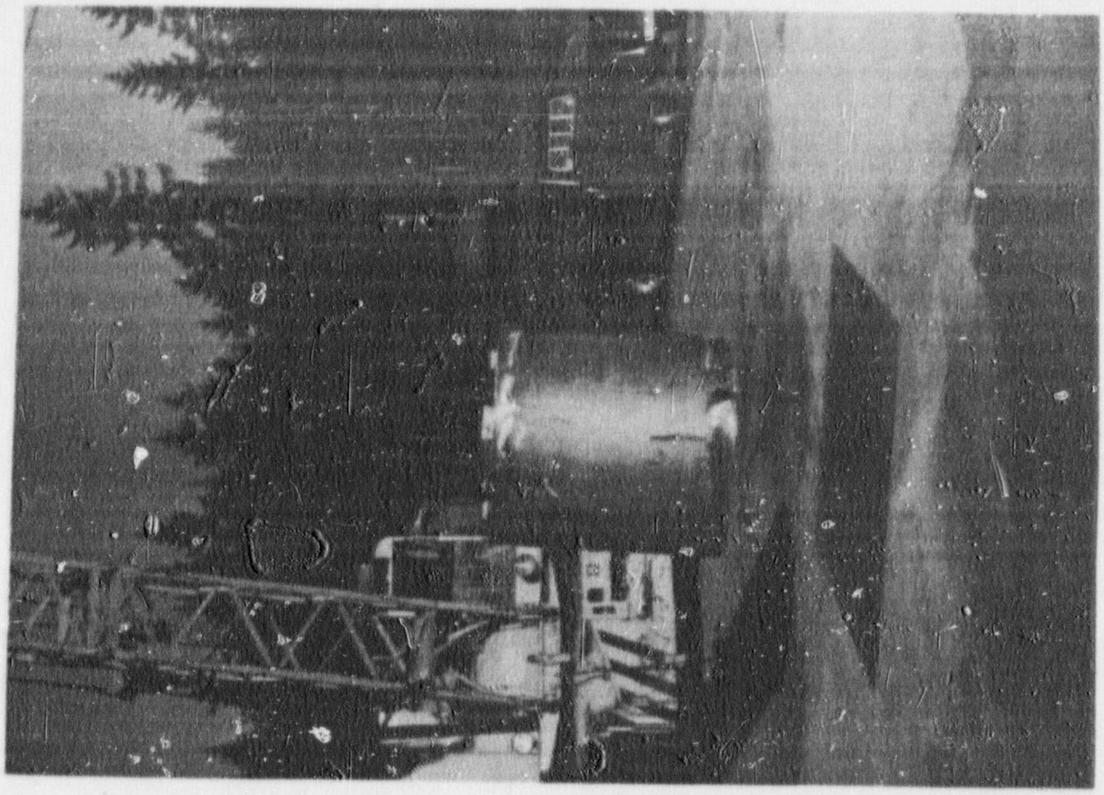

Figure B-2 4-Ft. Bottom Down Drop

Figure B-3 4-Ft. Top Corner Down Drop

Figure B-4 4-Ft. Side Drop

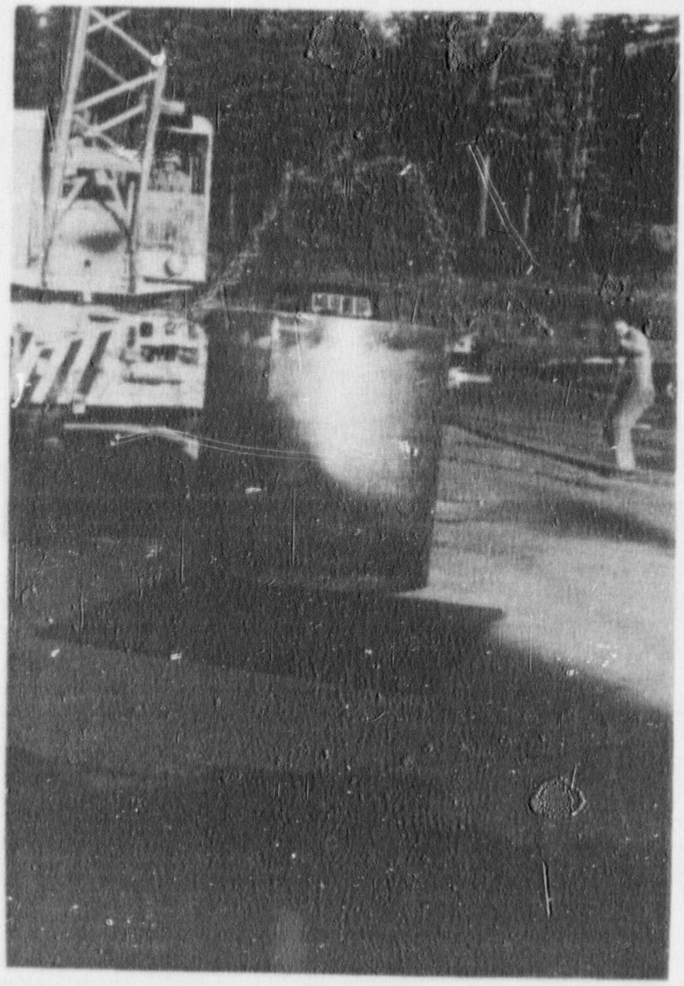

Figure B-5 4-Ft. Top Down Drop

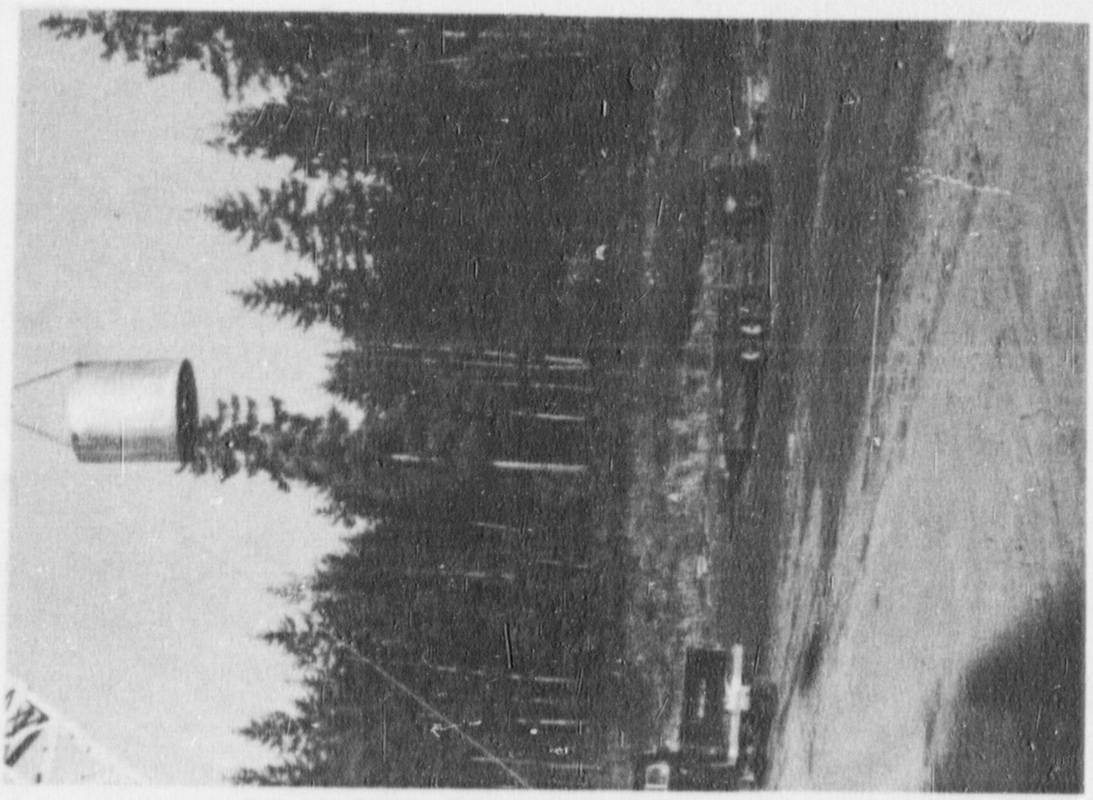

Figure B-6 25-Ft. Top Down Drop

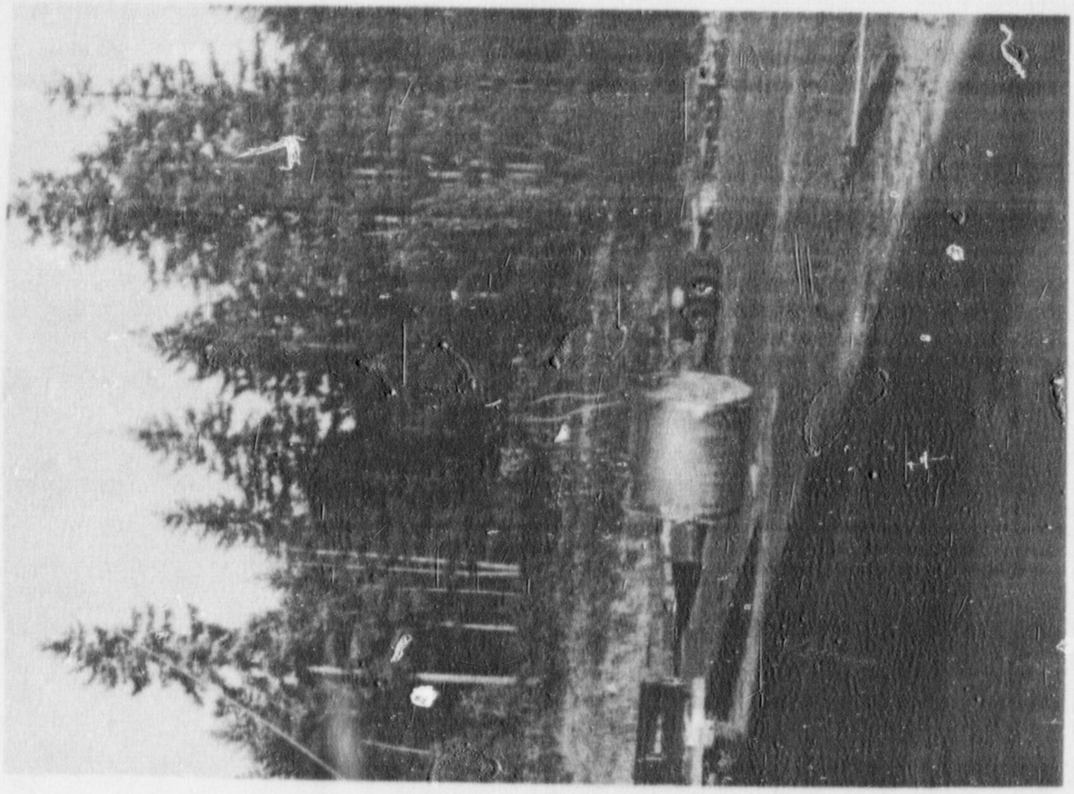

Figure B-7 25-Ft. Side Drop

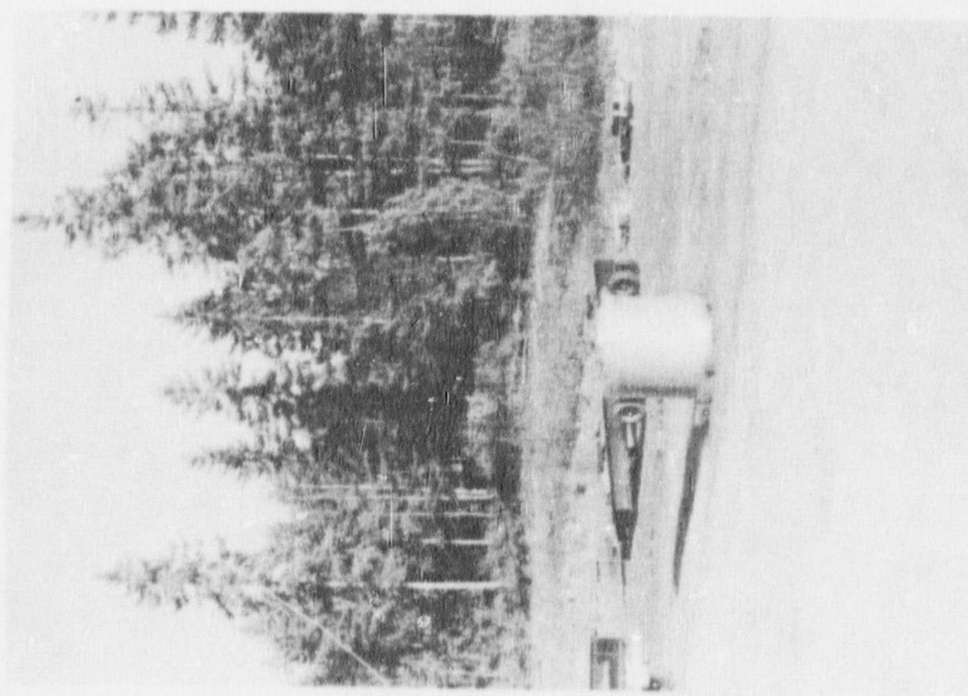

Figure B-8 25-Ft. Bottom Drop

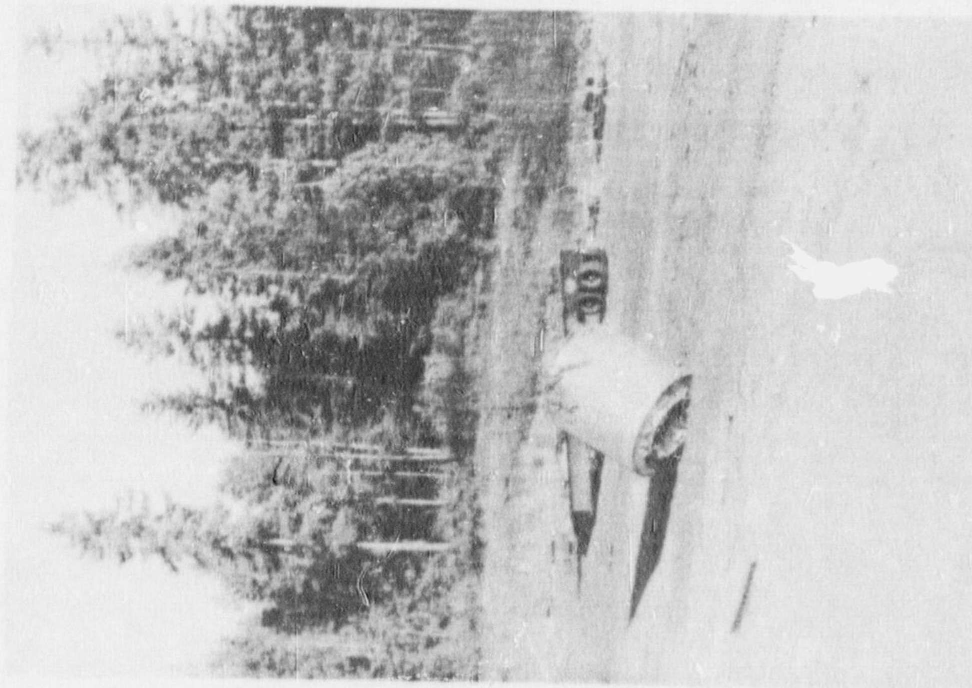

Figure B-9 25-Ft. Top Corner Down Drop

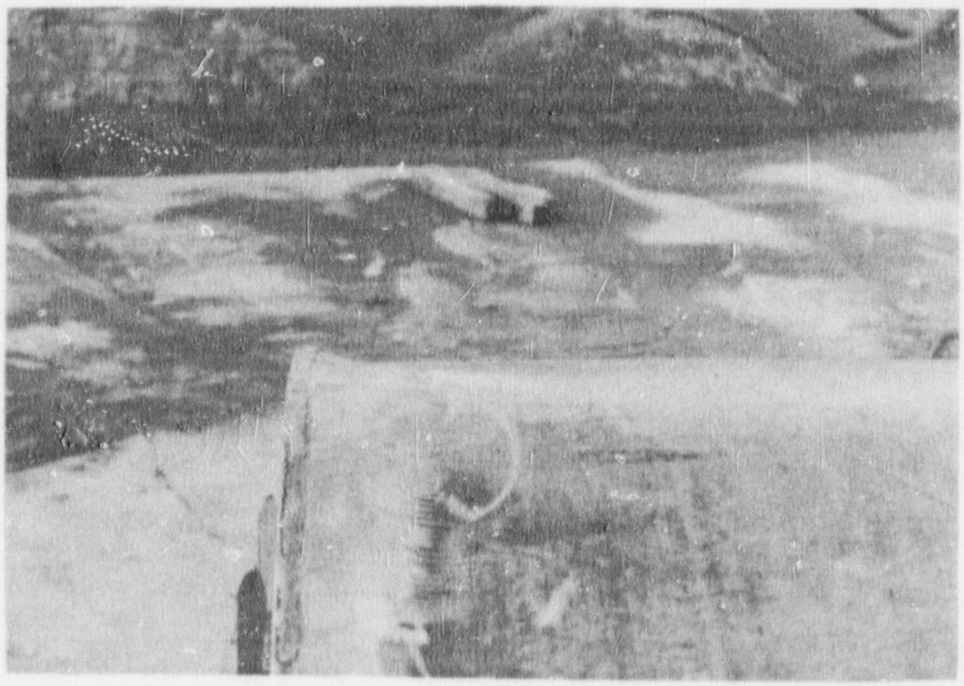

Figure B-10 Damage to Container Shell

APPENDIX C

Quality Assurance Documents

NRC QA Program Approval Letter No. 0192.

NuPac Operating Procedure OM-32, Rev. 2.

NuPac Handling Procedure H-24, Rev. 0.

NRC FORM 311 (6-83)

U.S. NUCLEAR REGULATORY COMMISSION

QUALITY ASSURANCE PROGRAM APPROVAL FOR RADIOACTIVE MATERIAL PACKAGES

1. APPROVAL NUMBER: 0192

REVISION NUMBER: 2

Pursuant to the Atomic Energy Act of 1954, as amended, the Energy Reorganization Act of 1974, as amended, and Title 10, Code of Federal Regulations, Chapter 1, Part 71, and in reliance on statements and representations heretofore made in item 5 by the person named in item 2, the Quality Assurance Program identified in item 5 is hereby approved. This approval is issued to satisfy the requirements of Section 71.101 of 10 CFR Part 71. This approval is subject to all applicable rules, regulations, and orders of the Nuclear Regulatory Commission now or hereafter in effect and to any conditions specified below.

2. NAME: Pacific Nuclear Systems/Nuclear Packaging

STREET ADDRESS: 1010 South 336th Street

CITY: Federal Way | STATE: WA | ZIP CODE: 98003

3. EXPIRATION DATE: December 31, 1990

4. DOCKET NUMBER: 71-0192

5. QUALITY ASSURANCE PROGRAM APPLICATION DATE(S): October 11, 1985

6. CONDITIONS

Activities conducted under applicable criteria of Subpart H of 10 CFR Part 71 to be executed with regard to transportation packages.

FOR THE U.S. NUCLEAR REGULATORY COMMISSION

Charles E. MacDonald

Charles E. MacDonald

CHIEF, TRANSPORTATION CERTIFICATION BRANCH
DIVISION OF FUEL CYCLE AND MATERIAL SAFETY
OFFICE OF NUCLEAR MATERIAL SAFETY AND SAFEGUARDS

DEC 2 3 1985

DATE

NUCLEAR

A Pacific Nuclear Company

OPERATING PROCEDURE

FOR

ENVIRALLOY DISPOSAL CONTAINERS

WITH SERIES A (WEDGE) CLOSURE

OM-32

ESSENTIAL RELATED NUPAC DOCUMENTS

The following related NuPac document(s) contain operations or information essential to performance of instructions herein and must be issued in conjunction with this document:

1. NONE
2.
3.
4.
5.
6.

Gary L. Clark	4 April 1986
Prepared By	Date
C.J. Temme	4/8/86
Engineering	Date
D.E. Hill	4/9/86
Quality Assurance	Date
[illegible]	[illegible]
Manufacturing/Production	Date
[illegible]	4.9.86
Other	Date
C.A. Peters	4.9.86
Document Control/Release	Date

Nuclear Packaging Inc. 1010 South 336th Street Federal Way Washington 98003 (206) 874-2235 Telex 15266 PNSI UD

OM-32 April 4, 1986

TITLE: Operating Procedure for Enviralloy Disposal Containers w/ Series A Closure

RECORD OF REVISIONS

REV	DESCRIPTION	PAGE(S) AFFECTED	DATE	SIGNATURE
0	Original	All		
1	Added Sections 5.5, 6.1.5, 6.2.3, and 2.3 to Check Off Sheet.	3, 4, 6	8/29/85	GL Clark
2	Revised Table 4-1 Tare Weight. Revised Section 6.1.2, 6.1.5, and 6.2.3 regarding UV vent cover removal.	3 4	4/4/86	GL Clark

LIST OF EFFECTIVE PAGES

Page No.	Rev	Page No.	Rev	Page No.	Rev
1 - 11	0				
1 - 11	1				
1 - 11	2				

OM-32, Rev. 2 April 4, 1986

TABLE OF CONTENTS

OM-32, Rev. 2 April 4, 1986

1.0 GENERAL SCOPE

1.1 Purpose

This document delineates several procedures that are required for personnel and property safety and adherence to the applicable regulations for containment and burial of an Enviralloy High Integrity Container (HIC).

1.2 Content

This procedure describes the methods and techniques required to operate any container in the Ferralium family of High Integrity Containers from fabrication through burial. It is an all encompassing generic procedure unless specific site, customer, or application requirements are indicated by the procedure cover page and Section 1.3, Applicability.

Addendums may be attached as necessary. Any addendums are noted in the Table of Contents and Section 1.3, Applicability.

1.3 Applicability

This procedure applies to the related activities of all Nuclear Packaging, Inc. employees, their contract personnel, utility customers and their contract personnel. Any applicable personnel that handle load, procure, store, close and ship the container are bound by this procedure.

2.0 REFERENCES

2.1 United States Code of Federal Regulations Title 10 Part 61

2.2 United States Code of Federal Regulations Title 10 part 71

2.3 Nuclear Packaging Cask handling procedures

2.4 Nuclear Packaging Quality Assurance Program, NRC Approval No. 0192

2.5 Nuclear Packaging, Inc. Enviralloy High Integrity Containers Topical Report

2.6 NuPac Procedure CP-05, Cleaning of Enviralloy Containers

2.7 NuPac Procedure No. LT-17, General Procedure - Soap Bubble (Low Pressure) Test for Enviralloy Containers

2.8 Nupac Procedure NO. FS-01, Sec for Fab/Mach of Steel Parts

2.9 Criteria for High Integrity Containers, Washington State Radiation Control Program, August 25, 1983.

2.10 US NRC Final Waste Classification and Waste Form Technical Position Papers, May 11, 1983

3.0 DEFINITIONS

3.1 HIC: High Integrity Container

3.2 Liquid Free Waste: Dry waste such as dried filters, DAW, hardware etc.

3.3 DAW: Dry Activated Waste

4.0 LIFTING AND HANDLING PROCEDURE

4.1 Empty Container

The empty containers can be lifted by any one of the normal lifting connections (lifting slings, lifting padeye or lifting eye) or by lifting beneath the container with a forklift or other suitable device such as a lifting platform. Care should be taken not to drop or damage the container. The tare weights of the containers are noted in Table 4-1.

4.2 Loaded Container

Lift the loaded container only by the lifting sling assembly or the special lifting lugs designed for remote handling equipment or from beneath the container with a forklift or lifting platform. The maximum gross weight of each container is listed in Table 4-1.

Table 4-1

Model	Tare weight (lbs.)	Gross Weight (lbs.)
EA-210H	3790	20000
EA-210B	3450	20000
EA-190H	3455	20000
EA-190B	3060	20000
EA-142H	2900	10000
EA-142B	2545	10000
EA-140H	2925	15000
EA-140B	2185	15000
EA-7-100H	2640	13000
EA-7-100B	2545	13000
EA-6-100H	2110	12000
EA-6-100B	2060	12000
EA-50H	1475	4200
EA-50B	1475	4200

5.0 STORAGE PROCEDURE

5.1 The containers shall not be stored where they will come in contact with an environment that violates the requirement of 7.4

5.2 Store the closure gasket in a cool dry place out of direct sunlight. Protect the closure gaskets from abrasion, cutting, harsh chemicals and fumes or excessive loaded pressure during storage.

5.3 Take precautions to prevent the container from filling with rain water.

5.4 Store containers in an area where they will not sustain impacts, abrasions, gouging, or other damage.

5.5 Vent must be covered during storage with a ultraviolet (UV) opaque cover (i.e., black polyethylene, black poly vinyl chloride tape, etc.).

6.0 CLOSURE PROCEDURE

6.1 Manual Closure

6.1.1 Clean seal area both on container and on the lid to remove any dirt, grease, oils, or other debris.

6.1.2 Inspect gasket for any cuts or damage. Replace if necessary. Prior to placing lid on HIC, remove vent UV cover.

6.1.3 Place lid on gasket and align handles so they are between closure wedge holes on the series A containers.

6.1.4 Place wedges in holes and drive until secure. The wedges should be driven until the lid is metal to metal on the stops under the lid. Note: the wedges do not normally require driving to their full ramp length.

6.1.5 Verify removal of vent UV cover.

6.2 Remote Closure

6.2.1 Perform steps 6.1.1 through 6.1.3

6.2.2 Drive wedges in place using a remote closure tool.

6.2.3 Verify removal of vent UV cover.

7.0 WASTE COMPATIBILITY VERIFICATION PROCEDURE

NOTE: THIS PROCEDURE SECTION APPLIES TO ALL PERSONNEL AS OUTLINED IN SECTION 1.3, APPLICABILITY. THIS SECTION MAY BE PARTICULARLY APPLICABLE TO THE PLANT CHEMICAL MATERIALS COORDINATOR, RADWASTE OPERATIONS SUPERVISOR, RADWASTE TRANSPORTATION SUPERVISOR AND, SECONDARY, TO THOSE WHO USE THE CHEMCIALS SUCH AS THE APPROPRIATE OPERATIONS, CHEMISTRY AND MAINTENANCE GROUPS.

7.1 Scope

7.1.1 Purpose

The waste material placed in the container must be compatible with the operation of the container in addition to the container's material corrosion properties. Verification of the compatibility of the waste and the processes performed on it is required to meet the applicable safety, transportation and burial requirements of a High Integrity Container (HIC).

7.1.2 Content

The waste compatibility procedure is designed to require minimum steps and no plant chemical analysis. The procedure requires less than 5 steps.

7.1.3 Applicability

Waste compatibility verification applies to all waste placed in the container regardless of the nature of the material or mixture. It includes, but is not limited to:

7.1.3.1 Ion exchange resins

7.1.3.2 Cartridge filters

7.1.3.3 Cloth material

7.1.3.4 Paper wastes, other small containers and their contents,

7.1.3.5 Hardware and the liquids coating it

7.1.3.6 Stabilization media and the chemicals incorporated in the stabilization media.

7.2 Prerequisites

7.2.1 Utilities and Tools

No utilities or tools are required for this part of the procedure.

7.2.2 Other Procedures and Checklists

No other procedures are required. The checklist that is a duplicate of Figure 1 is required to complete this part of the chemical compatibility section of the container procedure.

The flow diagram, Figure 2, is to be used in conjunction with the chemical compatibility procedure found in Section 7.3.

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FIGURE 1 - ENVIRALLOY CONTAINER PROCEDURE CHECK OFF SHEET

A) CONTAINER PREREQUISITES PER THE PROCEDURE

1.0 User____________________ Date_________

2.0 Model Number ______________ Serial Number ________________

3.0 Waste Description (cation resin, anion resin, DAW, filters, etc.) ____

____

		Yes	No	Verification
4.0	Containers handled per 4.0 of procedure.			_______________
5.0	Container stored per 5.0 of procedure.			_______________
6.0	Chemical Compatibility per Section 7.0.			_______________
	The waste is corrosive per section 7.3.1	___	___	_______________
	Temperature limits met per section 8.0	___	___	_______________

B) USAGE VERIFICATION

1.0	Container filled with dry waste or has been dewatered per an approved dewatering procedure.	_______________
2.0	Closure	
	2.1 Seal area clean prior to closing.	_______________
	2.2 Wedges secured per 6.1.4 or 6.2.2 of procedure.	_______________
	2.3 UV vent cover removed per 6.1.5 or 6.2.3 of procedure.	_______________

NOTE: A COMPLETED COPY OF THIS FORM SHALL BE INCLUDED WITH THE SHIPMENT OF EACH APPLICABLE LOADED CONTAINER. THE ORIGINAL SHALL BE RETAINED BY THE USER IN ACCORDANCE WITH THEIR RECORD KEEPING PROCEDURE.

Signature ______________________ Title____________________

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FIGURE 2 - CHEMICAL COMPATIBILITY PROCEDURE FLOW DIAGRAM*

```
        Yes
|<----------Liquid Free Waste(DAW, Dry Filters, Etc.)
|                             |
|                          No |
|        Yes                 \|/
||<-------------pH Greater Than 3_____________
|   |                         |              /|\
|   |                      No |      Neutralize |
|   |                        \|/    Yes  Dilute |
|   | Greater Than 2 wt.% Cl- Plus F--->WASTE IS CORROSIVE
|   |                         |
|   |                      No |
|  \|/                       \|/          No
|   |------------->Water Treatment Media------>|
|                             |                |
|                         Yes |                |
|                            \|/               |
|         Cautionary Phrase on Oxidizers       |
|                             |                |
|                             |<---------------|
|                            \|/
|                             |
|                             |
|                          No |
|                            \|/
|------>WASTE IS CHEMICALLY O.K. FOR THE CONTAINER
```

*Work the flow diagram with the procedure found in Section 7.3.

7.3 Chemical Compatibility Check Off Procedure

The following check off procedure for chemical compatibility does not require specific chemical analysis or a plant wide chemical inventory. The check off procedure eliminates such analysis and inventories. The check off procedure considers the waste source and the operating function before its chemical composition.

7.3.1 Overall Chemical Compatibility

a). Is the waste completely free of liquids? (dewatered resins and damp cloths are considered wet)

Yes - the waste is not corrosive, note on the check list and go to 7.3.2.

No - continue.

b). Does the waste liquid, or contact water, have a pH greater than 3?

Yes - the waste is not corrosive, note on the check list and go to 7.3.2.

No - continue.

c). Does the waste liquid, or contact water, have greater than 2% by weight chloride plus fluoride ions?

Yes - the waste is corrosive, note on the check list and go to 7.3.4.

No - there are no corrosives, note on the check list and continue.

7.3.2 Water Treatment Media

a). Is the waste media ion exchange resins?

Yes - continue.

No - go to 7.3.4.

7.3.3 Oxidizer Caution

NOTE: OXIDIZERS DO NOT POSE ANY PROBLEMS TO THE CONTAINER ITSELF. AN OPERATIONAL CAUTION IS INCLUDED IN THIS PROCEDURE APPLYING TO THE WASTE HANDLING AND PROCESSING THAT MAY BE PERFORMED IN CONJUNCTION WITH THE CONTAINER.

CAUTION: ION EXCHANGE RESINS WHEN EXPOSED TO SUFFICIENT QUANTITIES OF OXIDIZING CHEMICALS (NITRIC ACID, ALKALINE PERMANGANATES, PEROXIDES, HYPOCHLORITES, ETC.) CAN PRODUCE REACTIONS RANGING FROM INCREASED TEMPERATURES UP TO EXPLOSIONS. SMALL AMOUNTS OF CLEANERS AND DECONTAMINATION SOLUTIONS USED IN NORMAL DAILY OPERATIONS WOULD NOT BE EXPECTED TO BE A PROBLEM. HOWEVER, LARGE HARDWARE DECONTAMINATIONS OR LARGE AREA CLEANINGS COULD POSE A PROBLEM. AN EXAMPLE WOULD BE THE TREATMENT OF THE RINSE WATER FROM A RECIRC PIPE DECONTAMINATION PROCESS. THE ION EXCHANGE RESIN VENDOR SHOULD BE CONSULTED WHEN THERE IS ANY POTENTIAL FOR LAODING OF OXIDIZERS ON ION EXCHANGE RESINS.

7.3.4 If the waste media is too corrosive for the container, the waste may be diluted, neutralized or rinsed to meet the corrosion criteria. Consult with NuPac personnel. Restart the entire procedure when the corrosive nature of the waste is corrected.

7.4 Chemical Corrosion

Chemicals on this list must not be present in the container in sufficient acidic concentrations to corrode the container past acceptable limits for a 300 year life. The use, or evolution of hydrochloric acid above a 2 wt.% chloride concentration and less than a pH of 3 is the situation to avoid ($pH<3$ and $Cl^- + F^-$ >2%wt.).

TABLE 7.1 CORROSIVE CHEMICAL LIST

Chemical Name	Possible Sources
Ammonium Chloride	
Anion Ion Exchange Resins	Treating seawater with the radwaste system
Carbon Tetrachloride	Lab Wastes
Cation Ion Exchange Resins	Unused or partially used hydrogen form resin
Chloroform	Lab Wastes
Degreasers	See Freons, Trichloroethylene, Trichloroethane
Freons R-10, 11, 12, 13, 14, 20, 21, 22, 23, 30, 40, 41, 113, 114, 115, 142, 152, 160, 216, 500's	Refrigerant systems, lab wastes, ultrasonic decon
Halogenated Hydrocarbons	
Hydrochloric Acid (Muriatic Acid)	
Hydrofluoric Acid	
Methylene Chloride	Solvents, degreasing
Muriatic Acid (Hydrochloric Acid)	
Refrigerants - See Freons	
Sea Water and acids	Sump intrusion+acid
Trichloroethylene	Solvents, degreasing
Trichloroethane	Solvents, degreasing
Trifluoroacetic Acid	
Chlorides and Acids	

8.0 TEMPERATURE LIMITS FOR WASTE MEDIA

8.1 For media that have a ph less than 7.0, but not less than 3.0, container-media contact temperature must be less than 180°F.

8.2 For the media container contact temperature to exceed 180°F and remain below 500°F the medium must have a ph ≥7.0 and the media container contact temperature must be cooled to less than 120°F within four hours.

8.3 In no case shall the media-container contact temperature be above 120°F for greater than tweleve hours.

9.0 DOCUMENTATION AND CHECK OFF

The use of the Enviralloy containers shall be in accordance with this procedure. Verification requires the use of the check off sheet provided in Figure 1. One sheet shall be filled out for each container. A copy of the sheet shall accompany the filled container. the original shall be retained by the user in accordance with their record keeping procedure.

NUCLEAR PACKAGING
A Pacific Nuclear Company

PROCEDURE

FOR

PACKAGING, HANDLING, AND SHIPPING

OF

ENVIRALLOY HIGH INTEGRITY CONTAINERS

PRIOR TO INITIAL USE

E - 24

REVISION 0

JULY 19, 1985

Gary L. Clark Prepared By	23 July 1985 Date
Engineering	7/23/85 Date
Joe R. [illegible] Quality Assurance	7/23/85 Date
Manufacturing/Production	7/23/85 Date
N/A Other	— Date
Document Control Release	7.24.85 Date

H-24, REV. 0 7/85

1.0 SCOPE

This procedure delineates the requirements for packaging, handling, and shipping of Enviralloy High Integrity Containers prior to initial use.

2.0 REFERENCED DOCUMENTS

2.1 NuPac Quality Procedure - 5, Quality Planning

2.2 NuPac Quality Procedure - 6, Inspection and Verification

2.3 NuPac Quality Procedure - 12, Material Control

3.0 SHIPPING, HANDLING, AND PACKAGING MATERIALS

3.1 All materials utilized for sealing, packaging, cushioning, and/or securing shall not contaminate or deteriorate any container they come in contact with.

These materials shall include but not be limited to the following:

3.1.1 1" thick commercial grade pine or fir boards of various widths.

3.1.2 2" x 4" minimum commercial grade pine or fir studding.

3.1.3 1/2" thick minimum commercial grade plywood.

3.1.4 Commercial grade Styrofoam cast in cushioning forms or shapes.

3.1.5 Commercial grade 3/4" minimum width steel banding with corner clips as required.

3.1.6 Commercial grade fir in shapes required for cradling.

3.1.7 4 - 6 mil commercial grade polyethylene film.

3.1.8 Commercial grade PVC clear sealing tape, 2" width.

3.1.9 Standard 1" ID rubber water hose.

3.1.10 Commercial grade strapping tape, 1" width.

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4.0 PACKAGING

4.1 Series A Containers

4.1.1 Place the container on a standard wooden pallet.

4.1.2 Ensure that the container interior, gasket sealing surfaces, and lid are free of all grease, contaminates, and foreign debris.

4.1.3 Place the silicone gasket in its normal position in the container opening.

4.1.4 Place the lid on top of the gasket in its normal position.

4.1.5 Attach the appropriate sling and shackles to the lifting eyes, if specified. Coil the sling inside the top ring.

4.1.6 Utilizing a section of studding (Section 3.1.2) that will fit inside the top ring, strap the eight locking wedges to the stud using strapping tape (Section 3.1.10).

4.1.7 Place the stud and the wedges on top of the lid. Secure the container to the pallet, using steel banding (Section 3.1.5), by running the banding through the container wedge holes over the top of the stud and through the pallet.

4.1.8 Repeat 4.1.7 for a second banding so that the container is crossbanded to the pallet.

4.2 Series B Containers - TBD

4.3 Series C Containers

4.3.1 Place the container on a standard size wooden pallet.

4.3.2 Ensure that the container interior, gasket sealing surfaces, and lid are free from all grease, contaminates, and foreign debris.

4.3.3 Apply RTV adhesive per manufacturer's instructions to the gasket sealing area on the container, if not previously installed.

4.3.4 Place the silicone gasket on the container with the largest dimension of the gasket facing the lid (up), if not previously installed.

4.3.5 Place the lid on the container using the 3/4 inch locating pins to position the lid.

4.3.6 Start the sixteen 1-inch cap screws into their respective holes. Tighten to a snug tight condition.

4.3.7 Attach the appropriate sling and shackles to the container if specified. This step may be performed prior to step 4.3.5 to facilitate placement of the lid. Coil the sling on top of the container as flat as possible.

4.3.8 Seal the joint between the lid and container body with PVC clear sealing tape (Section 3.1.8).

4.3.9 Cross tie the container to the pallet utilizing steel banding and corner clips.

5.0 HANDLING AND SHIPPING

5.1 Handling

The container/shipping pallet shall be handled in such a manner so as to minimize damage to the container. Lifting the container shall only be performed using the pallet. Any other proposed method of lifting shall be approved by NuPac Engineering prior to implementation.

5.2 Shipping

All containers shall be transported in a manner that will minimize container exposure to dirt, grease, water, acids, contaminates, and foreign debris. All containers transported on open vehicles shall be tarped.